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Child maltreatment under the skin: Basal activity and stress reactivity of the autonomic nervous system and attachment representations in maltreating parents

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CHAPTER 2

AUTONOMIC REACTIVITY TO INFANT CRYING IN MALTREATING MOTHERS

Reijman, S., Alink, L.R.A., Compier-de Block, L.H.C.G., Werner, C.D., Maras, A., Rijnberk, C., Van IJzendoorn, M. H., & Bakermans-Kranenburg, M.J. (2014). Autonomic reactivity to infant crying in maltreating mothers, *Child Maltreatment, 19,* 101-112.

Abstract

We examined autonomic reactivity to infant crying in a sample of 42 maltreating and 38 non-maltreating mothers. Exploratively, we tested if differential reactivity was related to child neglect versus the combination of neglect and abuse, and we tested whether mothers' experiences with maltreatment in their own childhood moderated the association between their current maltreatment status and physiology. During a standardized cry paradigm, mothers listened to cry sounds of various pitches. Heart rate (HR), pre-ejection period (PEP), skin conductance levels (SCLs), and vagal tone (root mean square of successive differences [RMSSD]) were measured as indicators of underlying sympathetic and parasympathetic reactivity. The maltreating mothers showed lower SCL reactivity to the cry sounds than non-maltreating mothers. Furthermore, significant negative correlations between HR and PEP in the non-maltreating group differed from nonsignificant correlations in the maltreating group, which suggests a lack of sympathetic cardiac control in maltreating mothers. We found no differences between neglectful mothers and those who were additionally abusive. Together, our findings support the notion of sympathetic hypoarousal as a risk factor for child maltreatment, which may be indicative of disengagement in a caregiving context. Intervention programs might focus on improving maternal sensitivity to improve responsiveness to child signals.

Keywords: child maltreatment, autonomic reactivity, infant crying

Introduction

Child maltreatment is the outcome of multiple pathways with various interacting risk factors, including parent and child characteristics (Cicchetti & Valentino, 2006). Infant cries, for example, can be perceived as aversive by parents and as such put children at risk for harsh caregiving responses (Out, Pieper, Bakermans-Kranenburg, Zeskind, & Van IJzendoorn, 2010). The ''early crying paradox'' (Barr, 1990) refers to how infant crying ensures survival by eliciting parental care, yet heightens the vulnerability to potentially harmful responses. A partial explanation for abusive responses of some parents but not others has long since been suggested to lie in physiological reactivity to negative infant stimuli such as crying (Frodi & Lamb, 1980; Out, Bakermans-Kranenburg, Van Pelt, & Van IJzendoorn, 2012), but findings have been inconsistent. This stresses the need for methodological consistency and a multidimensional measurement of autonomic arousal (McCanne & Hagstrom, 1996). Therefore, the current study aims to evaluate sympathetic and parasympathetic nervous system reactivity to infant crying in mothers with substantiated neglect and abuse as compared to non-maltreating mothers using a standardized cry paradigm. We included mothers' experiences with maltreatment in their own childhood as a possible moderator.

An integrated ecological/transactional model for the etiology of child maltreatment was proposed by Cicchetti and Lynch (1993). As suggested by these authors, dynamic transactions between risk and protective factors take place within and among levels of ecology, the outcome of which tips the balance toward or away from child maltreatment. They further proposed a distinction between enduring and transient risk factors. Well-researched pervasive risk factors include having been maltreated as a child (e.g., Pears & Capaldi, 2001), low socioeconomic status, and parental psychopathology (Stith et al., 2009). Risk factors of a potentially transient nature are, for example, parental unemployment and single parenthood (Stith et al., 2009). According to the model, deviant autonomic reactivity to infant crying might be seen as a vulnerability that, in interaction with other risk factors, adds weight to the scale of potentiating factors, thus increasing the risk for child maltreatment.

The autonomic nervous system (ANS; part of the peripheral nervous system) controls the internal organs, of which the sympathetic and the parasympathetic systems are two main divisions (Larsen, Schneiderman, & DeCarlo Pasin, 1986). Generally, the sympathetic branch procures

bodily energy mobilization when action is required, whereas the parasympathetic system is concerned with energy conservation and recuperation during resting states. Thus, stress commonly activates the sympathetic system while the parasympathetic system is inhibited (Michels et al., 2013; Viamontes & Nemeroff, 2009).

In psychophysiological research, heart rate (HR), which is under the influence of both the sympathetic and parasympathetic system (Cacioppo, 1994), requires complementing measures to reflect the activity of one system, more or less exclusively. For example, pre-ejection period (PEP; the systolic period of the cardiac cycle between the initiation of pressure on the left ventricles and the opening of the aortic valves) and skin conductance levels (SCLs; electrodermal activity of the skin) predominantly indicate underlying *sympathetic* activity (Mauss & Robinson, 2009). Respiratory sinus arrhythmia (RSA; HR variability associated with respiration) is frequently used as an indicator of *parasympathetic* activity. It is an indirect measure of vagal tone, which reflects parasympathetic influence on HR via the vagus nerve, a cranial nerve pertaining to the parasympathetic branch of the ANS. Therefore, in a typical response to stress, HR goes up; the systolic period shortens, so PEP decreases; the sweat glands are activated, increasing SCLs, and vagal cardiac control withdraws to make way for sympathetic cardiac control, as seen in an RSA decrease. Furthermore, correlations between the different measures are informative as to whether sympathetic or parasympathetic activity underlies HR *within* individuals.

It appears that ANS reactivity to children's signals is a requirement for sensitive parenting, of which *promptness* of response is a core component (Joosen et al., 2013a; Moore et al., 2009). This is consistent with the notion of autonomic contagion (the sharing of autonomic arousal) that has been found in mother–child dyads as mothers watched their child in distress, a possible indication of empathy (Ebisch et al., 2012). Studies on autonomic hyper- and hyporeactivity underlying maladaptive behavior have usually compared the focal group to a control group in which the maladaptive behavior was absent, whose reactivity pattern in response to stressful stimuli then served as referential norm. Hyperreactivity, therefore, is seen in stronger HR and SCL increases and stronger PEP and RSA *de*creases in the focal group than in the reference group. Hyporeactivity, on the other hand, implies weaker HR and SCL increases and weaker PEP and RSA decreases for the focal group than the comparison group.

