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Maternal Depressive Symptoms and Affective Responses to Infant Crying and Laughing

Annemiek Karreman[1], Myra P. R. Starmans[1], and Madelon M. E. Riem[2, 3]
[1] Department of Medical and Clinical Psychology, CoRPS—Center of Research on Psychological Disorders and Somatic Diseases, Tilburg University
[2] Behavioural Science Institute, Radboud University Nijmegen
[3] Clinical Child & Family Studies, Faculty of Behavioral and Movement Sciences, Vrije Universiteit Amsterdam

Depressive symptoms are common in the postpartum period and can affect mother–infant interaction. To better understand the role of depressive symptoms in the mother–infant interchange, this study examined whether maternal depressive symptoms are associated with self-reported, physiological, and facial expressive responses to infant crying and laughing sounds. A nonclinical sample was used, consisting of 101 mothers (Age $M = 30.88$ years, 33% scored 7 or higher on the Edinburgh Postnatal Depression Scale) with a young child. Mothers were exposed to standard infant crying and laughing sounds. Affect, perception of crying and laughing, intended caregiving responses, skin conductance level reactivity, and facial expressive responses to infant crying and laughing were measured. Higher levels of depressive symptoms were associated with more self-reported negative affect in general and a more negative perception of infant crying. Depressive symptoms were not associated with intended caregiving responses and physiological responses to infant crying. Infant laughing increased self-reported positive affect and happy facial expressions in mothers with all levels of depressive symptoms. Higher levels of depressive symptoms were associated with higher sad facial expressivity in general. Depressive symptoms were not related to positive perception of infant laughing, intended caregiving responses, and physiological responses to infant laughing. The findings suggest that mothers who score high on depressive symptoms send subtle facial cues showing sadness, which may overshadow happy facial expressions during infant laughing and may affect mother–infant interaction.

Keywords: infant crying, infant laughing, maternal depressive symptoms, parental responses, emotional facial expressivity

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Mild depressive symptoms are common in mothers with a young child: 27.8% of the mothers in the postpartum period have mild depressive symptoms (Lyubenova et al., 2021). Even mild depressive symptoms can impede maternal sensitivity to the infant and relate to negative coercive behaviors (Bernard et al., 2018; Lovejoy et al., 2000). Low maternal sensitivity can affect mother–infant attachment, which is essential for children's emotional, cognitive, and social development (Behrendt et al., 2016; Mesman et al., 2009; Raby et al., 2015). Therefore, it is important to detect early signs of mothers' deteriorated sensitivity. The present study aims to examine how maternal depressive symptoms are associated with self-reported, physiological, and emotional facial expressive responses to infant crying and laughing sounds in a nonclinical sample of mothers with a young child.

Depressive symptoms are likely associated with maternal responses to infant crying through several mechanisms. In general, infant crying is an evolutionary adaptive signal that elicits emotional and physiological (e.g., increased skin conductance level [SCL] reactivity) arousal (Emery et al., 2014; Groh & Roisman, 2009), stimulating sensitive caregiving responses (Dix, 1991). Mothers with higher levels of depressive symptoms may be particularly sensitive to the aversive characteristics of infant crying as they generally have emotion and emotion regulation problems (Dix, 1991). Therefore, infant crying may trigger negative emotions in mothers with higher levels of depressive symptoms, which can undermine sensitive caregiving responses (Dix, 1991; Dix et al., 2004, 2014). To minimize distress, mothers with higher levels of depressive symptoms may show reduced physiological reactivity to infant crying to disengage from the caregiving context (Dix et al., 2014). A study showed that severely depressed women rated infant crying sounds as less perceptually salient and reported less intended sensitive caregiving responses than women with lower depression scores (Schuetze & Zeskind, 2001). Depressed mothers show reduced neural activation to their own infant's crying (Laurent & Ablow, 2012). Even at a nonclinical level, depressive symptoms were found associated with reduced physiological responses to infant crying (Mutschler et al., 2016; Riem et al., 2011). Thus, studies report associations between depressive symptoms and responses to infant crying.

Depressive symptoms also seem to be associated with maternal responses to infant laughing in several ways. Like infant crying, infant laughing is an evolutionary adaptive signal that elicits emotional and physiological arousal (Emery et al., 2014; Groh & Roisman, 2009)

Annemiek Karreman https://orcid.org/0009-0006-7710-6649
The data, materials, and study analysis codes are available from the authors upon request. This study was not preregistered.
Correspondence concerning this article should be addressed to Annemiek Karreman, Department of Medical and Clinical Psychology, CoRPS—Center of Research on Psychological Disorders and Somatic Diseases, Tilburg University, P.O. Box 90153, 5000 LE, Tilburg, The Netherlands. Email: A.Karreman@tilburguniversity.edu

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and fosters sensitive caregiving responses (Dix, 1991). Infant laughing triggers reward regions in the parental brain and generates feelings of happiness and love, reinforcing parental proximity (Ferrey et al., 2016; Groh & Roisman, 2009; Kringelbach, 2005; Riem et al., 2012). However, mothers with higher levels of depressive symptoms have a cognitive bias for perceiving stimuli as primarily negative (Beck, 1976). They also tend to perceive their infants' behavior and temperament (e.g., smiling and laughter) more negatively (T. Field et al., 1993; Pesonen et al., 2004). Therefore, they may perceive infant laughing as less rewarding, relating to reduced physiological reactivity to infant laughing. Depressive symptoms are also associated with lower attentiveness and empathy, which can affect sensitive responses to infant laughing (Dix, 1991; T. Field et al., 2009). In general, depressed individuals show reduced self-reported and facial expressive reactivity but not reduced physiological reactivity in response to positive emotional stimuli (Bylsma et al., 2008; Davies et al., 2016). However, the previous research on emotional reactivity to positive stimuli has predominantly been conducted with adults without children. How mothers' depressive symptoms are associated with affective responses to infant laughing is unknown.

