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Research article

The past is present: The role of maltreatment history in perceptual, behavioral and autonomic responses to infant emotional signals

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ABSTRACT

In the current study associations between parents' experiences of childhood maltreatment and their perceptual, behavioral and autonomic responses to infant emotional signals were examined in a sample of 160 parents. Experienced maltreatment (both physical and emotional abuse and neglect) was reported by the participants and, in approximately half of the cases, also by their parents. During a standardized infant vocalization paradigm, participants were asked to squeeze a handgrip dynamometer at maximal and at half strength while listening to infant crying and laughter sounds and to rate their perception of the sounds. In addition, their heart rate (HR), pre-ejection period (PEP), and vagal tone (RSA) were measured as indicators of underlying sympathetic and parasympathetic reactivity. Results indicated that participants did not differ in their perceptions of the infant vocalizations signals according to their maltreatment experiences. However, maltreatment experiences were associated with the modulation of behavioral responses. Experiences of neglect during childhood were related to more handgrip force during infant crying and to less handgrip force during infant laughter. Moreover, a history of neglect was associated with a higher HR and a shorter PEP during the entire infant vocalization paradigm, which may indicate chronic cardiovascular arousal. The findings imply that a history of childhood neglect negatively influences parents' capacities to regulate their emotions and behavior, which would be problematic when reacting to children's emotional expressions.

1. Introduction

The experience of childhood maltreatment (i.e., abuse and neglect) has long-term negative consequences for a range of behaviors, including those associated with later parenting (Norman et al., 2012; Pears & Capaldi, 2001). Emotional dysregulation can be considered a key pathway through which experiences of child maltreatment influence how parents respond to their children. Numerous studies have shown that adverse caregiving experiences, including child maltreatment, contribute to emotion dysregulation in general (e.g., Dvir, Ford, Hill, & Frazier, 2014), yet fewer attempts have been made to study the effects of childhood maltreatment on emotion regulation specifically in response to child emotional signals. Only three studies so far have examined whether parents' history of maltreatment was related to their emotion regulation and responding to infant emotional signals, using relatively small samples of mothers only (Casanova, Domanic, McCanne, & Milner, 1994; Compier-de Block et al., 2015; Reijman et al., 2014). Since

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emotion regulation and responding to infant emotional signals are considered important mechanisms underlying sensitive parenting (e.g., Joosen et al., 2013; Reijman et al., 2016), a significant gap in the literature exists. In the current study, we examined whether parents' childhood maltreatment experiences contribute to their emotion regulation and response to infant distress in a large sample of both mothers and fathers. Previous studies have used either cognitive, physiological, or behavioral measures as indices of emotion regulation in response to infant emotional signals (e.g., Compier-de Block et al., 2015; Groh & Roisman, 2009). To our knowledge this study is the first to examine all three domains, in both fathers and mothers.

Attachment theory (Bowlby, 1969) offers an integrative theoretical framework to understand how exposure to childhood maltreatment can impact adult processing of and responding to child emotional signals. A central tenet of attachment theory (Bowlby, 1969) is that children develop an internal working model (i.e., a mental representation) of the self and others through repeated interactions with their primary caregiver(s), which guides their future social and emotional behavior. These internal working models are assumed to characterize distinct strategies of emotion regulation that children and adults employ to manage distress and negative emotions in a range of contexts, including interactions of parents with their children (Mikulincer & Shaver, 2008). Experiences of childhood maltreatment have been longitudinally linked to adults' formation of insecure working models (Raby, Labella, Martin, Carlson, & Roisman, 2017), and insecure working models in turn have been found to translate into insensitive caregiving behavior (Dykas & Cassidy, 2011). Moreover, it has been suggested that individual variation in adults' internal working models as reflected in different styles of emotional responding is most evident when adults are confronted with attachment-related stressors (Kobak, Cole, Ferenz-Gillies, Fleming, & Gamble, 1993). Infant crying is a typical attachment-related stressor and has been shown to elicit physiological arousal in both parents and non-parents, and in both females and males (Frodi, Lamb, Leavitt, & Donovan, 1978; Groh & Roisman, 2009). Crying may be adaptive and necessary for a baby's survival (Bowlby, 1969), but it can also evoke irritation and may trigger abuse and neglect (e.g., Out, Bakermans-Kranenburg, van Pelt, & van IJzendoorn, 2012).

An important prerequisite for emotion regulation and responding to emotional stimuli is the ability to process social information effectively (Gross, 2002). According to Dykas and Cassidy (2011), individuals process social information in accordance with their attachment- related experiences. Secure individuals draw on their positive attachment-related knowledge to process social information in a positively biased manner, whereas insecure individuals process attachment-relevant social information in a negatively biased manner. Thus, parents' experiences of childhood maltreatment might influence the way in which they process child emotional signals. Indeed, it was shown that mothers who received harsh parenting during childhood had more negative attitudes about their child's behavior (Daggett, O'Brien, Zanolli, & Peyton, 2000). Furthermore, adults with a history of parental emotional rejection have been found to make more negative attributions (e.g., child just wants attention, is selfish) about a distressed infant (Leerkes & Siepak, 2006).

The experience of childhood maltreatment may also compromise parents' autonomic responses to child emotional signals. The autonomic nervous system (ANS) is part of the peripheral nervous system that influences the function of internal organs, and has two main divisions: the sympathetic nervous system (SNS) and the parasympathetic nervous system (PNS). Generally, the SNS causes bodily energy mobilization during stressful or emergency situations, whereas the PNS is concerned with energy conservation and restoration during resting states (Larsen, Schneiderman, & DeCarlo Pasin, 1986). Measurement of heart rate (HR) alone does not indicate whether SNS or PNS influences are predominant. A widely used measure to monitor changes in cardiac SNS activity is the pre-ejection period (PEP), which is determined by indirect measurement of systolic time intervals and reflects cardiac contractility (Newlin & Levenson, 1979). The degree of cardiac control by the PNS division is commonly quantified by measuring the amplitude of respiratory sinus arrhythmia (RSA; Porges, 1995). In a typical stress response, HR will increase, PEP will decrease due to a shortening of the systolic period, and RSA will decrease due to inhibition of the vagal brake.