In a review of eight early studies, in which mainly HR and SCLs were measured, physiological hyperreactivity was concluded to be related to

(increased risk for) abusive parenting (McCanne & Hagstrom, 1996). However, as indicated in the review, findings included inconsistent results and null results (Frodi & Lamb, 1980; Stasiewicz & Lisman, 1989, respectively). This may be because methodologies varied between studies, including parents and non-parents as participants, and child-related as well as non-child-related stimuli. More recently, hyperreactivity of SCLs to infant cry sounds predicted harsh discipline during mother–child interactions 9 months later (Joosen, Mesman, Bakermans-Kranenburg, & Van IJzendoorn, 2013b). In addition, using salivary a-amylase (sAA) as a marker of ANS activity in a sample of adult twin pairs (parents and non-parents), it was found that sAA hyperreactivity to infant cry sounds was associated with intended harsh caregiving responses (Out et al., 2012). Congruent with the *hypo*reactivity hypothesis, mothers of children with an avoidant attachment strategy showed less vagal withdrawal during the reunion episode of the Strange Situation Procedure (Hill-Soderlund et al., 2008). This may correspond to low responsiveness to child signals and an affectively disengaged representation of their child, as has been observed in mothers of avoidant dyads (Raval et al., 2001; Zeanah, Benoit, Hirshberg, Barton, & Regan, 1994). Furthermore, fathers of families with interparental physical aggression showed overall lower sAA levels and lower sAA reactivity to, and recovery from, a conflict discussion (Gordis, Margolin, Spies, Susman, & Granger, 2010). In half of these cases, interparental physical aggression was reported by the adolescent, indicating that in *at least* half of these families, children had witnessed physical conflicts between their parents. When witnessed by children, interparental aggression is a form of child neglect (Barnett, Manly, & Cicchetti, 1993). Interparental aggression was not related to sAA levels in mothers. Overall, these findings tentatively suggest that ANS hyperreactivity may mark child abuse while hyporeactivity may characterize neglect. Indeed, one study has suggested a possible association between autonomic hyperarousal and harsh or hostile caregiving behavior, while autonomic hypoarousal was related to maternal disengagement from her child (Sturge-Apple, Skibo, Rogosch, Ignjatovic, & Heinzelman, 2011).

An important aspect to consider in research on physiological reactivity underlying child maltreatment is the maltreatment experienced by current perpetrators in their youth. Evidence shows that early maltreatment experiences are associated with subsequent dysfunctional parenting (Pears & Capaldi, 2001). Furthermore, psychobiological development differs for individuals with and without childhood maltreatment experiences, though how exactly is not yet fully

understood. Results are diverse and have been suggested to vary according to genetic and temperamental disposition (Gunnar & Quevedo, 2007) and to change over time (Yates, 2007). For the ANS, findings seem to point mostly toward autonomic hyperreactivity as a function of child maltreatment experiences. For example, foster children with a history of child neglect and those with disordered attachment showed sympathetic hyperreactivity during the Strange Situation Procedure (Oosterman, De Schipper, Fisher, Dozier, & Schuengel, 2010). Increased HR reactivity was found in women who had been physically and sexually abused in childhood (Heim et al., 2000).

The current study extends the existing literature by evaluating mothers with substantiated maltreatment, taking their own experiences with childhood maltreatment into account, including a wide range of autonomic measures of both the SNS and the PNS, and using a standardized cry paradigm that enhances the comparability of results among studies. Since a recent prevalence study in the Netherlands found child neglect to be the most prevalent form of child maltreatment (Euser et al., 2013), we expected to find more neglect than abuse in our sample. Consequently, we expected HR, PEP, RSA, and SCL hyporeactivity to the cry sounds for the maltreating group as a whole compared to the non-maltreating group. We tentatively hypothesized that we would find autonomic hyperreactivity in the subgroup of mothers who additionally displayed child physical and/or emotional abuse compared to non-maltreating mothers. In an explorative way, we tested mothers' own maltreatment experiences as a possible moderator of the relation between maltreating parenting and autonomic reactivity, such that maltreating mothers who experienced severe maltreatment would show less hyporeactivity than maltreating mothers who experienced (almost) no maltreatment in childhood. We emphasize the preliminary nature of this analysis, since subgroup sizes were small.

Method

Participants

We recruited 45 maltreating and 45 non-maltreating mothers at a mental health clinic. Mothers in the maltreating group received therapy for their parenting problems and were informed about the study by their therapists. We coded Child Protection Services (CPS) records to substantiate recent or ongoing maltreatment using the Maltreatment Classification System (MCS; Barnett et al., 1993). When records were inconclusive, we interviewed the mother's psychiatrist about her

parenting problems using a semi-standardized interview. For three mothers, neither their records nor their psychiatrists provided proof of maternal maltreatment. In these cases, we conducted a Dutch adaptation of the Maternal Maltreatment Classification Interview (MMCI; Cicchetti, Toth, & Manly, 2003). Absence of maltreatment was verified for two mothers who were considered as non-maltreating in the analyses. One mother could not be reached for a follow-up MMCI and was excluded from analyses because of her inconclusive current maltreatment status (i.e., whether she was maltreating or not).

Non-maltreating mothers were recruited by research assistants in a clinical subdivision of the facility, where their child was in therapy for developmental or learning problems. To verify absence of maltreatment, the MMCI (Cicchetti et al., 2003) was used. Three mothers were counted as maltreating in the analyses because incidents were coded from the interview which had taken place less than 5 years ago. There were no mothers with incidents of maltreatment that had occurred more than 5 years ago.