Although there is a dearth of studies on the role of depressive symptoms in mothers' facial expressive responses to infant signals, this knowledge is essential to understand mother–infant interactions (Braarud et al., 2017). According to the affection exchange theory, affectionate communication between parent and child enhances an intimate bond and promotes chances of survival (Floyd, 2006). Reciprocal social interaction between the child and parent is crucial for the infant's emotional and cognitive development (Liu et al., 2017; Mesman et al., 2009). This is illustrated by the still-face paradigm (Tronick et al., 1978), which shows that children are active contributors to social interaction and that when mother's face remains unresponsive, it affects the child's behavior negatively. Mothers who show signs of depression express less positive and more neutral affect when interacting with their infant (Aktar et al., 2017; T. Field et al., 2007). Studies generally observe affective behaviors (see Mesman et al., 2009) rather than assessing specific emotional facial expressions. However, happy and sad facial expressions can already be distinguished and imitated by newborns (T. M. Field et al., 1982) and can affect infants in several ways. Mothers' happy facial expressions in response to infant laughing elicit reciprocal interactions with the child (Beebe et al., 2016; Mendes et al., 2009; Mireault et al., 2015). Depressed mothers' sad facial expressions could negatively affect infants' processing of emotional facial expressions (Diego et al., 2004; T. Field et al., 1998). Therefore, it is important to examine how depressive symptoms relate to happy and sad facial expressions in mothers exposed to infant crying and laughing sounds.

The present experimental study examines how mild depressive symptoms are associated with mothers' responses to standardized infant crying and laughing sounds in a nonclinical sample of mothers with a young child. The study is conducted in the mothers' home environment, which we expected to result in more natural responses than the laboratory. This study adds to the previous literature by not only examining mothers' self-reported and physiological responses to infant signals, but also their sad and happy facial expressive responses to infant signals, assessed by means of facial expression recognition software. Moreover, examining how depressive symptoms are related to the perception of infant laughing adds to the literature, as previous studies on maternal depression predominantly focused on the perception of infant distress signals and neglected the role of positive, rewarding infant cues.

Based on the prior studies (e.g., Mutschler et al., 2016; Riem et al., 2011; Schuetze & Zeskind, 2001), we expected that higher levels of depressive symptoms in mothers who were exposed to the infant crying sound were associated with higher increased self-reported negative affect compared to baseline, a more negative perception of the crying sound, a lower intended sensitive and higher intended insensitive (harsh) caregiving response, and lower SCL reactivity. Though limited research on maternal depressive symptoms and responses to infant laughing is available, studies suggest that mothers with higher levels of depressive symptoms are less sensitive to infant laughing and express less positive affect to their infant (e.g., Aktar et al., 2017; Field et al., 2007, 2009). Therefore, we expected that higher levels of depressive symptoms in mothers who were exposed to the infant laughing sound were associated with a less pronounced increase in self-reported positive affect compared to baseline, a less positive perception of the laughing sound, a lower intended sensitive and higher intended insensitive caregiving response, and lower SCL reactivity. Finally, we expected that mothers' depressive symptoms were positively associated with sad facial expressivity, in particular when exposed to crying, and negatively associated with happy facial expressivity, in particular when exposed to laughing.

Method

We report how we determined our sample size, all data exclusions (if any), all manipulations, and all measures in the study.

Participants

Mothers of children up to the age of 3 years old were recruited by contacting day-care centers, which were asked to distribute recruitment flyers and information letters about the study, and by asking among acquaintances (directly and indirectly, using Facebook). Exclusion criteria were hearing problems because of the need to accurately hear the infant crying and laughing sounds, and insufficient mastery of the Dutch language because of the need to understand all instructions and questionnaires. The total sample consisted of 101 mothers with an age range from 21 to 41 years ($M = 30.88$ years, $SD = 4.23$). Children were between the ages of 1 and 36 months ($M = 13.68$ months, $SD = 8.99$). Of the mothers, 3.1% were single, 54.2% were married, 9.4% were in a civil partnership, 32.3% were living with a partner, and 1% was a widow (demographic data of five participants were missing). Most mothers were born in the Netherlands (85.4%) and had a paid job (84.4%). Of the mothers, 4.2% had completed elementary school, 35.4% had completed intermediate/higher secondary education, 35.4% had completed higher secondary education, and 25% had a bachelor's or master's degree. Furthermore, 46.9% of the mothers had one child, 39.6% had two children, 10.4% had three children, and 3.1% had four children. G*Power 3.1 showed that a sample size of 90 is sufficient to detect small to medium effects ($f = .15$, $\alpha = .05$, power .80) when performing a repeated measures analysis (within-subjects factors, two measurements). The local ethics committee granted permission for this study (protocol number: EC-2016.38).

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Procedure

This study is part of a larger project on the perception of infant signals. Mothers who signed consent were asked to complete online questionnaires (e.g., demographics, depressive symptoms) at home. One or two weeks later, they were visited at home by trained (under)graduate students. Mothers performed different tasks behind a laptop at a high table in the living room or kitchen. When children were at home, the experimenter looked after them to prevent mothers from being distracted during the assessment as much as possible. First, electrodes of an ambulatory monitoring system were fitted to the middle and index finger of mothers' nondominant hand for the measurement of skin conductance. Mothers' fingers were cleaned with water, and two electrodes were filled with isotonic electrode gel before fitting them to the fingers. Next, a cognitive assessment was administered for the purpose of another study (Karreman & Riem, 2020b), followed by the Cry Paradigm and Laugh Paradigm (see Figure 1) that were used in the present study. During the Cry and Laugh Paradigm, mothers wore headphones to listen to audio fragments. An external webcam was attached to the top of the laptop screen to record the mother's face.