Studies that focused on the association between ANS reactivity to psychosocial stressors and childhood maltreatment mainly point to physiological *hyper*-reactivity in response to stressors (i.e., overarousal) after childhood maltreatment (e.g., Heim et al., 2000; Dale et al., 2009), but *hypo*-reactivity (i.e., underarousal) has also been documented (e.g., Ginty, Masters, Nelson, Kaye, & Conklin, 2016). To our knowledge only two studies have associated maltreatment experiences with ANS reactivity specifically to child emotional signals (Casanova et al., 1994; Reijman et al., 2014). In both studies differential reactivity to infant emotional signals was found depending on maltreatment experiences, however, conclusions warrant caution because sample sizes were small.

In addition to ANS reactivity, which reflects responsivity to distress, a history of childhood maltreatment may compromise sustained (i.e., basal) ANS activation. Sustained ANS activation may more generally represent the capacity for emotion regulation (Appelhans & Luecken, 2006). In spite of a paucity of research, convergent findings point to chronic ANS arousal as a result of childhood maltreatment experiences (e.g., Dale et al., 2009; Miskovic, Schmidt, Georgiades, Boyle, & MacMillan, 2009).

The influence of childhood maltreatment experiences on emotion regulation and responding may not only be reflected in physiological dysregulation, but also in behavioral dysregulation. A documented way to operationalize behavioral responses to infant signals is to use a handgrip dynamometer to measure participants' use of excessive force when exposed to infant stimuli. According to Bugental, Lewis, Lin, Lyon, and Kopeikin (1999) adults who process the motives of their children in a negatively biased manner might use excessive punitive force in order to control their children. This reasoning finds support in the study of Riem, Bakermans-Kranenburg, van IJzendoorn, Out, and Rombouts (2012) who used the handgrip dynamometer to examine the association between attachment representations and behavioral reactivity to infant crying. Adults with insecure attachment representations experienced more irritation and used more excessive force when listening to infant crying than individuals with secure representations. Lack of modulation of handgrip force might thus be a correlate of insecure internal working models. Moreover, research has shown that maltreating mothers used excessive force more often while listening to infant crying and laughter than non-maltreating mothers (Compier-de Block et al., 2015). The inability to modulate behavioral responses to infant emotional signals might, therefore, be a risk factor for maltreating behavior. Although the association between excessive handgrip force and maltreatment history was not significant in this study, the group of mothers who experienced childhood maltreatment was small (n = 39), which might have limited the power to detect an effect.

Lastly, it may be important to distinguish between experiences of abuse *versus* neglect when examining the consequences of child maltreatment on the regulation of stress and emotion, though few studies did so. Child neglect implies an act of *omission* and is related to the failure to meet the child's physical and emotional needs, whereas child abuse implies acts of *commission* which can be verbal or physical. Both abuse and neglect have been associated with maladaptive development, yet it is still unclear whether abuse and neglect differentially affect behavioral and biological systems (Gunnar & Quevedo, 2007).

In the current study cognitive, physiological, and behavioral responses to infant emotional vocalizations were examined in relation to experienced childhood maltreatment. We hypothesized that individuals with childhood maltreatment experiences (physical and emotional neglect vs. physical and emotional abuse) are more likely to report negative feelings and exhibit autonomic hyperreactivity (HR increase, PEP and RSA decrease) in response to infant crying. It was also hypothesized that childhood maltreatment experiences are associated with overall sustained physiological arousal. On the behavioral level, childhood maltreatment experiences are expected to predict lower modulation of handgrip force (and thus more excessive force) in response to infant crying. To explore whether the effects of experienced maltreatment on cognitive, behavioral and autonomic responses were specific to infant crying, infant cry sounds were compared to infant laughter sounds.

2. Method

2.1. Participants

Participants of the current study were part of the larger Three Generation (3G) parenting study, a family study on the intergenerational transmission of parenting styles, stress and emotion regulation (see also Compier-de Block et al., 2016). Participants from the current study were recruited via three other studies that included the assessment of caregiving experiences (Joosen, Mesman, Bakermans-Kranenburg, & van IJzendoorn, 2013; Penninx et al., 2008; Scherpenzeel, 2011). From two of these studies we recruited only participants who reported that they had experienced some form of maltreatment in their childhood. All participants from the third study were recruited. Thus, participants with an increased risk of experienced maltreatment were oversampled. From these studies, individuals who had agreed to being invited for participation in future studies, and who had at least one child of 8 years or older were invited. These individuals served as target participants. A total of 63 target participants agreed to participate in the current study. After their consent, we invited their family members (parents, partners, children, adult siblings, nephews, nieces and in-laws) to participate as well. This resulted in a total of 332 family members who also agreed to participate. The included family members were not screened for childhood maltreatment.

The infant vocalizations paradigm was administered to parents who were not older than 70 years to prevent confounds due to hearing loss and other medical conditions (e.g., hypertension). A total of 190 participants were eligible for the task. However, due to technical problems, schedule mistakes, and lack of time during the lab visits 30 participants did not complete the infant vocalizations paradigm and were excluded. Due to technical problems, 13 participants had missing data on handgrip force, and an additional 12 participants (nine for technical reasons, three because of a heart condition incompatible with electrocardiogram analysis) had no physiological data. Therefore 160 participants were included in the perception analysis, 147 participants in the analysis on behavioral responses, and 135 participants in the analyses on autonomic responses. See Supplement for a comparison of included and excluded participants on demographics and childhood maltreatment experiences.

2.2. Procedure

Participants and their families were invited to the lab for one or two days, depending on family composition. Participants with children visited the lab once with their nuclear family and once with their family of origin (if their parents were willing and able to participate). During the lab visits, participants individually completed computer tasks and questionnaires, and did several interaction tasks together with other family members. Furthermore, saliva and hair samples were collected, and during specific tasks skin conductance and heart rate were measured. Eligible participants were also invited for a functional magnetic resonance imaging (fMRI) session.

The study was approved by the ethics committee of the Leiden University Medical Center. Written informed consent was obtained from all participants before participation. As a compensation for participation, adults received 50 Euros for one lab visit and up to 100 Euros for two lab visits, as well as travelling expenses.

2.3. Measures

2.3.1. Childhood maltreatment

Experienced abuse and neglect were assessed with the Conflict Tactics Scale, Parent-Child version (CTS-PC, Straus, Hamby, Finkelhor, Moore, & Runyan, 1998) supplemented with items from the Childhood Trauma Questionnaire (CTQ, Bernstein et al., 1994; see also Compier-de Block et al., 2016). The CTS-PC and the CTQ have demonstrated construct validity in measuring a range of child maltreatment behaviors (Bernstein et al., 1994; Straus, Hamby, Finkelhor, Moore, & Runyan, 1998). Participants filled out a version in which they reported on experienced childhood maltreatment before the age of 18 years by (each of) their parent(s). Their parents filled out a version that assessed the extent to which they had conducted maltreating behaviors towards (each of) their child(ren) in the past, before their children had reached the age of 18 years.