Due to technical problems, eight participants had missing HR, PEP, root mean square of successive differences (RMSSD), and SCL data. Additionally, one mother had a heart condition incompatible with electrocardiogram (ECG) analysis. Therefore, the final sample consisted of 42 maltreating and 38 non-maltreating mothers. The maltreating group consisted of 20 neglectful and 22 neglectful and additionally abusive mothers who will henceforth be referred to as NE (neglectful) and AN (abusive and neglectful) mothers. Included and excluded mothers did not differ on any of the background variables (ethnicity, educational level, exercise during the week prior to the research appointment, smoking on the morning of the study, medication affecting HR, or hearing problems, maternal age, number of children, and children's mean age; *p*s > .24). In the final sample, 94% of mothers were of Caucasian ethnicity, 47% had completed secondary school, and 33% had finished elementary school or a short track of secondary school. Their mean age was 40.79 (*SD* = 7.26) and on average they had 2.41 children (*SD* = 1.19). Finally, three mothers in the maltreating group (one NE and two AN) had no data for PEP because of flat impedance cardiograms (ICGs). They did not differ from the other mothers on any of the background variables (*p*s > .06). Excluding them from the other analyses did not affect the results, so we included 80 mothers (42 maltreating and 38 non-maltreating) in the HR, SCL, and RMSSD analyses, and 77 mothers (39 maltreating and 38 non-maltreating) in the PEP analyses.

The study was approved by the Medical Ethics Review Committee for Mental Health Care (METiGG). All mothers gave informed consent for participation and, in the maltreating group, for researchers' access to the family files. As a compensation for participation, mothers received 40 Euros as well as traveling expenses.

Procedure

Two individual appointments took place at the facility. During the first session, mothers completed three computer tasks, of which the cry paradigm (Zeskind & Shingler, 1991) reported here was the first. During the task, an ECG signal, an ICG signal, and SCLs were recorded. Afterward, mothers completed a questionnaire on health-related issues, such as smoking and exercising prior to the session, and on their family situation, including educational level, number of children, and children's age. We administered the MMCI to the non-maltreating group. During the second session, the Adult Attachment Interview (George, Kaplan, & Main, 1985) was conducted (data will be presented elsewhere), after which mothers completed the short form of the Childhood Trauma Questionnaire (CTQ-SF; Bernstein et al., 1994; Bernstein & Fink, 1998).

Measures

MCS. We used the MCS (Barnett et al., 1993), a reliable and valid system to code incidents of maltreatment reported in the family's records from CPS and the child care office (Cicchetti, Rogosch, Gunnar, & Toth, 2010). According to the MCS, physical abuse is coded ''when a caregiver . . . inflicts physical injury upon a child by other than accidental means,'' including hitting or kicking, violent handling (e.g., shoving and dragging), smothering, burning, shaking, or other, and non-descript abuse. Physical neglect encompasses the failure to provide adequate food, clothing, shelter, health care, or hygiene, and a lack of adequate supervision that ensures the child's safety. Emotional maltreatment involves "persistent or extreme thwarting of children's basic emotional needs'' and ''parental acts that are harmful because they are insensitive to the child's developmental level.'' We further distinguished between incidents of emotional maltreatment directed *at* the child (emotional *abuse*, e.g., belittling the child, or calling the child derogatory names) and incidents demonstrative of inattentiveness rather than rejection (emotional *neglect*, e.g., expecting an inappropriate level of responsibility from the child, exposing the child to marital violence). In accordance with these operational definitions, we coded abuse (physical and emotional) and neglect (again, physical, and emotional). The fact that

certain types of maltreatment were recorded in the files suggests them to be of a structural rather than incidental nature. Since mothers were in therapy for their parenting problems, a relatively high level of severity of these problems may be assumed. Information on the consequences of recorded examples of maltreatment was often too unspecific to reliably distinguish between severity grades. Only incidents of *maternal* maltreatment were considered. Coding was done by trained research assistants. Interrater reliability on 15 files was excellent, with $\kappa = .82$ for abuse and $\kappa = 1.00$ for neglect. For the presence versus absence of maltreatment, there was full agreement ($\kappa = 1.00$). Subsequently, all records were coded by two different research assistants and discrepancies were resolved through discussion. We found that all mothers in the maltreatment group had been neglectful toward their children, either physically or emotionally. Fifty-four percent ($n = 22$) of maltreating mothers had been additionally abusive, physically or emotionally.

MMCI. The MMCI (Cicchetti et al., 2003) is a semi-structured interview that evaluates whether the mother has maltreated any of her children recently and during their lifetime. Mothers are asked about incidents of physical and emotional abuse and neglect, as well as sexual abuse, and about any contact the family may have had with the CPS. We translated the interview into Dutch for this study. Coding was done by trained research assistants. Interrater reliability on 12 interviews was excellent, with full agreement for the presence versus absence of maltreatment, incidents of neglect versus abuse, and severity of the incidents (for all κs = 1.00). Interviews were coded by two different research assistants and discrepancies were resolved through discussion.

Cry paradigm. The cry paradigm was presented on a laptop with E-prime software. A 6-min baseline of neutral images was followed by three blocks with three cry sounds each (for details on the sounds' derivation, see Out et al., 2010). Within each of the blocks, sounds differed in fundamental frequency, congruent with the idea of infant crying as a graded signal of varying acoustic properties that communicate the cause's urgency (Gustafson, Wood, & Green, 2000). In each block, the three cries, of 500, 700, and 900 Hz, were presented in a random order. All sounds lasted 10 s, containing seven cry expirations and were presented through Sennheiser HD202 headphones at a constant volume. The paradigm ended with another 4-min baseline of neutral images. As a manipulation check, we tested whether the perception of the cry sounds differed for sounds with different fundamental frequencies. After each cry sound, mothers were presented

with four questions on the extent to which they perceived the sound as urgent, aversive, the child as sick, and themselves as aroused (Out et al., 2012; Zeskind & Lester, 1978; Zeskind & Marshall, 1988). They answered on a 5-point scale, ranging from very little to very much. Each fundamental frequency was presented 3 times, resulting in 12 ratings per pitch. Following Out, Pieper, Bakermans-Kranenburg, Zeskind, and Van IJzendoorn (2010), who found one component underlying these 12 ratings, averages were aggregated to form the overall perceived urgency. Cronbach's αs ranged from .88 to .89. There was an overall main effect of pitch ($p < .001$), with a significant increase in perceived urgency from 500 to 700 Hz, from 500 to 900 Hz, and from 700 to 900 Hz (*p*s < .001). Maltreating and non-maltreating mothers did not rate the sounds differently, not overall nor as a function of pitch (*p*s > .54). To get acquainted with a cry sound and the questions, participants practiced with one cry sound of 500 Hz. The cry paradigm has been used in previous studies with childless adults and parents and has been shown to evoke physiological stress responses, harsh caregiving intentions, and emotional irritation (e.g., Joosen et al., 2013a; Out et al., 2010).