Measures

Depressive Symptoms

Depressive symptoms during the past 7 days were assessed using a validated Dutch version of the ten-item Edinburgh Postnatal Depression Scale (EPDS; Pop et al., 1992). Each item (e.g., "I have been so unhappy that I have had difficulty sleeping") was rated on a 4-point scale (0–3; e.g., *Yes, most of the time, Yes, sometimes, Not very often, No, not at all*; reversed scored). Total scores could range from 0 to 30. In the current sample, scores ranged from 0 to 19 (M = 5.14, SD = 4.03). Cronbach's α in the present study was .83. Seven participants did not complete the EPDS. Of the participants who completed the EPDS, 13.8% scored equal to or above 10, indicating possible depression (Cox et al., 1987). According to the classification of McCabe-Beane et al. (2016) who identified depression severity ranges, 67% scored 0–6 (none or minimal depression), 27.7% scored 7–13 (mild depression), and 5.3% scored 14–19 (moderate depression, including one score of 19, which could also indicate severe depression, 19–30).

Self-Reported Affect

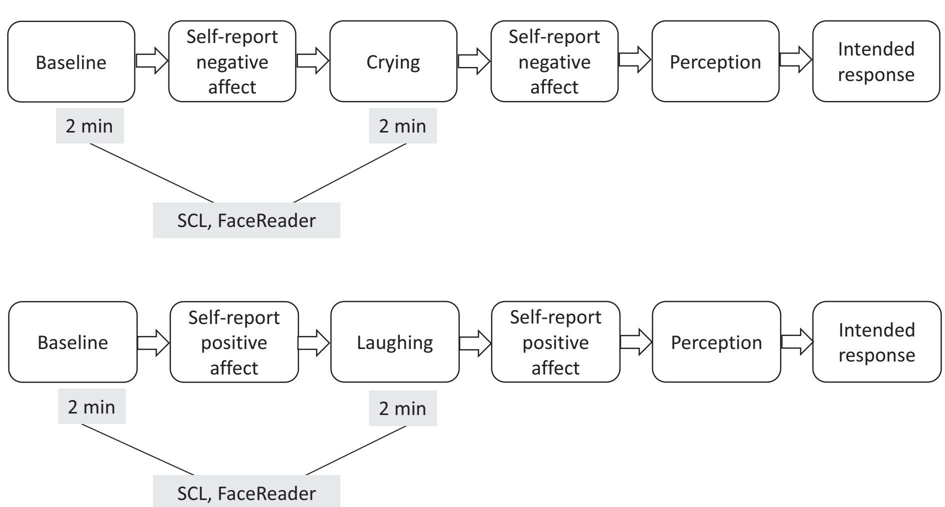
Current mood was measured with the Positive Affect Negative Affect Scale (PANAS; Watson et al., 1988). This scale includes 10 items for negative affect (e.g., upset, irritable, nervous) and 10 items for positive affect (e.g., interested, alert, enthusiastic). Each item was rated on a 5-point Likert scale (1 = *not at all* to 5 = *a lot*). The PANAS was administered at four different time points during the paradigms. Self-reported negative affect was measured at baseline of the Cry Paradigm (α = .74) and after the crying sound (α = .89). Self-reported positive affect was measured at baseline of the Laugh Paradigm (α = .91) and after the laughing sound (α = .90). Affect scores were calculated by averaging ratings at the baselines and after the infant crying and laughing sound. Self-reported negative and positive affect scores of two participants were missing.

Cry Paradigm

The cry perception task, also used by Riem and Karreman (2019), was administered on a laptop using the E-Prime 2.0 software (Schneider et al., 2012). First, as in previous studies (e.g., Out, Pieper, Bakermans-Kranenburg, & van IJzendoorn, 2010; Riem et al., 2011), there was a baseline in which mothers were instructed to relax and look at three landscape photographs for 2 min in total. Skin conductance was measured during the baseline, followed by a baseline measurement of self-reported negative affect. Then, the mothers listened to an infant crying sound for 2 min through headphones. The infant crying sound from Groh and Roisman (2009)

Figure 1

A Visualization of the Cry Paradigm (Upper Panel) and Laugh Paradigm (Lower Panel)



Note. SCL = skin conductance level.

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was used. The instruction that was presented on the screen was: "You will hear an infant crying sound. Listen to it." Mothers listened to the crying sound three times in different conditions: a neutral condition, the only condition that was used in this study, and two conditions in which mothers received different instructions on how to regulate their emotions during exposure to the crying sound, which were part of other studies (Karreman & Riem, 2020a; Riem & Karreman, 2019). The order of conditions was randomly assigned across participants. We controlled for order of conditions in additional analyses to check potential effects on the results of this study. After the crying sound presentation, mothers' self-reported negative affect was measured. In addition, mothers rated their perception of the cry. They were asked to indicate how sick, aversive, and urgent the crying sounded, and whether they experienced irritability during exposure to the cry. Each item was rated on a 5-point Likert scale (e.g., 1 = *not sick* to 5 = *sick*). Finally, mothers were asked to rate their intended caregiving response. They were asked to rate the likelihood of using the following behaviors on 5-point Likert scales (1 = *probably not* to 5 = *probably yes*): pickup, cuddle, wait and see, feed, firm handling, and focus on something else than on the crying baby. Facial expressions during the presentation of the crying sounds were recorded using a webcam. E-prime data of two participants were missing due to technical problems.