The CTS-PC originally consists of four scales. In the current study, the *Nonviolent Discipline* scale (4 items) was excluded, because it includes no items on maltreatment. The *Psychological aggression* scale (i.e., emotional abuse) consists of 5 items (e.g., "Shouted, yelled, or screamed at me"). Cronbach's alphas were adequate: $\alpha_{mother} = 0.81$, $\alpha_{father} = 0.73$. *Physical Assault* (i.e., physical abuse) is comprised of 13 items, including corporal punishment (5 items, e.g., "Being spanked on the bottom with a bare hand"), severe assault (4 items, e.g., "Being hit with a fist or kicked hard"), and very severe assault (4 items, e.g., "Being burned or scalded"). Cronbach's alphas for Physical Assault were excellent: $\alpha_{mother} = 0.92$, $\alpha_{father} = 0.93$. The *Neglect* scale consists of 5 items (e.g., "My father/mother was not able to make sure I got the food I needed"). Cronbach's alphas for the four items about physical neglect were adequate: $\alpha_{mother} = 0.73$, $\alpha_{father} = 0.67$. Since the *Neglect* scale includes only one item on emotional neglect ("My father/mother never told me he/she loved me"), we added five items of the *Emotional Neglect* scale of the Childhood Trauma Questionnaire (CTQ, Bernstein et al., 1994), reverse coded for the purpose of analysis. To match the response categories of the CTS and CTQ, we used a 5-point scale ranging from 1 = *never* to 5 = *almost always* for all items. Cronbach's alphas for *Emotional Neglect* were excellent: $\alpha_{mother} = 0.94$, $\alpha_{father} = 0.91$.

To create a maltreatment history score, four scale scores (*Emotional* and *Physical Abuse*, and *Emotional* and *Physical Neglect*) were calculated from participants' self-reported experienced maltreatment by their parents. Scale scores were comprised of the highest score for father or mother (e.g., the highest score of *Emotional Abuse by father* and *Emotional Abuse by mother* was used to comprise the scale *Emotional Abuse*). Next, an overall *Abuse* score by averaging Emotional and Physical Abuse, and an overall *Neglect* score was comprised by averaging Emotional and Physical Neglect. In the same way, scale scores were calculated for their parents' self-reported maltreating behavior. On a scale ranging from (1) never to (5) (almost) always, average *Abuse* scores ranged from 1 to 4.5 and average *Neglect* scores ranged from 1 to 5. Because the distribution of the CTS data was skewed, scores were log-transformed and then multiplied by 10 to scale up the variance. There was one outlier ($n = 1$), which was winsorized, i.e., the difference between the two next highest values was added to the next highest value with standardized value < 3.29 (Tabachnik & Fidell, 2001) to fit the distribution.

Whenever possible, we combined information from two informants: participants (experienced childhood maltreatment) and their parents (perpetrated child maltreatment during their child's childhood). For 65 out of 160 participants at least two informants (participants and their parents) reported on experienced maltreatment. In these cases, *Abuse History* and *Neglect History* scores were calculated by averaging parent report and child reports of abuse and neglect. For 95 participants only self-report information on experienced maltreatment was available. Although convergence between parent- and child reported incidence of maltreatment can be modest (e.g., Compier-de Block et al., 2016), we choose to include information from multiple informants whenever possible to produce a more comprehensive picture. As a check, we did sensitivity analyses using only self-report data. These analyses yielded the same pattern of results for all outcomes, except for PEP. A summary of the model of PEP conducted with only self-report data can be found in the Supplement, Table 1.

2.3.2. Behavioral responses to infant cry and laughter sounds

An adult handgrip dynamometer was used to assess the use of excessive force during a standardized infant vocalizations paradigm (for a detailed description of the dynamometer and the derivation of the infant sounds, see Compier-de Block et al., 2015). Participants were first asked to practice maximally squeezing the handgrip dynamometer with their preferred hand several times, and were then asked to practice squeezing at 50% of their maximum grip strength. During the practice period participants could check their performance on a monitor. Participants performed as many trials as necessary until they were able to modulate the force of their second squeeze to half the strength of their first squeeze. During the remainder of the task, the monitor was directed away from the participants.

The infant vocalizations paradigm was administered on a laptop using E-prime software. Participants were prompted to squeeze the handgrip dynamometer eight times at full and half strength, respectively, during a silent period (no sound) and while listening to infant cry and laughter sounds. The cry and laughter sounds were presented in counterbalanced order. Test–retest reliability for handgrip strength measurement has been shown to be adequate (0.91 for men and 0.94 for women across a 10-week period; Reddon, Stefanyk, Gill, & Renney, 1985). Following previous studies (e.g., Compier-de Block et al., 2015) grip strength modulation was calculated by dividing the half-strength squeeze intensity by the full-strength squeeze intensity, so that scores of over 0.50 indicated excessive force on the half-strength squeeze attempt. Scores were then multiplied by 10 to scale up the variance. Data inspection revealed one outlier in the first and one in the second relative squeeze intensity during the no sound period, and one in the third relative squeeze intensity during laughter sound. These outliers were winsorized. Fourteen participants had missing data on one squeeze intensity (six during no sound, four during laughter, and four during cry), and one participant had missing data on three squeeze intensities (one during laughter sounds and two during cry sounds). These were imputed with the average of the other squeeze intensities of the participant in that particular episode (as was also done in Compier-de Block et al., 2015).

2.3.3. Perception of infant cry and laughter sounds

After each infant sound, participants rated their perception of the sound on four 5-point scales: not aroused–aroused, not urgent–urgent, healthy–sick, and not aversive–aversive (Zeskind & Lester, 1978). A principal component analysis (PCA) on the four ratings for crying and laughter sounds pointed to one underlying component, explaining 53% and 57% of the variance, respectively. Factor loadings ranged from 0.63 to 0.84 for crying and from 0.67 to 0.83 for laughter. Therefore, the ratings were aggregated to obtain scores for the overall perception of the sound, for crying and laughter separately. Higher scores indicated a more negative perception of the sound. Cronbach's alphas were adequate (crying: $\alpha = 0.68$, laughter: $\alpha = 0.72$).