HR, RSA, PEP, and SCL. During the cry paradigm, an ECG, ICG, and SCL were measured using an ambulatory monitoring system (VU-AMS5 fs; TD-FPP, Vrije Universiteit, Amsterdam, the Netherlands). For the ECG, three disposable pre-gelled Ag-AgCI electrodes (ConMed, New York, USA) were placed slightly below the right collar bone 4 cm to the right of the sternum, between the two lower ribs on the right side, and under the left breast (4 cm under the nipple). For the ICG, four electrodes were attached at the top end of the sternum between the tips of the collarbones, on the spine (at least 3 cm above the previous one), at the low end of the sternum where the ribs meet, and again on the spine (at least 3 cm under the previous one). Before the assessment of the SCLs, mothers washed their hands with a mild soap. Then two Ag-AGCI electrodes, filled with isotonic GEL101 electrode paste, were placed on the middle and index finger of mothers' non-dominant hand. E-prime had been pro-grammed so that markers were sent to the ECG and SCL recording during baseline, the presentation of each cry sound, the answering of the questions, and recovery.

A complementary VU-DAMS software package derived interbeat interval time series (IBIs) by visual peak detection of the R-wave. For HR, we inspected each ECG recording and corrected it manually when necessary (following VU-DAMS instructions). We labeled the data according to the markers sent by the E-prime. From each ICG recording, the PEP was scored manually per labeled segment by trained research

assistants. Interrater reliability was excellent, with intraclass correlations ≥ .97. The short duration of our labeled segments of interest (i.e., 10 s of cry sounds) resulted in missings on RSA. Therefore, RMSSD was used as an indication of RSA. RMSSD and RSA have been shown to correlate highly and stably across time and ambulatory conditions (Goedhart, Van der Sluis, Houtveen, Willemsen, & De Geus, 2007). As a correlate of RSA, it has previously been used as a measure of vagal tone (e.g., in Joosen et al., 2013a, 2013b). In our sample, the mean of same-time correlations between RSA and RMSSD (e.g., RSA baseline with RMSSD baseline and RSA recovery with RMSSD recovery) was r = .70. Average HR, PEP, SCL, and RMSSD were derived per labeled segment, after which the mean over the segments was calculated per episode (baseline; blocks 1, 2, and 3 of cry sounds; and recovery) in SPSS. We checked for outliers (using standardized scores of -3.29 and 3.29 as cutoff) per labeled segment as well as per aggregated episode. For SCL one participant, and for RMSSD seven participants showed outliers for individual segments, which were winsorized (Tabachnik & Fidell, 2001). The least extreme outlier was replaced with a value .10 above the highest non-outlying score, and for each next outlier .10 was added to its preceding value, preserving the original order. For RMSSD, its combined episodes showed four outliers, which were winsorized as well. Combined episodes showed no further outliers.

CTQ-SF. The CTQ-SF (Bernstein et al., 1994; Bernstein & Fink, 1998; Thombs, Bernstein, Lobbestael, & Arntz, 2009) is a self-report questionnaire that consists of 27 items (24 clinical items and 3 validity items), with which the childhood experiences of abuse and neglect are retrospectively assessed. It has shown measurement invariance across four different populations (clinical and normal; Bernstein et al., 2003), and contains five subscales: physical abuse (α = .88), emotional abuse (α = .88), physical neglect (α = .65), emotional neglect (α = .88), and sexual abuse (α = .90; Cronbach's αs for the current sample). Each scale consists of 5 items with a 5-point scale ranging from *never true* to *very often true*.

We categorized scores per subscale according to severity using the manual's cutoff scores (minimal, low, moderate, and severe, taking into account that the Dutch version of the CTQ has 4 instead of 5 items for sexual abuse). They were then assigned a total severity score that was equal to their highest severity score on the subscales. Two mothers (3%) had missing data on the CTQ. These were imputed with the average of mothers with the same current maltreatment status. Finally, we distinguished mothers with minimal/low scores (n = 43, 18 maltreating and 25 non-maltreating) from mothers with moderate/severe scores (n =

37, 24 maltreating and 13 non-maltreating). Fifty-seven percent of maltreating mothers scored high on experienced maltreatment compared to 34% of non-maltreating mothers. For both groups emotional neglect was the most frequently reported type of experienced maltreatment.

Data Analysis

We performed Pearson's χ^2 tests to compare maltreating (NE and AN together as well as separately) and non-maltreating mothers on ethnicity, educational level, medication, hearing problems, whether their children had a clinical diagnosis, exercise, smoking, and CTQ scores (minimal/low vs. moderate/severe). *T*-tests were done to check for differences in maternal age, children's mean age, and number of children. We calculated Pearson's correlation coefficients for the relation between maternal age and children's mean age, between maternal age and the baseline levels of the autonomic measures, and between the number of days maltreating mothers had been in therapy before participation and the baseline levels of the autonomic measures. We performed *t*-tests to evaluate whether exercise and smoking had an effect on the baseline levels of the physiological variables.

Partial correlation coefficients were calculated for the association between HR, PEP, SCL, and RMSSD on all measurement points, with smoking and maternal age as covariates. Univariate analyses of covariance (ANCOVAs) were conducted to compare maltreating and non-maltreating mothers on baseline levels of HR, PEP, SCL, and RMSSD, with only smoking as covariate. To evaluate the association between current and experienced maltreatment status and physiological reactivity to cry sounds, we performed repeated measures ANCOVAs for HR, PEP, SCL, and RMSSD. Current and experienced maltreatment status refer to whether mothers are currently maltreating or not and whether they were maltreated in their own childhood, respectively, and these terms will be maintained throughout. To reduce the number of statistical tests, we included three episodes (rather than five) as within-subjects factor: baseline, block 3 of cry sounds, and recovery. We chose the third block because previous research has found an accumulative effect of the cry sounds on autonomic reactivity using the same cry paradigm (Out et al., 2012), as well as group differences being most pronounced during block 3 (Joosen et al., 2013b). Current maltreatment status (maltreating vs. non-maltreating) and experienced maltreatment (minimal/low vs. moderate/severe) were entered as between-subjects factors. We included smoking and maternal age as covariates. We repeated the analyses with three levels of current maltreatment status as

between-subjects factor: NE mothers, AN mothers, and non-maltreating mothers.