Laugh Paradigm

Mothers performed a laugh perception task (Riem et al., 2012), created in E-prime, on a laptop (see also Karreman & Riem, 2020a). The procedure was similar to that of the Cry Paradigm. The task started with a baseline during which mothers were instructed to relax and look at three landscape photographs for 2 min in total. SCL was measured during the baseline, which was followed by a baseline measurement of self-reported positive affect. Subsequently, mothers listened to an infant laughing sound (Groh & Roisman, 2009) with a duration of 2 min in three different conditions. As in the Cry Paradigm, the neutral condition was used in this study, in which the following instruction was presented on the screen: "You will hear an infant laughing sound. Listen to it." After the laughing sound presentation, mothers' self-reported positive affect was measured. In addition, mothers rated their positive perception of the laughing sound. They indicated how much affection, aversion, and warmth they felt while listening to the laughing sound. Each item was rated on a 5-point Likert scale (e.g., 1 = *no aversion* to 5 = *aversion*). Moreover, intended caregiving responses were measured. Mothers were asked to rate the likelihood of using the following behaviors on 5-point Likert scales (1 = *probably not* to 5 = *probably yes*): pickup, cuddle, play, wait and see, firm handling, and focus on something else than on the laughing baby. Facial expressions during the laughing sounds were recorded by the webcam. Due to procedural errors in administering the Laugh Paradigm, data were missing for one mother. One participant lost her attention and started talking and laughing during the laugh condition. The scores of this condition were coded as missing. Furthermore, because of technical problems E-prime data of three participants were missing.

SCL

SCL was assessed with the VU University Ambulatory Monitoring System (VU-AMS, https://vu-ams.nl/ams/) during four 2-min phases (i.e., the conditions cry baseline, crying sound, laugh baseline, and laughing sound). Markers indicating the start of the baseline and infant signal were recorded. The data were labeled according to these markers, and mean SCL was calculated for the four conditions. For both infant crying and laughing, baseline SCL was subtracted from SCL during the infant signal to calculate reactivity measures, which are often used in stress response studies (e.g., Leerkes et al., 2016). There were missing data because of technical problems (infant crying sound: 7 missings, infant laughing sound: 12 missings).

Facial Expressions

Mothers' emotional facial expressions during the four 2-min phases (i.e., the conditions cry baseline, crying sound, laugh baseline, and laughing sound) were recorded and analyzed afterward using Noldus's FaceReader 7 of the Behavioral Physiology Research Lab (GO-LAB, Tilburg University). This software was trained using the Facial Action Coding System (Ekman et al., 2002). FaceReader first detects the face. Then, the face is modeled in 3D by describing over 500 key points in the face and the facial texture. Finally, the facial expressions are classified (https://www.noldus.com/facereader/facial-expression-analysis). To achieve a higher classification accuracy, the results of face modeling are combined with the results of the Deep Face algorithm, based on Deep Learning. In the case of unsuccessful face modeling, for example, when a mother covers her mouth with her hand, the Deep Face algorithm takes over. High accuracy and convergent validity with Facial Action Coding System ratings have been reported (Lewinski et al., 2014).

Happy and sad facial expressions were analyzed during the 2-min phases using intervals of approximately .033 s, resulting in 3,597 scores for the two emotion expression scores for the four conditions (i.e., cry baseline, crying sound, laugh baseline, and laughing sound). Happy and sad facial expression scores range from 0 (*absence of emotion*) to 1 (*full intensity of emotion*). The overall missing data rate was 1.3% for the Cry Paradigm and 4.6% for the Laugh Paradigm, primarily due to blurred frames that resulted from movement. We created sad and happy facial expression scores for the cry baseline, crying sound, laugh baseline, and laughing sound conditions by averaging all available data of the specific condition. Mean emotion expression scores have been used in the previous studies using the FaceReader (e.g., Garcia-Burgos & Zamora, 2013; Karreman & Riem, 2020a; Riem & Karreman, 2019). The correlation between the cry baseline and laugh baseline was $r = .67$, $p < .001$ for happy facial expressions and $r = .76$, $p < .001$, for sad facial expressions. Complete facial expression scores for the Cry and Laugh Paradigm were missing for two participants due to technical problems.

Statistical Analyses

A cry perception score was calculated by averaging the scores for perceived sickness, aversiveness, urgency, and irritability, as in the previous studies (Out, Pieper, Bakermans-Kranenburg, & van IJzendoorn, 2010; Out, Pieper, Bakermans-Kranenburg, Zeskind, et al., 2010) and confirmed by principal component analysis (factor loadings: .52–.84). Higher perception scores reflect a more negative perception of the crying sound. A laugh perception score was

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calculated by averaging the scores for affection, aversion (reversed), and warmth. Higher scores reflect a more positive perception of the laughing sound. Moreover, based on the previous studies (Out, Pieper, Bakermans-Kranenburg, & van IJzendoorn, 2010; Out, Pieper, Bakermans-Kranenburg, Zeskind, et al., 2010) and confirmed by principal component analysis (Riem & Karreman, 2019) two scores for intended caregiving response to infant crying were created. The ratings for pickup, cuddle, feed, wait and see (reversed), and focus on something else (reversed) were averaged to create the score for sensitive caregiving response, and the rating for firm handling reflected the score for intended harsh response. Similarly, two scores for intended caregiving response to infant laughing were created (Karreman & Riem, 2020a). The ratings for pickup, cuddle, and play were averaged to create the score for sensitive caregiving response, and the ratings for wait and see, firm handling, and focus on something else were averaged to create the score for insensitive caregiving response. The correlation between sensitive and harsh caregiving response to infant crying was $r = .09$, $p = .38$; the correlation between sensitive and insensitive caregiving response to infant laughing was $r = -.08$, $p = .42$.

Data were inspected for outliers and distributions. Outliers were detected by inspecting boxplots and standardized values. Because the outliers could represent true scores, cases were retained, but scores were replaced by the most extreme value of the variable in the data set after excluding the outliers (infant crying: self-reported negative affect baseline $n = 3$, neutral $n = 1$; harsh caregiving $n = 5$; happy facial expressions baseline $n = 3$, neutral $n = 3$; infant laughing: skin conductance reactivity $n = 2$; happy facial expressions baseline $n = 4$). Analyses were repeated, including outliers, which yielded the same results (not reported).

