Depressed Mothers Show Increased Anxiety and Negativity and Differential Salivary Cortisol in Response to Infant Cries

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Abstract

Objective: The impact of postpartum depression on mother-infant interaction, affective responses to infant cries, as well as hormonal and autonomic responses to infant stimuli were examined in a sample of primiparous and multiparous women.

Methods: A sample of 140 depressed and non-depressed women where randomly assigned to one of two conditions: 1) cry (pain; hunger); and 2) neutral (female neutral voice). Emotional response scores, salivary cortisol, and heart rate were collected. Depression was designated if women scored 12 or above on the Edinburgh Postpartum Depression Scale (EPDS).

Results: Depressed mothers reported feeling more anxious and negative when listening to infant cries and responded more strongly to the pain as opposed to the hunger cries compared to non-depressed mothers. Depressed mothers also showed higher overall cortisol levels compared to non-depressed mothers, with non-depressed mothers demonstrating a slight increase in response to the cries, while depressed mothers had a blunted response to the cries. No differences were reported in maternal heart-rate.

Conclusions: PPD has a clear impact on a mother's interaction with her infant which in turn, can have substantial effects on the infant's social and emotional development.

Keywords: Postpartum depression; Maternal behavior; Cortisol; Autonomic response; Infant stimuli; Infant cries

Introduction

Many new mothers feel depressed at some point after the birth of their infants [1]. Postpartum blues; the most mild form of the postpartum mood disturbances; has been reported at a prevalence of 26-85% depending on the diagnostic criteria used [1-3]. In some women however, the disturbance may persist beyond the *blues*, leading to more serious postpartum depression (PPD) [3-5]. Epidemiological studies report that between 10-20% of women exhibit depressive symptoms in the first weeks following delivery [6,7]; that the rise in incidence is within 6 weeks postpartum; symptoms may persist for up to two years [8]; and that a large majority of these depressive episodes resolve spontaneously within three to six months [6,9]. The symptom profile of PPD resembles that of a major depressive episode experienced at other times in life; including fatigue, negative affect, negative thoughts, suicidal ideation, and low self-esteem [3,10-13], but it is unique in it's timing, always involves at least the mother-baby dyad, and in most cases an entire family unit [14].

Not surprisingly, PPD can adversely affect not only the mother's self-perception and world view, but also her relationship with her partner and infant. Depressed mothers do not report feeling less attached to their infants [15], and in fact, may show considerable warmth and interest [16]. Comparisons between depressed and non-depressed mothers indicate that the former respond less sensitively and more negatively to their infants than the latter [15,17-20]. At two months postpartum, the speech of depressed mothers tends to contain more negative affect, while in play interactions they exhibit fewer responses to the infant's behaviour [19]. During face-to-face interactions with their infants, depressed mothers are also more prone to exhibit either controlling, intrusive, and over-stimulating behaviour, or withdrawal,

passivity or disengagement [17,18,21,22]. Moreover, when observed interacting with their infants they tend to spend less time than non-depressed mothers engaging in behaviours considered congruent with that of their infants. When behaviours were compatible, they were more likely negative, as opposed to positive [18]. Other studies have found that the depressed dyad presented less vocalizations and less visual communications; at 6-months postpartum they used less affective and less informative speech; and their overall level of tactile interaction behaviour was reduced [15,23,24].

The present study is the second in a series of studies examining what aspects of the mother-infant interaction are especially challenging for the depressed mother. Although, in comparison to non-depressed mothers, depressed mothers clearly behave differently with their infants [25], the pathophysiology underlying these deficits in behavioral interactions is not clear. It is possible that depression reduces the mother's ability to pay attention to social cues and hence, the infant; alternately, depression may alter the mother's attraction to infant related

cues; or it may reduce the mother's sensitivity to differences in these cues. Moreover, these deficits may result from, or produce, changes in the mothers' hormonal and/or autonomic responsiveness to infant cues, in particular infant cries.

Infant cries are provocative stimuli for the new mother [26,27] reflected in both her affective emotional response to the cries, and in her physiology [26,27]. The body of work on autonomic measures, including heart rate, skin conductance, blood pressure, and the hypothalamic-pituitary-adrenal (HPA) axis response, suggests that these measures can be useful tools for evaluating the impact of infant signaling on parental behaviour [26-33]. We have previously found [34] that non-depressed mothers are more sympathetic to infant cries than are childless women and that mothers who are more affectively sympathetic to the cries of newborn infants also have higher baseline heart rates than mothers low in sympathy. They also show small and reliable heart rate accelerations with the onset of pain and hunger cries; in contrast, non-mothers tend to show heart rate decelerations in response to cries [34]. More sympathetic mothers also show higher levels of circulating cortisol both prior to, and after exposure to the cries. Cortisol levels are higher among mothers who show a greater differential responsiveness to pain versus hunger cries [34]. Hence, these mothers seemed better able to distinguish between the two types of cries. Interestingly mothers that were more sympathetic to the recorded cries of unknown infants also reported greater feelings of attachment to their own infants on day two post-partum [34]. Moreover, within the postpartum period, there are variations across women in their cortisol profiles; mothers who experience postpartum depression show dysregulation, and often dampening, of their HPA axis responses during the peripartum period [35-37].