Results

Preliminary Analyses

Maltreating and non-maltreating mothers did not differ on ethnicity, educational level, medication, hearing problems, number of children, or whether their children had been clinically diagnosed (*p*s > .12). However, fewer maltreating mothers (48%) than non-maltreating mothers (71%) had exercised in the week prior to the research appointment, $\chi^2(1, N = 80) = 4.52$, $p < .05$; specifically, fewer NE mothers (35%) than non-maltreating mothers had exercised, $\chi^2(2, N = 80) = 7.03$, $p < .05$. More maltreating mothers (45%) than non-maltreating mothers (13%) had smoked on the morning of the research appointment, $\chi^2(1, N = 80) = 9.78$, $p < .01$; specifically, more AN mothers (55%) than non-maltreating mothers had smoked, $\chi^2(2, N = 80) = 11.68$, $p < .01$. Mothers and their children in the maltreating group were significantly younger than their counterparts in the non-maltreating group, $t(72.55) = 4.86$, $p < .001$ and $t(78) = 4.36$, $p < .01$, respectively. Maltreating mothers' mean age was 37.52 (*SD* = 7.45), while that of non-maltreating mothers was 44.39 (*SD* = 5.06). This was true for both NE and AN mothers (*p*s < .05). Maltreating mothers' children's mean age was 9.38 (*SD* = 5.06), while non-maltreating mothers' children on average were 13.78 years old (*SD* = 3.84). Since maternal age and children's average age were highly correlated (*r* = .79), only maternal age was considered as a covariate for the analyses. Exercise and maternal age were not correlated to baseline levels of HR, PEP, RMSSD, or SCL (*p*s > 09). Smokers differed significantly from non-smokers on baseline levels of HR and PEP (*p*s ≤ .02). For the maltreating group, the number of days they had been in therapy before participating in the study was not related to baseline levels of the autonomic measures (*p*s > .11). Finally, more maltreating mothers (57%) than non-maltreating mothers (34%) had moderate/ severe childhood maltreatment experiences, $\chi^2(1, N = 80) = 4.22$, $p = .04$, $\varphi = .23$.

Correlations Between Autonomic Measures for Maltreating and Non-Maltreating Mothers

Partial correlations between HR and PEP as well as between HR and RMSSD for maltreating mothers and non-maltreating mothers are displayed in Table 1. HR and PEP were not significantly associated in

maltreating mothers, whereas they were significantly negatively correlated for non-maltreating mothers. The differences between the correlations for maltreating and non-maltreating mothers were significant across all episodes of the cry paradigm (*p*s < .05). HR and RMSSD were significantly, negatively correlated for both groups. There were no significant correlations between SCL and any of the other physiological measures for either group (*p*s > .08).

Differences in Autonomic Measures for Maltreating and Non-Maltreating Mothers

Table 2 shows means (*SD*s) for all autonomic measures for episode (baseline, block 3, and recovery) by maltreatment group. No differences were found between maltreating and non-maltreating mothers in the baseline levels of any of the physiological variables, when controlling for smoking (*p*s > .16).

Skin conductance level. We found an overall (multivariate) effect of episode, with SCL increasing from baseline to the third block of cry sounds and decreasing from block 3 to recovery (*p*s < .03). In line with our expectations, Figure 1 shows a significant overall interaction effect of current maltreatment status with episode, $F(1.41, 73) = 3.79$, $p = .04$, partial $\eta^2 = .05$ (Greenhouse-Geisser correction for sphericity). Contrast analyses showed that from baseline to block 3, maltreating mothers showed a significantly smaller increase from baseline to the third block of cry sounds compared to non-maltreating mothers, $F(1, 74) = 4.54$, $p = .04$, partial $\eta^2 = .06$. Furthermore, there was a significant interaction effect of current maltreatment status with episode from baseline to recovery, $F(1, 74) = 3.85$, $p = .05$, partial $\eta^2 = .05$, with the increase in SCL being less pronounced for maltreating mothers. There were no effects of experienced maltreatment (*p*s > .19).

PEP. There was an overall interaction effect between current maltreatment status and episode, $F(1.83, 70) = 3.70$, $p = .03$, partial $\eta^2 = .05$ (Greenhouse Geisser correction for sphericity). In the direction opposite to our hypothesis, contrast analyses showed that the decreasing trend of PEP for maltreating mothers from baseline to block 3 was significantly different from the increasing trend of PEP for non-maltreating mothers, $F(1, 71) = 5.31$, $p = .02$, partial $\eta^2 = .07$. Furthermore, for the contrast from block 3 to recovery, the increasing trend of PEP for maltreating mothers was significantly different from the stable PEP of non-maltreating mothers, $F(1, 71) = 4.13$, $p = .046$, partial $\eta^2 = .06$. Figure 2 shows how this effect was further qualified by a three-way interaction of episode with current maltreatment status and experienced maltreatment, $F(1, 71) =$

3.96, p = .050, partial η^2 =.05, indicating that for the non-maltreating group, the PEP values for mothers who experienced low levels of maltreatment tended toward declination, whereas the PEP for mothers who experienced high levels of maltreatment showed an upward trend from block 3 to recovery. The direction of these reactivity patterns held when analyses were done only with unambiguous ICGs (i.e., indicated by the coders as straightforward to score; Riese et al., 2003). There were no overall (multivariate) or main (between-subjects) effects for episode, current maltreatment status, or experienced maltreatment (ps > .20).

HR. We found an overall (multivariate) effect of episode on HR, with HR increasing from baseline to the cry sounds, and decreasing from the cry sounds to recovery (ps < .01). Unexpectedly, there were no significant overall (between-subjects) main effects of current maltreatment status or experienced maltreatment or interaction (multivariate) effects with episode (ps > .11).