Linear mixed models (LMMs) were tested and hierarchical multiple regression analyses were performed in IBM SPSS 24 to test the hypotheses. Five LMMs were tested for the outcome variables for which multiple assessments (conditions) were available: (a) self-reported negative affect (cry baseline, crying sound), (b) self-reported positive affect (laugh baseline, laughing sound), (c) SCL reactivity (crying sound, laughing sound), (d) happy facial expressions (cry baseline, crying sound, laugh baseline, laughing sound), and (e) sad facial expressions (cry baseline, crying sound, laugh baseline, laughing sound). By performing LMMs, we were able to examine differences between conditions. Cry and laugh baselines were examined separately to control for possible carryover effects.

Covariance pattern LMMs were tested. The accurateness of the fixed-effect parameter estimates and appropriateness of the statistical significance tests depend on the covariance structure of the tested models (West et al., 2007). Model fit of two covariance structures (unstructured, compound symmetry) was tested. We chose the best fitting covariance structure to test our models, indicated by the Bayesian information criterion (BIC). The covariance structure of compound symmetry was the best fitting structure in the models testing sad facial expressions and self-reported positive affect after infant laughing. The unstructured covariance structure was the best fitting structure in the models testing self-reported negative affect after infant crying, SCL reactivity, and happy facial expressions. Parameters were estimated using the maximum likelihood (ML) method.

The models included a fixed intercept. Condition, depressive symptoms (centered), and the interaction between condition and depressive symptoms (centered) were entered as fixed factors. Age of the child was included as a covariate because mothers of a newborn may respond differently to infant crying and laughing sounds than mothers of toddlers, which we wanted to control for. In the analyses with the dependent variable happy facial expressivity, sad facial expressions during infant crying and laughing were furthermore included as covariates because we aimed to examine effects independent of expressed sadness. Similarly, in the analyses with dependent variable sad facial expressivity, happy facial expressions during infant crying and laughing were included as covariates. All covariates were entered as fixed factors. In the case of a nonsignificant interaction, the analysis was rerun without including the interaction term.

To interpret main effects of condition, post hoc pairwise comparisons based on the estimated marginal means were used. To visualize effects of depressive symptoms, we dichotomized depressive symptoms using a cutoff score of 7 for mild depression (McCabe-Beane et al., 2016). We used this cutoff score instead of the frequently used clinical cutoff score of 10 (Cox et al., 1987) because it yields more statistical power to visualize results as only 13.8% of the participants scored in the clinical range. We consider the cutoff score of 7 as meaningful because the study aims to examine mild depressive symptoms in a nonclinical sample. Categories were referred to as no or minimal depression (scores below 7) and mild depression (scores of 7 and higher). Because the infant cry and laugh conditions were neutral conditions as part of experimental studies on effects of emotion regulation strategies, the variables order of cry conditions and/or order of laugh conditions (see Karreman & Riem, 2020a; Riem & Karreman, 2019) were tested as fixed factors but as they did not change the results they were not included in the final models.

Six hierarchical multiple regression analyses were performed to test our hypotheses concerning the dependent variables with one assessment: (a) perception of the infant crying sound, (b) perception of the infant laughing sound, (c) intended sensitive caregiving responses to infant crying, (d) intended harsh caregiving responses to infant crying, (e) intended sensitive caregiving responses to infant laughing, and (f) intended insensitive caregiving responses to infant laughing. To control for age of the child, we entered age of the child in the first step of the regression analyses. Level of depressive symptoms was entered as independent variable in the second step of the regression analyses. The data, materials, and study analysis codes are available from the authors upon request. This study was not preregistered.

Results

Preliminary Analyses

Table 1 shows the descriptive statistics of all study variables. The correlations among the dependent variables and depressive symptoms are presented in Table 2.

Responses to Infant Crying and Laughing

In the LMMs, there were no significant interaction effects between condition and depressive symptoms. Therefore, the

Table 1
Descriptive Statistics of All Study Variables

Study variable	*M*	*SD*	Min–Max
Depressive symptoms	5.14	4.03	0–19
Cry Paradigm			
Self-reported negative affect—baseline	1.27	0.28	1.00–2.00
Self-reported negative affect—infant cry condition	1.63	0.64	1.00–3.50
Negative perception	2.31	0.79	1.00–5.00
Intended sensitive caregiving	4.18	0.82	1.20–5.00
Intended harsh caregiving	1.36	0.84	1.00–4.00
Skin conductance level reactivity[a]	.23	0.66	−1.32–2.17
Happy facial expressions—baseline	.07	0.08	.00–.30
Happy facial expressions—infant cry condition	.08	0.11	.00–.40
Sad facial expressions—baseline	.20	0.17	.01–.75
Sad facial expressions—infant cry condition	.22	0.15	.01–.62
Laugh Paradigm			
Self-reported positive affect—baseline	2.84	0.88	1.00–4.60
Self-reported positive affect—infant laugh condition	3.39	0.83	1.00–5.00
Positive perception	4.60	0.50	2.67–5.00
Intended sensitive caregiving	3.88	0.95	1.00–5.00
Intended insensitive caregiving	1.66	0.67	1.00–4.00
Skin conductance level reactivity[a]	.07	0.46	−0.81–1.24
Happy facial expressions—baseline	.07	0.10	.00–.38
Happy facial expressions—infant laugh condition	.18	0.18	.00–.80
Sad facial expressions—baseline	.18	0.13	.01–.57
Sad facial expressions—infant laugh condition	.18	0.13	.01–.54

[a] Scores are calculated by subtracting baseline skin conductance level from skin conductance level during the infant cry/laugh condition.

analyses that are reported do not include the interaction term. Results of the covariates are described only if significant.

Self-Reported Responses

Responses to Infant Crying. The LMM with self-reported negative affect as dependent variable showed there was a significant effect of condition (cry baseline, crying sound) on self-reported negative affect, F (1, 92.000) = 38.79, $p < .001$. Pairwise comparison indicated that mothers reported higher negative affect scores after listening to infant crying compared to the baseline, $M_{\text{difference}} = .35$, 95% CI [.24, .46], $p < .001$. There was also an effect of depressive symptoms on self-reported negative affect, F (1, 92.000) = 10.33, $p = .002$. An additional LMM was performed, using the dichotomized score of depressive symptoms. Figure 2 shows that mothers with mild depression reported higher negative affect across conditions (cry baseline, crying sound) than mothers with no or minimal depression.