2.3.4. Autonomic responses to infant cry and laughter sounds

During the infant vocalizations paradigm, Electrocardiogram (ECG) signals and Impedance Cardiogram (ICG) signals were recorded using an ambulatory monitoring system (VU-AMS5 fs; TD-FPP, Vrije Universiteit, Amsterdam, the Netherlands). The ECG signal was 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. 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). E-prime had been programmed to send markers to the ECG and ICG recording during no sound, the presentation of each infant sound (crying and laughter) and the answering of the questions. To control for physical influences on the ECG and ICG data, participants were asked to refrain from alcohol and physical exercise for twenty-four hours prior to the experimental session.

The 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). Next, we labeled the data according to the markers sent by E-prime. From each ICG recording, PEP was scored manually per labeled segment by the first author and two trained research assistants. Interrater reliability between all pairs of observers was adequate to excellent, with intraclass correlations (single measures, absolute agreement) ranging from 0.83 to 0.97. The respiration signal was obtained from filtered (0.1–0.4 Hz) thoracic impedance signal. The beginning and end of inspiration and expiration were detected by an automatic scoring algorithm. RSA was derived by the peak-valley method, which combined the respiratory time series and the interbeat intervals (IBI) to calculate the shortest IBI during HR acceleration in the inspiration phase, and the longest IBI during deceleration in the expiration phase (de Geus, Willemsen, Klaver, & van Doornen, 1995). RSA was defined as the difference between the longest and the shortest IBI. Scoring of the respiration signal and the IBI was done automatically. Average HR, PEP, and RSA were derived per labeled segment, i.e., 12 20-s intervals preceding each prompt to squeeze at full strength for squeezing during the no-sound condition, and during cry and laughter sounds (thus, the periods in which the participants squeezed at full and half strength were not coded). Subsequently, the mean within the segments was calculated per episode (no sound, cry, laughter) in SPSS. Prior to the infant vocalization paradigm, participants were presented with a series of landscape pictures for 2 min to measure resting autonomic activity. The no-sound condition, however, was used for comparison with the infant cry and laughter conditions to measure activity specific to emotional signals and in order to keep activity related to the use of hand-grip force constant.

Outliers were inspected per labeled segment as well as per aggregated episode. For both HR and PEP one participant showed outlying values for individual segments, which were winsorized. Combined episodes showed no outliers. Since RSA data were negatively skewed, these were logarithmically transformed. The log-transformed data were then multiplied by 10 to scale up the variance. Remaining outliers (n = 3) were winsorized. Respiration rate was taken into account in analyses on RSA, as RSA is known to be susceptible to changes in breathing pattern (e.g., Bernardi, Porta, Gabutti, Spicuzza, & Sleight, 2001).

2.4. Analyses

To examine whether maltreatment experiences were associated with parents' resting autonomic activity, separate multiple regression analyses were run for HR, PEP and RSA, with experienced abuse and neglect as independent variables and age, gender and several lifestyle and disease factor entered as covariates. To examine the effects of infant crying and laughter sounds on participants' perceptions, autonomic responses, and behavioral responses, separate stepwise multilevel analyses were employed for each outcome measure. Multilevel modeling was used to match the hierarchical structure of the data: the measurements of perceptions, autonomic responses and behavioral responses were nested within individuals, while individuals were nested within families. Thus, three levels were specified: stimulus, person, and family level. Because of the large age range, and in accordance with previous studies on reactivity to infant sounds (e.g., Out et al., 2012; Reijman et al., 2014), age and gender were included as covariates in all multilevel analyses. Additionally, pertinent lifestyle and disease variables (e.g., socio-economic status (SES), alcohol, smoking, exercise, heart medication, anti-depressants) were entered in the models on HR, PEP, and RSA, and omitted when p values exceeded .05.

For every outcome we started with an unconditional means model-which decomposed the variance in the outcome measures into three independent components, $\sigma_e{}^2$, $\sigma_{u0}{}^2$ and $\sigma_{v0}{}^2$ (Model 1). This model was used to compute the intraclass correlation coefficient (ICC) at the family level ($\sigma_{v0}{}^2/\sigma_{v0}{}^2 + \sigma_{u0}{}^2 + \sigma_e{}^2$) and the individual level ($\sigma_{u0}{}^2/\sigma_{v0}{}^2 + \sigma_{u0}{}^2 + \sigma_e{}^2$). When the ICC at the family or individual level was (close to) zero and showed extremely large confidence intervals, that level was removed from the analysis. However, including the level did not affect the results. Gender and age were then added to the unconditional means model (Model 2). In the next step the unconditional growth model- random intercept only was tested, in which episode (dummy-coded with cry as the reference category) and order of presentation were added as predictors (Model 3). Next the unconditional growth model-random intercepts and slopes was tested (Model 4). Subsequently, experienced abuse and neglect were added as continuous predictors (Model 5). Based on this model, two separate analyses were run: one with experienced abuse and the interaction with episode and one with experienced neglect and the interaction with episode, to see whether this resulted in an improved model fit (Models 6 and 7). Multilevel regression analyses were fitted using the '***nlme***' package (Pinheiro, Bates, DebRoy, Sarkar, & R Core Team, 2017) in R (R Core Team, 2017). Likelihood ratio tests were used to evaluate whether model fit improved. Continuous predictors were centered around their mean.

3. Results

Participants included in the current study (n = 160) were on average 45.8 years old (SD = 10.0, range: 28.8–69.7 years) and the sample was rather homogenous in terms of ethnicity: 96% of the participants were Caucasian. More females (58%) than males participated in the current study. The majority of participants (63%) had an advanced secondary school or vocational school diploma, 26% held a college or university degree, 5% had completed only elementary school or a short track of secondary school, and 6% of the participants did not report their education.

3.1. Preliminary analyses

As a check, we examined whether infant crying provoked more negative feelings than infant laughter. A paired comparison *t*-test revealed that the cry sound ($M = 10.04$, $SD = 2.45$) evoked significantly more negative feelings than the laughter sound ($M = 5.49$, $SD = 3.39$), $t(159) = 15.84$, $p < .001$).