Vagal tone. For RMSSD, not in accordance with our expectations, we found no significant main (between-subjects) effect of current maltreatment status or experienced maltreatment, or overall interaction (multivariate) effects with episode (ps > .26).

Differences in Autonomic Measures Between NE, AN, and Non-Maltreating Mothers

There were no differences between NE, AN, and non-maltreating mothers in the baseline levels for any of the autonomic measures, controlling for smoking (ps > .25). For HR and SCL, there was an overall (multivariate) effect of episode, with HR and SCL increasing to the cry sounds and decreasing to recovery (ps < .03). There were no significant main (between-subjects) effects of current maltreatment status or experienced maltreatment or overall (multivariate) interaction effects with episode (ps > .13).

Table 1

Partial Correlations between HR and PEP, and HR and RMSSD for Maltreating (M) *and Non-maltreating* (N-m) *Mothers*

	HR baseline			HR block 3			HR recovery		
	M	N-m	*z*	M	N-m	*z*	M	N-m	*z*
PEP									
Baseline	.13	-.41*	2.39	.15	-.49**	2.89	.21	-.42*	2.78
Block 3	.17	-.48**	2.93	.18	-.53**	3.25	.23	-.48**	3.19
Recovery	.13	-.45**	2.59	.14	-.49**	2.85	.19	-.46**	2.91
RMSSD									
Baseline	-.50**	-.51**	ns.	-.46**	-.47**	ns.	-.47**	-.46**	ns.
Block 3	-.44**	-.45**	ns.	-.50**	-.46**	ns.	-.48**	-.44**	ns.
Recovery	-.34*	-.52**	ns.	-.32	-.51**	ns.	-.34*	-.56**	ns.

Note: M = maltreating; N-m = non-maltreating; HR = heart rate; PEP = pre-ejection period; RMSSD = root mean square of successive differences (measure for vagal tone). For HR – PEP correlations $N = 77$; for HR- RMSSD correlations $N = 80$. Correlations were controlled for smoking and maternal age. All reported Fisher's *z*s were significant, *p*s < .01.

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

Table 2

Estimated Means and Standard Deviations on Autonomic Measures for Maltreating and Non-Maltreating Mothers Who Experienced High and Low Levels of Maltreatment

		Maltreating mothers			Non-maltreating mothers		
		Total (N = 42)	High (n = 24)	Low (n = 18)	Total (N = 38)	High (n = 13)	Low (n = 25)
SCL							
Baseline	M	4.52	4.86	4.19	4.20	4.42	3.98
	SD	2.43	2.20	2.76	2.16	2.57	1.96
Block 3	M	5.35	5.79	4.91	5.71	6.24	5.18
	SD	2.68	2.58	2.86	2.92	3.76	2.39
Recovery	M	4.86	5.30	4.42	5.07	5.35	4.80
	SD	2.46	2.51	2.44	2.52	3.20	2.15
PEP*							
Baseline	M	110.05	109.45	110.64	105.24	107.95	102.53
	SD	19.45	20.73	18.29	24.88	21.43	26.48
Block 3	M	108.67	108.74	108.61	106.89	109.91	103.86
	SD	19.95	21.36	18.60	23.27	20.85	24.27
Recovery	M	110.99	110.32	111.67	106.99	111.16	102.82
	SD	19.79	21.58	17.85	24.38	23.46	24.40

HR							
Baseline	M	76.18	76.06	76.29	72.54	70.31	74.78
	SD	10.51	10.16	11.13	10.13	7.86	11.05
Block 3	M	79.67	79.30	80.04	77.68	76.66	78.71
	SD	11.35	10.82	12.20	10.36	9.46	10.92
Recovery	M	73.78	73.56	74.01	71.72	70.47	72.98
	SD	10.11	9.84	10.68	8.9	8.82	9.13
RMSSD							
Baseline	M	35.79	34.61	36.96	33.33	36.61	30.06
	SD	22.39	22.07	23.30	17.25	22.62	13.85
Block 3	M	26.72	26.84	26.60	27.33	27.83	26.83
	SD	17.23	18.88	15.26	14.93	18.21	13.33
Recovery	M	35.43	32.45	38.42	31.15	32.67	29.63
	SD	20.93	20.62	21.22	14.97	18.40	13.20

Note: High = moderate / high scores on experienced maltreatment; low = minimal / low scores on experienced maltreatment; HR = heart rate; *M* = mean; PEP = pre-ejection period; RMSSD = root mean square of successive differences (measure for vagal tone); SCLs = skin conductance levels; SD = standard deviation.
Estimated means were controlled for maternal age and smoking.
* *N* was decreased for PEP analyses: 3 maltreating mothers (2 high on experienced maltreatment) had missing PEP data.

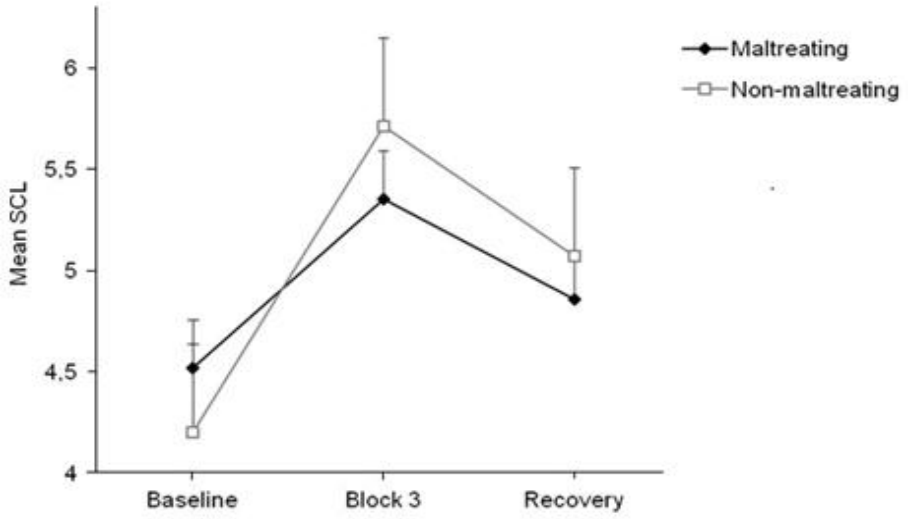

Figure 1. Responses of skin conductance levels (SCLs) to cry sounds for maltreating and non-maltreating mothers. *Note:* Baseline to Block 3: smaller increase in SCLs for maltreating mothers as compared to non-maltreating mothers (N = 80).