Regression analysis with dependent variable negative cry perception showed an effect of depressive symptoms, ΔF (1, 89) = 11.81, $p < .001$, $\Delta R^2 = .12$. Higher depressive symptom scores were associated with more negative perception of the crying sound ($B = .068$, $SE = .02$, $\beta = .34$, 95% CI [.03, .11]). Figure 3 shows the average negative perception scores for the two categories of depression symptoms reflecting no or minimal depression and mild depression, after controlling for age of the child.

There was no effect of depressive symptoms on intended sensitive caregiving response, ΔF (1, 89) = 2.87, $p = .094$, $\Delta R^2 = .03$. Neither was there an effect of depressive symptoms on intended harsh caregiving response, ΔF (1, 89) = 2.54, $p = .12$, $\Delta R^2 = .03$.

Responses to Infant Laughing. The LMM with self-reported positive affect as dependent variable showed there was a significant effect of condition (laugh baseline, laughing sound) on self-reported positive affect, F (1, 90.576) = 39.07, $p < .001$. Pairwise comparison indicated that mothers reported higher positive affect scores after listening to infant laughing compared to the baseline, $M_{\text{difference}} = .56$, 95% CI [.38, .73], $p < .001$. There was no effect of depressive symptoms on self-reported positive affect, F (1, 90.712) = .24, $p = .62$.

Regression analysis with dependent variable positive laugh perception showed no effect of depressive symptoms, ΔF (1, 87) = 0.01, $p = .92$, $\Delta R^2 = .00$. There was also no effect of depressive symptoms on intended sensitive caregiving responses, ΔF (1, 87) = 0.03, $p = .87$, $\Delta R^2 = .00$. Neither was there an effect of depressive symptoms on intended insensitive caregiving responses, ΔF (1, 87) = 2.73, $p = .10$, $\Delta R^2 = .03$.

Physiological Responses

The LMM with SCL reactivity as dependent variable showed an effect of condition (crying sound, laughing sound), F (1, 84.488) = 5.92, $p = .017$. Pairwise comparison revealed that mothers showed lower SCL reactivity to infant laughing compared to infant crying (exploratory), $M_{\text{difference}} = -.18$, 95% CI [−.33, −.03], $p = .017$. There was also an effect of the moderator age of the child, F (1, 83.672) = 5.74, $p = .019$. To interpret this effect, an additional LMM was performed for lower levels ($n = 43$) and higher levels ($n = 45$) of age of the child based on median split (median = 11.00 months). Mothers with younger children overall showed higher SCL reactivity than mothers with older children. There was no effect of depressive symptoms, F (1, 81.786) = .02, $p = .89$.

Facial Expressions

The LMM with happy facial expressivity as dependent variable showed an effect of condition (cry baseline, crying sound, laugh baseline, laughing sound), F (3, 80.000) = 14.54, $p < .001$. Pairwise comparison showed that mothers had higher happy facial expressivity scores when listening to the laughing sound compared to the other three assessments: cry baseline, $M_{\text{difference}} = .11$, 95% CI [.07, .15], $p < .001$, crying sound, $M_{\text{difference}} = .10$, 95% CI [.07, .14], $p < .001$, and laugh baseline, $M_{\text{difference}} = .12$, 95% CI [.08, .15], $p < .001$. There was no effect of depressive symptoms, F (1, 80.000) = .54, $p = .47$.

The LMM with sad facial expressivity as dependent variable showed an effect of condition (cry baseline, crying sound, laugh baseline, laughing sound), F (3, 240.000) = 3.37, $p = .019$. Pairwise comparison showed that mothers had higher sad facial expressivity scores during the crying sound than during the laughing sound, $M_{\text{difference}} = .04$, 95% CI [.01, .06], $p = .003$, and at laugh baseline, $M_{\text{difference}} = .03$, 95% CI [.00, .05], $p = .02$. An effect of depressive symptoms was found, F (1, 80.000) = 3.99, $p = .049$. An additional LMM was performed, using the dichotomized score of depressive symptoms. As shown in Figure 4, mothers with mild depression

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Table 2
Correlations Among the Dependent Variables and Depressive Symptoms

Study variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Depressive symptoms	—														
Cry Paradigm															
2. Self-reported negative affect	.24*	—													
3. Negative perception	.33**	.62***	—												
4. Intended sensitive caregiving	.18	.12	.13	—											
5. Intended harsh caregiving	.17	.23*	.12	.09	—										
6. Skin conductance level reactivity	.11	.07	.08	.14	.06	—									
7. Happy facial expressions	−.02	−.07	−.09	−.12	.11	.01	—								
8. Sad facial expressions	.12	.11	.14	.21	−.02	.04	−.27*	—							
Laugh Paradigm															
9. Self-reported positive affect	.09	.29**	.17	.09	.09	.02	−.20	.05	—						
10. Positive perception	.01	.11	−.09	.09	−.07	−.07	−.10	.21	.52***	—					
11. Intended sensitive caregiving	.04	−.01	−.08	.17	.15	−.13	−.10	.12	.34**	.44***	—				
12. Intended insensitive caregiving	.19	.23*	.10	.10	.29**	−.03	.09	−.05	.07	−.18	−.08	—			
13. Skin conductance level reactivity	−.06	.13	.04	−.08	−.27*	.23*	−.09	−.18	.01	−.07	−.14	−.12	—		
14. Happy facial expressions	.01	.22*	.07	.04	−.04	.09	.42***	−.22*	.10	.12	−.07	−.11	.26*	—	
15. Sad facial expressions	.13	.10	.24*	.12	.04	−.07	−.16	.77***	−.04	.07	.12	−.09	−.18	−.33**	—

* $p < .05$. ** $p < .01$. *** $p < .001$.