Autonomic measures (HR, PEP, RSA) and the behavioral measure (handgrip force) correlated highly over the paradigm conditions. Correlations ranged from 0.86 to 0.98 for the autonomic measures and from 0.77 to 0.86 for handgrip force. Participants with higher HR during the entire paradigm had significantly lower RSA during the entire paradigm, with correlations ranging from −0.39 to −0.47. Higher HR was also related to shorter PEP during no sound ($r = -0.18$, $p = .04$). RSA during no sound was associated with handgrip force during no sound ($r = 0.19$, $p = .03$), laughter ($r = 0.22$, $p = .01$), and crying ($r = 0.21$, $p = .02$). More experienced abuse was related to more negative perceptions of infant laughter ($r = 0.17$, $p = .03$), and experienced neglect was negatively related to RSA during no sound, laughter and crying (with a correlation of r = -0.24 and $p < .01$). See Supplement, Table 2 for a summary of the descriptive statistics and correlations.

Experienced neglect was positively associated with resting HR ($\beta = 0.26$, $t = 2.76$, $p = .007$), but not with resting RSA ($\beta = -0.15$, $t = -1.95$, $p = .053$) or resting PEP ($\beta = -0.08$, $t = -0.80$, $p = .45$). No associations were found between experienced abuse and resting HR, PEP or RSA ($ps > .17$). See Supplement, Table 3 for the multiple regression analyses on resting HR, PEP and RSA.

3.2. Perception

The results of the unconditional means model (Model 1) revealed that the proportion of explained variance (ICC) was close to zero for both the variance at the family level (< .001) and the individual level (< .001), indicating no dependency in the data. Therefore two multiple regression analyses were done for the perception of infant laughter and cry sounds, respectively, as dependent variables. For laughter, age, gender and order of presentation were included in the first step. This model explained 9% of the variance in the perception of laughter sounds. In the second step experienced abuse and neglect were included as predictors. There was no significant increase in explained variance ($\Delta R^2 = 0.02$, $F(2,154) = 1.45$, $p = .24$). Experienced abuse and neglect were both not significantly associated with perception of laughter sounds, $\beta = 0.15$, $t = 1.69$, $p = .09$ and $\beta = -0.04$, $t = -0.44$, $p = .66$, respectively. For cry sounds, the first model with age, gender and order of presentation included, explained 8% of the variance in perception of cry sounds. Including experienced abuse and neglect in the second step did not result in a significant increase in the amount of explained variance ($\Delta R^2 = 0.02$, $F(2,154) = 1.40$, $p = .25$). Experienced abuse and neglect were not significantly associated with perception of cry sounds, $\beta = 0.14$, $t = 1.58$, $p = .12$ and $\beta = -0.01$, $t = -0.14$, $p = .89$, respectively. See Supplement, Table 4 for the multiple regression analyses on perceptions of cry and laughter sounds.

3.3. Autonomic responses

3.3.1. Heart rate (HR)

The results of the stepwise multilevel model on HR are presented in Table 1. The unconditional means model (Model1) revealed that the proportion of explained variance (ICC) was < .001 at the family level and. 96 at the individual level, indicating high dependency at the individual level and no dependency at the family level. Because the variance of the family level was close to zero with an extremely large confidence interval, the family level variance was omitted from the model. Of the lifestyle and disease factors only alcohol use and physical exercise were significantly related to HR across the task. Caffeine, smoking, use of medication, hearing problems, and SES were not significantly related to HR across the task ($ps > .09$) and omitted from the model. Adding gender, age, physical exercise, and alcohol use as predictors to the intercept-only model (Model 2) resulted in an improved model fit ($\chi^2(4) = 21.08$, $p < .001$). In Model 3 episode and order of presentation were added as predictors, which further improved model fit ($\chi^2(3) = 28.47$, $p < .001$). This model showed a significantly higher HR during laughter than during crying ($t = 4.35$, $p < .001$), but no significant difference between no sound and cry ($t = -0.63$, $p = .53$). Adding a random slope did not significantly improve model fit ($\chi^2(5) = 5.19$, $p = .39$), therefore we continued with the unconditional growth model. Experienced abuse and neglect were added to this model (Model 4), which resulted in a significant model improvement ($\chi^2(2) = 7.90$, $p = .02$). Experienced neglect was significantly positively related to HR ($t = 2.58$, $p = .01$), meaning that participants who experienced more childhood neglect had a significantly higher HR than participants that experienced less neglect. See Fig. 1, for an illustration of this finding. Experienced abuse was not significantly associated with HR ($t = 0.02$, $p = .93$). Lastly, adding the interactions between episode and experienced abuse and neglect did not significantly improved model fit for experienced neglect, $\chi^2(2) = 1.76$, $p = .41$ or abuse, $\chi^2(2)$ 1.43, $p = .49$ (not reported in Table 1). Therefore, Model 4 was accepted as the final model including only the main effects of experienced abuse and neglect.

Table 1
Mean heart rate (HR) and Pre-ejection period (PEP) during infant sounds and experienced abuse and neglect.

	Model 1	Model 2	Model 3	Model 4
HR				
Fixed effects				
Intercept	67.61 (0.87)***	76.68 (2.91)***	75.96 (3.85)***	76.42 (3.81)***
Age		−0.08 (0.09)	−0.07 (0.09)	−0.17 (0.09)
Gender		1.38 (1.72)	1.40 (1.73)	1.51 (1.70)
Physical exercise		−2.78 (0.97)**	−2.86 (0.97)**	−2.85 (0.95)**
Alcohol use		−1.32 (0.46)**	−1.33 (0.47)**	−1.45 (0.46)**
Order			0.33 (1.63)	0.37 (1.63)
No sound – Cry			−0.11 (0.18)	−0.11 (0.18)
Laughter – Cry			0.79 (0.18)***	0.79 (0.18)***
Exp[a] Abuse				0.03 (0.80)
Exp Neglect				1.99 (0.77)*
Variance components				
Stimulus level Int[b]	2.40 (0.22)	2.39 (0.21)	2.16 (0.19)	2.16 (0.18)
Person level Int	102.01 (12.6)	87.04 (10.48)	87.23 (10.78)	82.08 (10.02)
Deviance	2165.13	2152.05	2129.58	2125.68
PEP				
Fixed effects				
Intercept	113.90 (2.01)***	109.41(3.09)***	119.89 (6.77)***	122.54 (6.81)***
Age		−0.04 (0.21)	−0.05 (0.21)	0.07 (0.23)
Gender		7.64 (4.05)	6.81 (4.04)	6.40 (3.99)
Order			−6.43 (3.96)	−7.87 (3.98)
No sound – Cry			−1.43 (0.51)**	−1.43 (0.51)**
Laughter – Cry			−0.60 (0.51)	−0.61 (0.51)
Exp[a] Abuse				3.30 (1.96)
Exp Neglect				−3.76 (1.88)*
Variance components				
Stimulus level Int[b]	17.72 (1.56)	17.72 (1.53)	17.22 (1.48)	17.22 (1.48)
Person level Int	538.24 (66.58)	523.50 (64.54)	507.15 (63.01)	489.29 (60.08)
Deviance	2912.36	2912.70	2908.18	2907.21