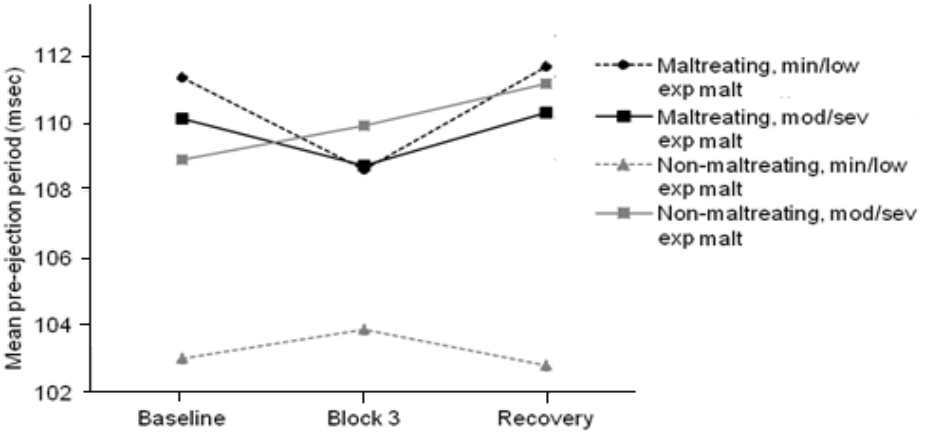

Figure 2. Pre-ejection period (PEP) responses to cry sounds in maltreating mothers moderated by experienced maltreatment. *Note:* Block 3 to recovery: decreasing PEP values for non-maltreating mothers who experienced low levels of maltreatment, as opposed to increasing PEP values for other subgroups (N = 77). Min/low = minimal/low; mod/sev = moderate/severe; exp malt = experienced maltreatment.

Summary of Main Findings

Maltreating mothers showed a significantly weaker SCL increase in response to the cry sounds than non-maltreating mothers. Furthermore, the decreasing trend of PEP for maltreating mothers in response to the cry sounds was significantly different from the increasing trend of PEP for non-maltreating mothers. During recovery, the increasing trend of PEP values for maltreating mothers was significantly different from the stable PEP of non-maltreating mothers. This effect was further qualified by an interaction with mothers' experienced maltreatment, such that for the non-maltreating group, PEP values for mothers low on experienced maltreatment tended to decline, whereas PEP for non-maltreating mothers high on experienced maltreatment tended to increase. This was different for maltreating mothers, for whom the PEP recovery did not vary according to the severity of experienced maltreatment. We found no differences in HR and vagal tone levels or reactivity patterns as a function of the current maltreatment status or the experienced maltreatment severity. Finally, nonsignificant positive correlations between HR and PEP in maltreating mothers differed significantly from moderate negative correlations between HR and PEP in non-maltreating mothers.

Discussion

Congruent with our hyporeactivity hypothesis, we found that maltreating mothers showed lower SCL reactivity to infant cry sounds than non-maltreating mothers, despite the fact that perceived urgency of the sounds was equal for both groups. Unexpectedly, our findings for PEP seemed to be in the opposite direction, but they were less pronounced. Even though the PEP reactivity patterns differed significantly between maltreating and non-maltreating mothers, for neither group did the PEP levels change in reaction to infant crying. PEP and SCL are both considered to be reliable measures of sympathetic activity (Goedhart, Willemsen, Houtveen, Boomsma, & De Geus, 2008), but SCL reacts quickly (see Lim et al., 1997), whereas sympathetic action on the heart (i.e., PEP) shows a long latency (Berntson, Cacioppo, & Quigley, 1993). Compared to PEP, SCL may therefore be a more appropriate measure of sympathetic reaction to stimuli of short duration (as our cry sounds were).

The hyporeactivity hypothesis was not supported by our findings for HR and vagal tone. For all mothers, HR increased as a response to infant crying, while vagal tone did not decrease significantly for either group.

The limited vagal tone reactivity in our study concurs with the previous findings in harsh and non-harsh mothers during the same cry paradigm (Joosen et al., 2013b). In another study, only highly sensitive mothers showed a pronounced withdrawal of vagal tone in reaction to the cry sounds (Joosen et al., 2013a). Considered together, these results may indicate that this particular reactivity pattern is specific to caregivers at the positive end of the sensitivity spectrum. Furthermore, the fact that there were no differences between maltreating and non-maltreating mothers in HR and vagal tone reactivity might reflect the extent to which the groups are comparable. Although they differed on several aspects (e.g., age and health-related issues, as discussed subsequently), children of both groups had at least one clinical diagnosis. This entails a minimum of family-related or caregiving challenges in the non-maltreating group as well, perhaps even rendering it as a high-risk control group.

Shorter PEP was associated with higher HR in non-maltreating mothers, but not in maltreating mothers, which suggests a lack of sympathetic cardiac boost in maltreating mothers. Low vagal tone was associated with high HR in both groups throughout the cry paradigm. For maltreating mothers, this lack of vagal cardiac control in combination with a lack of sympathetic cardiac control suggests the so-called *co-inhibition* of the PNS and SNS, which has been associated with externalizing problem behavior (El-Sheikh et al., 2009). In sum, although our findings are not unequivocal, the differences found between maltreating and non-maltreating mothers support the notion of sympathetic hypoactivity and reactivity as a risk factor contributing to child maltreatment.

The observed hyporeactivity to infant crying could be indicative of a dissociative coping strategy in maltreating mothers. A dissociative subtype of posttraumatic stress disorder has been distinguished from the reexperiencing/hyperaroused subtype and is marked by neurological overregulation of affect and arousal, accompanied by a lack of autonomic arousal in response to traumatic stimuli (Lanius et al., 2010). Based on the evidence of attenuated skin conductance responses in patients with derealization (a form of dissociation characterized by feelings of unreality or detachment), a neurobiological model of autonomic dampening was proposed (Sierra & Berrios, 1998). It conveyed that once a certain level of anxiety is reached, the medial prefrontal cortex inhibits emotional processing on the amygdala, resulting in attenuated sympathetic output and reduced emotional experience of stimuli. On a subclinical level, maltreating mothers may

similarly disengage from the emotional content of infant cry sounds. Future studies could include functional magnetic resonance imaging as a method to test this possibility.