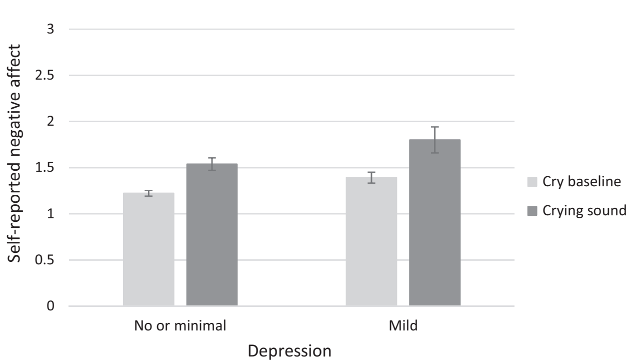
overall showed higher sad facial expressivity than mothers with no or minimal depression.

Discussion

In this study, we examined how depressive symptoms are associated with self-reported, physiological, and emotional facial expressive responses to infant crying and laughing sounds in a nonclinical sample of mothers. This study showed that exposure to an infant crying sound yielded increased self-reported negative affect. In addition, higher levels of depressive symptoms in mothers were associated with the experience of more negative affect in general, that is, both before and during exposure to infant crying. As expected, higher levels of depressive symptoms were associated with a more negative perception of the crying sound. In contrast to our expectations, depressive symptoms were not associated with intended caregiving responses. Exposure to an infant laughing sound yielded increased self-reported positive affect in mothers. This increase in self-reported positive affect, contrary to our expectations, was found regardless of mothers' level of depressive symptoms. Moreover, the infant laughing sound yielded increased happy facial expressivity in mothers, but in contrast to our expectations to the same extent in mothers scoring higher on depressive symptoms. Depressive symptoms were associated with sad facial expressivity: mothers with higher levels of depressive symptoms displayed more sadness, but unexpectedly not in particular during infant crying. Mothers with higher levels of depressive symptoms displayed more sadness before and during infant crying and laughing. Depressive symptoms were unexpectedly not associated with laugh perception, intended caregiving responses, and SCL reactivity to infant crying and laughing.

Taken together, although most findings were not consistent with our hypotheses, the results seem to show a response pattern in mothers with higher levels of depressive symptoms when exposed to infant crying and laughing. Higher levels of depressive symptoms were associated with more self-reported negative affect in general and a more negative perception of a standard infant crying sound. Exposure to a standard infant laughing sound elicited

Figure 2
M (SE) Self-Reported Negative Affect Scores at Cry Baseline and After the Crying Sound for Two Categories of Depressive Symptoms, Indicating No or Minimal Depression and Mild Depression



Note. Scores reflect estimated marginal means of LMMs, performed separately for the two categories of depressive symptoms (based on a cutoff score of 7), with age of the child included as covariate. *SE* = standard error; LMMs = linear mixed models.

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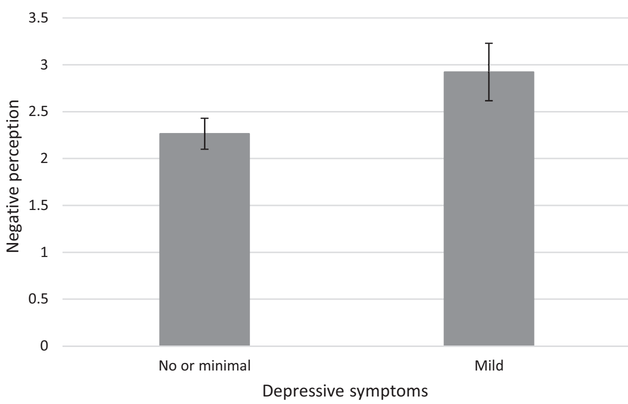
Figure 3

M (SE) Negative Cry Perception Scores for Two Categories of Depression Symptoms, Indicating No or Minimal Depression and Mild Depression

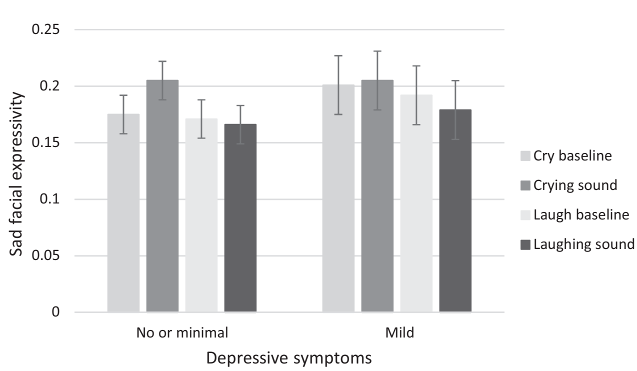


Note. The two categories of depressive symptoms were created using a cutoff score of 7. Age of the child was included as a covariate. *SE* = standard error.

increased self-reported positive affect and increased happy facial expressions regardless of the level of depressive symptoms. However, although mothers scoring higher on depressive symptoms also enjoyed infant laughing and expressed these feelings, they sent subtle facial cues displaying sadness similarly as during infant crying. These sad facial expressions may overshadow mothers' experience of positive affect and happy facial expressive responses to infant laughing. Further research should reveal if a similar pattern is shown by mothers with higher levels of depressive symptoms in response to their own infant's laughing. If so, this could affect the mother–infant interchange as subtle facial cues by mothers can be picked up by children (Mendes et al., 2009). When expressing sadness in addition to happiness, mothers may not convey a consistent emotional message in response to their infant's laughter. Though speculative, exposure to mother's constant mild sad facial expressions may relate to social–emotional processing difficulties in children of depressed mothers, such as lower responsiveness to and lower discrimination of facial expressions (Bornstein et al., 2011; Diego et al., 2004; Field et al., 1998, 2009). Future research should clarify the role of subtle maternal sad facial expressions in response to infant laughing in infants' cognitive and socioemotional development.