Note. Standard errors are in parentheses. Gender coded 0 = male, 1 = female. Order coded 0 = Laughter, 1 = Cry. Episode is dummy-coded in two dummies (No sound, Laughter) with Cry as the reference category. Because of extremely large confidence intervals for the variance at the family level, this level was removed from the analysis. Excluding variance at the family level did not influence the results.

[a] Exp = experienced.
[b] Int = intercept.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

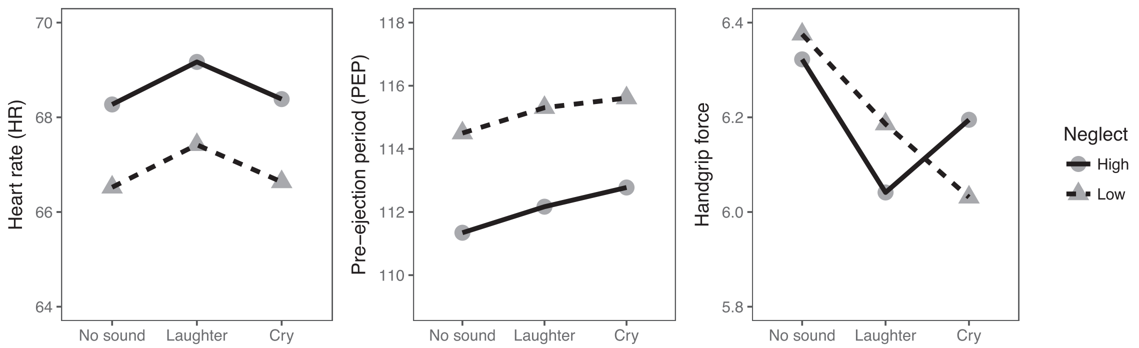

Fig. 1. Mean heart rate, pre-ejection period and handgrip force for each episode of the infant vocalizations paradigm, separately for different ratings for experienced neglect. For illustrative purposes participants were divided into two groups, a high and a low neglect group, based on a median split. A continuous score of experienced neglect was used in the multilevel analyses.

3.3.2. Pre-ejection period (PEP)

The results of the stepwise multilevel model on PEP are presented in Table 1. The results of the unconditional means model (Model 1) revealed that the proportion of explained variance (ICC) was < .001 at the family level (with extremely large confidence intervals) and 0.96 at the individual level, indicating high dependency at the individual level and (almost) no dependency at the family level. We therefore omitted the variance at the family level and continued with a two-level model. None of the lifestyle and disease factors were significantly related to PEP across the task (*ps* > .10) and they were omitted from the model. Gender and age were added as predictors to the intercept only model (Model 2). Adding the covariates did not result in an improved model fit ($\chi^2(2) = 3.66$, $p = .16$). Model 3, with order and episode added as predictors, showed significantly better model fit than Model 2 ($\chi^2(3) = 10.52$, $p = .02$). Participants had a significantly shorter PEP during no sound than during cry ($t = -2.79$, $p = .006$). PEP during laughter was not significantly different from PEP during cry ($t = -1.18$, $p = .24$). Adding a random slope did not improve model fit ($\chi^2(5) = 1.77$, $p = .88$), therefore analyses were continued with the unconditional growth model (Model 3).

In Model 4 experienced abuse and neglect were added as predictors, which tended to improve model fit ($\chi^2(2) = 4.97$, $p = .08$). Experienced neglect was significantly negatively associated with PEP ($t = -2.00$, $p = .047$), indicating that more experienced neglect during childhood was related to a shorter PEP. An illustration of this finding is provided in Fig. 1. Experienced abuse was not significantly associated with PEP ($t = 1.63$, $p = .11$). Lastly, adding the interactions between episode and experienced abuse and neglect did not significantly improve model fit for experienced neglect, $\chi^2(2) = 2.02$, $p = .37$ or abuse, $\chi^2(2) = 0.12$, $p = .94$ (not reported in Table 1). Therefore, Model 4 was accepted with only the main effects of experienced abuse and neglect as the final model.

3.3.3. RSA

The results of the unconditional means model (Model 1) showed that the proportion of explained variance (ICC) was close to zero at the family level (with a large confidence interval) and 0.82 at the individual level. We therefore omitted the variance at the family level and continued with a two-level model. Of the lifestyle and disease factors only exercise was significantly associated with RSA. None of the other lifestyle and disease factors were significantly related to RSA ($ps > .15$), and were omitted from the model. Gender, age, respiration rate and physical exercise were then added to the unconditional means model (Model 2), which resulted in improved model fit ($\chi^2(3) = 113.71$, $p < .001$). In the next step, order and episode were added the model (Model 3). There was no significant improvement of model fit ($\chi^2(2) = 3.51$, $p = .32$), meaning that RSA did not vary as a function of episode. In the next step experienced abuse and neglect were added (Model 3), which did not result in significant improvement of the model fit ($\chi^2(2) = 2.12$, $p = .35$). Moreover, the model showed no significant associations between experienced abuse and RSA, $t = -0.01$, $p = .99$ or experienced neglect and RSA, $t = -1.29$, $p = .24$. The interactions between episode and experienced abuse or neglect that were added in the next step did not significantly improve model fit for experienced neglect, $\chi^2(2) = 0.30$, $p = .86$ or abuse, $\chi^2(2) = 3.30$, $p = .19$. A summary of the model on RSA can be found in the Supplement (Table 5).