Contrary to our expectations, we did not find evidence for hyperreactivity in the subgroup of maltreating mothers who were AN. This might be because of insufficient statistical power due to smaller subgroup sizes. Another explanation could be that all maltreating mothers in our sample neglected their children, so that a clear-cut distinction based on the type of maltreatment was impossible. Future research would benefit from an operationalized distinction between emotional and physical abuse and neglect to see whether different patterns of dysfunctional autonomic reactivity are associated with different types of child maltreatment. As evident from our study, a complication may be that different types of maltreatment rarely occur in isolation (e.g., Manly, Cicchetti, & Barnett, 1994). Large sample sizes may facilitate the comparison of differential risk factors as related to subtypes of maltreatment, both separately and in co-occurrence.

However, another possibility is that sympathetic hyporeactivity marks both child abuse and neglect and reflects a certain inherent similarity between the two groups. Less affection, play behavior, and initiative to interact with their children was observed in both abusive and neglectful mothers compared to non-maltreating mothers at home (Bousha & Twentyman, 1984). More recently, no differences between abusive and neglectful mothers were found in their (limited) display of positive parenting and strict or hostile control toward their children during a challenge task, and both groups showed affective inconsistency (Skowron, Cipriano-Essel, Benjamin, Pincus, & Van Ryzin, 2013). The cry sounds we presented mothers with were mild child-related stressors of an intensity that mothers are likely to encounter on a daily basis. It is possible that abusive and neglectful mothers show limited responsiveness to children's quotidian signals on a physiological, affective, and behavioral level. Their behavioral (and possibly psychophysiological) coping strategies might diverge when presented with more severe educational challenges. Indeed, the risk of abuse has been known to increase during infant crying that is deemed excessive in duration (Reijneveld, Van der Wal, Brugman, Hira Sing, & Verloove-Vanhorick, 2004). Studies that include childrelated stimuli of an increasingly enduring and stressful nature as well as home observations of a wide range of natural scenarios are needed to enhance our understanding of this issue.

Finally, the severity of maltreatment experienced by mothers in their own childhood only moderated the relationship between current maltreatment status and PEP reactivity. PEP reactivity was not different for maltreating mothers who experienced low or high levels of maltreatment. However, for nonmaltreating mothers PEP recovery patterns differed according to maltreatment experiences, that is, those with more maltreatment experiences showed an increasing trend similar to that of maltreating mothers, while those with few or no childhood maltreatment experiences showed a declining trend. Since we would expect to see the most adaptive physiological pattern in non-maltreating mothers with minimal childhood maltreatment experiences, a possible inference might be that the recovery pattern of PEP in the other three groups is maladaptive. For the non-maltreating group, having experienced substantial maltreatment as a child appears to put their PEP recovery pattern together with that of maltreating mothers. However, as mentioned earlier, PEP reaction patterns were not pronounced and these results should therefore be interpreted with caution.

It is important to note that maltreating mothers were younger than non-maltreating mothers, and more maltreating mothers had smoked on the day of the research appointment (despite our request not to do so), while fewer had exercised the previous week. This seems in itself a meaningful profile. It is consistent with the finding that low parental age is modestly associated with risk for maltreatment (Stith et al., 2009). Smoking and lack of exercise are coping behaviors observed in people with early life trauma, such as experiences of child abuse and neglect (Kibler, 2013). We controlled for the potentially confounding influence of smoking and maternal age by including them as covariates in the analyses. In other important aspects maltreating and non-maltreating mothers were similar, such as the fact that children of both groups had at least one clinical diagnosis. This reduces the probability that observed differences stemmed from mothers' experiences with their own children and suggests a link to differences in caregiving.

Limitations of our study include the generalizability of the results. We presented short, standardized cry sounds in an experimental setting (albeit an environment familiar to the participants). Although child signals of a longer duration might have evoked stronger physiological effects, the length of the cry bouts we used rendered them comparable to infant crying on an everyday level. Furthermore, we compensated for their shortness by looking at the cumulative effect of repeated crying on physiological reactivity. Standardization enhances the comparability of results among studies, but it is unknown to what extent the results can

be generalized to mothers' natural caregiving context. As indicated, studies using observational methods in parents' natural surroundings are needed. Finally, our sample was homogeneous in various aspects, such as gender and ethnicity. Studies including heterogeneous samples need to be done to see to what extent these findings apply to different populations.

Effect sizes were small, similar to those found in other studies on physiological reactivity using the same cry paradigm (Joosen et al., 2013a, 2013b). This is not surprising, given that sympathetic hyporeactivity is one risk factor in a complex constellation of interacting risk factors (Cicchetti & Lynch, 1993). However, the suggestion that in common caregiving situations, maltreating mothers might be primarily disengaged from their children is useful for the focus of potentially effective intervention programs. Maternal unresponsiveness to infant signals and interactional withdrawal were found to predict infant disorganization of attachment (Lyons-Ruth, Bronfman, & Parsons, 1999), which is a risk factor for clinical problems later in life (particularly dissociative disorder; Dozier, Stovall-McClough, & Albus, 2008). A meta-analysis has shown that interventions that focus on increasing maternal sensitivity appear to be most effective in reversing disorganized attachment classifications (Bakermans-Kranenburg, Van IJzendoorn, & Juffer, 2005). This focus may be adequate for maltreating, disengaged mothers as well, not in the least by redirecting mothers' attention toward the child and making them continually aware of their child's signals (Bakermans-Kranenburg et al., 2005). Interestingly, it has been suggested that positive parenting might be taxing for abusive mothers, since they displayed low RSA levels during relatively positive parenting behaviors, which were then followed by an episode of strict control (Skowron et al., 2013). Intervention programs would therefore do well to include parental self-esteem and satisfaction as outcome measures to see whether interactional improvement between mother and child also changes mothers' intrinsic experience of parenting.