Figure 4

M (SE) Sad Facial Expressivity Scores in the Separate Conditions (Cry Baseline, Crying Sound, Laugh Baseline, and Laughing Sound) for Two Categories of Depression Symptoms, Indicating No or Minimal Depression and Mild Depression



Note. Scores reflect estimated marginal means of LMMs, performed separately for the two categories of depressive symptoms (based on a cutoff score of 7), with age of the child and happy facial expressivity during infant crying and laughing included as covariates. *SE* = standard error; LMMs = linear mixed models.

Our study findings showed that higher levels of depressive symptoms in mothers were not associated with physiological responses or intended caregiving responses to infant crying. We found that the crying sound in general elicited higher SCL reactivity than the laughing sound, consistent with research that showed that skin conductance was more responsive to negative stimuli than positive stimuli (Ohira et al., 2006). Crying may be more arousing than laughing as it is more alarming in expressing needs. Mothers' level of depressive symptoms may be associated with SCL reactivity when the mothers' own infant is crying. Alternatively, a measure of parasympathetic reactivity, such as respiratory sinus arrhythmia, may be more appropriate in the caregiving context, as according to polyvagal theory the parasympathetic nervous system is involved in social engagement behaviors (Porges, 2001). Mothers' depressive symptoms may be associated with caregiving responses when actual caregiving behaviors are assessed. Our measure of intended caregiving behaviors may to some extent reflect cognitions about what constitutes adequate parenting that may not be associated with depressive symptoms. Mothers' experience of inability to soothe her infant may be especially important in case of a crying infant, eliciting reactions in mothers with depressive symptoms (Radesky et al., 2013). We also did not find depressive symptoms to be associated with physiological responses and intended caregiving responses to infant laughing. Again, mothers' depressive symptoms may have effects when their own infant is laughing (Dix, 1991; Emery et al., 2014; Groh & Roisman, 2009). However, infant crying and laughing increased mothers' self-reported negative affect and positive affect, respectively, indicating successful induction of emotions.

The results of this study call for more research on emotional facial expressions when studying maternal sensitivity. Subtle facial cues are generally not coded when observing maternal sensitive behaviors (e.g., Ainsworth et al., 1974; NICHD Early Child Care Research Network, 1999). However, as explained before, these subtle cues may be important in mother–infant interaction and may therefore be included in sensitivity measures, which are associated with infant attachment (De Wolff & van IJzendoorn, 1997). The use of facial expression recognition software, such as Noldus's FaceReader, is a new method to assess maternal sensitive responses. More research is needed, because although the accuracy and validity of our used facial expression coding system has been confirmed (Lewinski et al., 2014), it is unknown how mothers' emotional facial expressions relate to mothers' emotions and behaviors.

Several limitations should be noted. The first set of limitations relates to design choices. First, we exposed mothers to standard crying and laughing sounds to rule out effects of cry and laugh characteristics and duration. Future research should examine actual

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responses to the mother' own infant's crying and laughing. Second, mothers were visited at home, a nonstandardized environment. Seating conditions differed among mothers. In some cases, siblings were present and although experimenters looked after them, this could have affected mothers' attention to the stimuli. During the home visits and processing of the facial expression data, we took notes of special environmental conditions. We decided to conduct the study in the home setting because it is more ecologically valid than a standardized laboratory setting. Third, because mothers knew they were being video recorded, they possibly suppressed facial expressions because of social norms. Fourth, the Laugh Paradigm was preceded by a Cry Paradigm. The baseline of the Laugh Paradigm was designed to achieve a neutral state in mothers, but we cannot rule out possible carryover effects of listening to crying sounds. Moreover, the infant cry and laugh conditions were the neutral conditions of other experimental studies on effects of emotion regulation strategies (Karreman & Riem, 2020a; Riem & Karreman, 2019). The experimental emotion regulation conditions may have affected mothers' responses in the neutral conditions. However, we controlled for order of conditions in additional analyses and found no effects on the results.

There were also limitations related to assessments and our sample. First, we assessed self-reported negative affect during the Cry Paradigm and self-reported positive affect during the Laugh Paradigm. We could not examine whether the crying sound decreased self-reported positive affect and the laughing sound decreased self-reported negative affect, related to the level of depressive symptoms. Second, the procedure for calculating scores for intended caregiving response differed for the Cry Paradigm and Laugh Paradigm, complicating the interpretation of the results. Principal component analysis of the intended caregiving responses resulted in different dimensions for the Cry Paradigm and Laugh Paradigm (Karreman & Riem, 2020a; Riem & Karreman, 2019), which could relate to the fact that infant crying demands different responses than infant laughing. Third and finally, we used a nonclinical sample. Our study shows that sadness shines through in the facial expressions of a nonclinical group of mothers with higher levels of depressive symptoms. This effect might be more pronounced in a clinical group.

In conclusion, the present study showed that higher levels of depressive symptoms were associated with more self-reported negative affect in general and a more negative perception of a standard infant crying sound. Exposure to a standard infant laughing sound elicited increased self-reported positive affect and increased happy facial expressions in mothers with all levels of depressive symptoms. However, higher levels of depressive symptoms in mothers were associated with overall higher sad facial expressivity, both before and during exposure to an infant crying and laughing sound. These findings suggest that mothers who score high on depressive symptoms send subtle facial cues showing sadness, which may affect mother–infant interaction. Future research should examine the role of facial expressions, assessed by means of facial expression recognition software, in mother's sensitivity to infant signals. Study findings further revealed that mothers' depressive symptoms were not associated with intended caregiving responses and physiological responses to infant crying and laughing. The crying and laughing of one's own infant may elicit specific behavioral and physiological responses in mothers with high levels of depressive symptoms, but more research is needed to draw conclusions about this. Including a clinical group of depressed mothers in future research could also be relevant.

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