3.4. Behavioral responses

The results of the stepwise multilevel model on handgrip force are presented in Table 2. The unconditional means model (Model 1) revealed that the proportion of explained variance (ICC) was 0.06 at the family level and 0.74 at the individual level. This indicated that a small amount (6%) of the variation in handgrip force was explained by differences between families and that a significant amount (74%) of the variation was explained by differences between individuals. Adding gender and age as predictors to the intercept-only model (Model 2) did not improve the model fit ($\chi^2(2) = 0.16$, $p = .90$). Episode and order of presentation were subsequently added to the model (Model 3), which resulted in an improved model fit ($\chi^2(3) = 12.67$, $p = .005$). Significantly more force was used during no sound than during crying ($t = 3.18$, $p = .002$), but force did not differ between the laughter and the cry

Table 2
Behavioral responses (handgrip force) to infant sounds and experienced abuse and neglect.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Fixed effects	Coef (se)	Coef (se)	Coef (se)	Coef (se)	Coef (se)	Coef (se)
Intercept	6.21 (0.13)***	6.21 (0.19)***	5.95 (0.41)***	5.99 (0.41)***	5.96 (0.42)***	5.96 (0.42)***
Age		0.01 (0.01)	0.01 (0.01)	0.01 (0.01)	0.01 (0.01)	0.01 (0.01)
Gender		−0.01 (0.24)	−0.01 (0.24)	0.05 (0.24)	0.06 (0.24)	0.06 (0.24)
Order			0.11 (0.23)	0.06 (0.23)	0.07 (0.24)	0.07 (0.24)
No sound – Cry			0.24 (0.08)**	0.25 (0.08)**	0.25 (0.08)**	0.25 (0.08)**
Laughter – Cry			0.01 (0.08)	0.02 (0.07)	0.02 (0.07)	0.02 (0.07)
Experienced Abuse					−0.04 (0.11)	−0.04 (0.11)
Experienced Neglect					−0.10 (0.11)	−0.06 (0.11)
Experienced Neglect x No sound						−0.10 (0.06)
Experienced Neglect x Laughter						−0.15 (0.05)**
Variance components						
Stimulus level Intercept	0.46 (0.04)	0.46 (0.04)	0.44 (0.04)	0.34 (0.04)	0.34 (0.04)	0.30 (0.04)
Person level Intercept	1.77 (0.26)	1.77 (0.27)	1.77 (0.27)	2.07 (0.24)	2.07 (0.31)	2.07 (0.43)
Slope (No sound)				0.30 (0.12)	0.30 (0.12)	0.32 (0.12)
Cov int/slope				0.18 (0.06)	0.20 (0.06)	0.18 (0.05)
Family level Intercept	0.14 (0.37)	0.13 (0.38)	0.13 (0.39)	0.06 (1.52)	0.06 (1.50)	0.06 (2.47)
Deviance	1300.44	1304.28	1297.61	1289.15	1291.82	1286.92

Note. Gender coded 0 = male, 1 = female. Order coded 0 = Laughter, 1 = Cry. Episode is dummy-coded in two dummies (No sound, Laughter) with Cry as the reference category.

** $p < .01$.

*** $p < .001$.

episode ($t = 0.23$, $p = .81$). Adding a random slope for laughter did not yield a reliable estimate, therefore only a random slope for no sound was specified in Model 4. This resulted in a significant model improvement from Model 3 to Model 4 ($\chi^2(2) = 12.45$, $p = .002$).

Next, experienced abuse and neglect were added as predictors (Model 5). There was no improvement from Model 4 to Model 5 ($\chi^2(2) = 1.55$, $p = .46$); experienced abuse and neglect were both not significantly related to handgrip force, $t = -0.37$, $p = .72$ and $t = -0.87$, $p = .38$, respectively. Lastly, adding the interactions between episode and experienced abuse, and between episode and experienced neglect in two separate analyses resulted in a significantly improved model fit for experienced neglect ($\chi^2(2) = 8.17$, $p = .016$, see Table 2), but not for experienced abuse ($\chi^2(2) = 2.43$, $p = .32$). Therefore, Model 6 with the inclusion of the interaction between experienced neglect and episode was accepted as the final model. The results of this model showed a significant interaction between experienced neglect and laughter ($t = -2.83$, $p = .005$), meaning that experiences of neglect were differently related to handgrip force during the cry and laughter episode. See Fig. 1 for an illustration of this finding. Regression analyses for cry and laughter separately showed that more neglect was related to more handgrip force during infant crying (controlling for laughter, $\beta = 0.11$, $p = .03$) and to less handgrip force during infant laughter (controlling for crying, $\beta = -0.13$, $p = .01$).

4. Discussion

In the current study we examined whether childhood maltreatment (physical and emotional neglect vs. physical and emotional abuse) experiences are negatively related to parents' emotion regulation and responses to infant signals across perceptual, physiological, and behavioral levels. Parents did not differ in their perceptions of infant crying and laughter according to their maltreatment experiences. In addition, a history of child abuse or neglect was not associated with autonomic hyper-reactivity to infant signals. However, a history of neglect was related to a higher HR and a shorter PEP during the entire infant vocalizations paradigm, which may be a sign of chronic cardiovascular arousal. Finally, experiences of neglect were differently related to modulation of handgrip force during listening to infant cry and laughter sounds.

Unexpectedly, parents did not rate the sounds differently according to their maltreatment experiences, which may seem to contradict previous research suggesting that parents with negative early caregiving experiences made more negative attributions about child emotional signals (Dykas & Cassidy, 2011; Leerkes & Siepak, 2006). However, in these studies participants were often asked to rate ambiguous child behavior. The infant vocalizations that were used in our study were unambiguously recognizable as infant happiness and infant distress. Therefore, our results indicate that maltreatment experiences do not influence processing of and responding to infant emotional signals on a conscious level.

However, we did find associations with experienced maltreatment on a physiological level. Although, unexpectedly, there was no evidence for ANS *reactivity* as a function of maltreatment experiences, the results point to *chronic* autonomic activation as a result of maltreatment experiences. Conform our expectations, a history of neglect was associated with higher resting HR paralleled by a higher HR and a shortened PEP throughout the entire infant vocalizations paradigm, which suggests that parents with a history of neglect exhibited elevated autonomic arousal regardless of the specific demands of the environment. Since RSA was not associated with maltreatment experiences, findings may suggest that elevated autonomic activity in neglected parents is mainly driven by activation of the SNS – a hypothesis that should be tested in future studies because effect sizes for PEP were modest. Our findings regarding chronic autonomic arousal are in line with previous investigations that indicated that a history of maltreatment was associated with elevated autonomic activity as seen in less vagal regulation of the heart (i.e., higher RSA; Dale et al., 2009; Miskovic et al., 2009) and higher SCL (Casanova et al., 1994) even in the absence of specific stressors. Whereas ANS reactivity provides insight into parents' responsivity to a stressor, sustained autonomic activation may more generally reflect the capacity to regulate emotions (Brosschot, Pieper, & Thayer, 2005; Reijman et al., 2016). Thus, parental emotion regulation deficits may not only be manifest when dealing with infant distress, but may also be observable in non-parenting situations. The present findings are also in line with McEwen's (1998) theory of allostatic load, which posits that the ANS attempts to maintain stability through change during stressful conditions in order to maximize survival, a process referred to as allostasis. When the system is exposed to repeated or chronic stress, such as child maltreatment, physiological responses may become dysregulated, a process called allostatic load.

Experiences of neglect were differently related to modulation of handgrip force during listening to infant cry and laughter sounds: more neglect related to greater use of handgrip force during infant crying and less handgrip force during infant laughter. The link between neglect and more force during infant crying was in line with our hypothesis, and may indicate that parents with more experiences of neglect are more negatively aroused by infant distress, increasing the likelihood that they respond with harsh and aggressive behavior. This reasoning builds on prior arguments that aversion and anxiety may cause parents to punish infants for displaying negative affect in order to end the aversive stimulus (e.g., Out et al., 2010). The link between neglect and less force during infant laughter may indicate that parents with more experiences of neglect are less positively aroused by infant laughter. Infant laughter is a rewarding stimulus that generally elicits feelings of love and happiness from parents and reinforces parental playful interactions (Bowlby, 1969; Groh & Roisman, 2009). It is possible that negative childhood experiences, such as neglect, reduce the rewarding value of infant laughter and thereby diminish parental playful interactions. In a recent fMRI study it was found that experimentally induced oxytocin enhanced the incentive salience of infant laughter in individuals by modulating neural circuits related to emotion processing (Riem, van IJzendoorn et al., 2012). Given that maltreated children have low levels of oxytocin (e.g., Seltzer, Ziegler, Connolly, Prosoki, & Pollak, 2014), it is tempting to suggest that infant laughter may be less rewarding for parents who experienced neglect because of reduced oxytocin levels.

Remarkably, parents used more handgrip force and exhibited more SNS activity during the no sound condition than during infant sound conditions, while the 'no sound' condition is usually assumed to be the least stressful. Although instructions for the no sound part were similar to the other parts of the task, it was the first part of the task and participants may have felt most insecure about their performance. This may have resulted in increased arousal during this part of the task.

Lastly, we found associations between various domains of emotion regulation and a history of neglect, but no associations with a history of abuse. This might indicate that experiences of neglect have a more profound impact on emotion regulation skills in response to infant emotional signals than experiences of abuse. Although childhood neglect is a relatively understudied form of child maltreatment, it has been argued that childhood neglect has lasting, significantly negative consequences, equal to or even exceeding the long-term consequences of childhood abuse, because neglect tends to be more chronic (Hildyard & Wolfe, 2002).

We focused on child abuse and neglect from a continuous measurement perspective. In clinical and legal contexts, a dichotomization of child maltreatment may be used to decide whether to act or not to act, but for research purposes a cutoff is rather arbitrary. Moreover, measuring maltreatment in a continuous manner enabled us to examine a dose-response relationship between child maltreatment and outcomes in adults.

Unlike most previous studies, we included both sympathetic and parasympathetic measures to investigate the relation between maltreatment and autonomic functioning, rather than measuring the activity of just one system. In doing so, we followed the recommendations of Reijman et al. (2016) who argued for examining multiple autonomic measures to clarify the concept of physiological arousal. The inclusion of multiple autonomic measures increases the number of statistical tests, which in turn may increase the risk of type 1 errors. However, we tested a set of a priori specified hypotheses, and the outcome variables are considered to be different domains of emotion regulation and not alternative measures of the same phenomenon, which reduces the relevance of the type 1 error problem (e.g., Streiner & Norman, 2011). Moreover, multilevel modelling was used to test our hypotheses. Unlike the commonly used repeated measures analysis of variance, in which the point estimates are kept stationary, multilevel models shift point estimates and their corresponding intervals toward each other (by a process referred to as "partial pooling"). Multilevel estimates are thus more conservative in the sense that intervals for comparisons are more likely to include zero (Gelman, Hill, & Yajima, 2012).

The limitations of the current study should be noted. First, we acknowledge the potential limitations of retrospective reporting of childhood experiences. Participants may have difficulty recalling childhood events (Edwards et al., 2001) or may be reluctant to disclose certain experiences or behaviors. A second limitation is the correlational design of the study, which precludes drawing causal inferences. Replication is needed in future studies with prospective and/or experimental intervention designs in order to more accurately isolate the effects of childhood maltreatment on adults' emotion regulation in response to infant emotional signals. Third, participants were exposed to cry and laughter sounds of unfamiliar infants in a laboratory context. Observations of parents' exposure to emotional signals of their own infants in a naturalistic setting would have increased the ecological validity. At the same time, it would have decreased the internal validity: the standardized design of the infant vocalization paradigm minimized the likelihood that the differences found between parents´ emotional responses to infant signals are due to child factors.

Taken together, we found evidence that parents who experienced neglect during their childhood show patterns of autonomic activity and behavioral responding to infant signals that are indicative of poor regulatory skills and that, in turn, may contribute to insensitive or even abusive caregiving (Compier-de Block et al., 2015; Joosen et al., 2013). Congruent with an attachment perspective, early attachment experiences may thus influence the development of emotion regulation strategies thought to be important for later adult adaptation (Bowlby, 1969). Together with the finding that parents´ perceptions of infant emotional signals did not vary as a function of their maltreatment experiences, these results indicate that the effects of maltreatment on emotional responding to infant signals operate mainly at an unconscious level. The findings may provide a basis for intervention modules that help parents with a history of neglect become aware of their physiological and behavioral reactions and to successfully regulate their responses in order to promote sensitive parenting. Since neglect is a highly prevalent type of maltreatment (Stoltenborgh, Bakermans-Kranenburg, & van IJzendoorn, 2013) and sensitive parenting is crucial for children's socio-emotional development (e.g., Leerkes, Blankson, & O'Brien, 2009), such intervention modules may ultimately benefit the development of many children.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.chiabu.2017.12.020

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