The present study aimed to examine, 1) the quality of mother-infant interactions among depressed mothers in comparison to non-depressed mothers as depressed mothers have been previously reported to be less responsive, display less affectionate behavior and are more hostile and intrusive compared to non-depressed mothers [38,39]. Here we also ask whether depressed mothers are as responsive in terms of their expressed feelings and physiology in response to infant cues as are non-depressed mothers or whether responsiveness in depressed mothers is altered. In order to investigate this question, the study will compare depressed and non-depressed mothers in terms of, 2) their affective responses to infant cries or non-cry vocalizations; and 3) their hormonal and autonomic (heart-rate) responses to infant or control stimuli. Groups were compared using analyses of variance and non-parametric statistics, where appropriate. We hypothesize that depressed mothers will be less affectively responsive to infant cries, and demonstrate elevated cortisol levels compared to non-depressed mothers.

Methods

Participants

New Mothers (depressed n=47, non depressed n=93) were recruited from the maternity ward at St. Josephs Healthcare in Hamilton, Ontario, Canada, and from community-based prenatal and postpartum groups in Southern Ontario, Canada. Both primiparious (n=69) and multiparious (n=71) English speaking mothers between the ages of 23 and 40 years, and in good general health, were recruited. All mothers participated in the study within 6-22 weeks postpartum. Women were designated depressed if they scored 12 or above on the Edinburgh Postpartum Depression Scale (EPDS). Women scoring 11 or below were designated as non-depressed. This cut off for postpartum depression is consistent

with previous work [40]. The correlation between EPDS and the CES-D (Center for Epidemiological Studies-Depression; a 20-item measure that asks caregivers to rate the frequency of symptoms associated with depression that were experienced in the past week [41]) in the present population was $r = .66$ (n=140, $p < .000$). Of the 47 depressed mothers 21 were on an anti-depressant medication.

Design

Depressed and non-depressed mothers were randomly assigned to one of two conditions: (1) infant pain and hunger cries (cry condition), or (2) neutral voice passages (control condition). All testing occurred between 09:00 and 14:00 hours.

Cry condition: The cry stimulus consisted of four cries: two hunger cries and two pain cries. The two 'hunger' cries were recorded from infants in a newborn nursery just before being taken to their mothers for a scheduled feeding. The two pain cries were recorded during circumcision procedures on healthy newborn males [34]. Each tape consisted of all four cries, each lasting 35 seconds, with 1-minute intervals. The order of the pain and hunger cries was counterbalanced across participants within each group.

Control condition: The control stimulus consisted of four 'neutral' passages delivered by a female, in a 'neutral' tone of voice. Passages described topic such as the mechanical strength of leaves or how termites are blind. Each tape consisted of four passages, each lasting 35 seconds long, with 1-minute intervals. Control neutral passage conditions were counterbalanced across subjects within each group.

Measures

Emotional response scores (ERS): Following the presentation of each stimulus segment, subjects completed a set of eleven 100 mm visual analogue scales (ranging from '*not at all*' to '*extremely*'). Each scale represented different affective states: reflecting reactions that were sympathetic, alert, and negative (irritated, annoyed, and distressed) or positive (relieved, happy, and delighted). The ERSs for the two hunger cries and the two pain cries were averaged to produce one ERS for pain and one for hunger.

Heart rate monitoring: Subjects were fitted with a heart rate monitoring system (POLAR S810I, Polar Electronics Inc., Lachine, Quebec), which includes a comfortable elastic transmitter belt and a wristwatch monitor (resembling a sports watch). The heart rate monitoring was initiated 15-minutes before and continued until 15-minutes after the stimulus presentation. The device allowed for collection of heart rate data at 1-second intervals and data was later downloaded for analysis. For the purpose of analyses, heart rate intervals of 5-seconds were calculated by averaging beats per minute across all cries (pain and hunger). Three, 5-second intervals - prestimulus (baseline), and three, 5-second intervals - following the onset of cry were delivered. All heart rate analyses used this interval pattern.

Hormones: Cortisol salivary samples were collected using salivettes (Staredt Canada, Inc., St. Laurent, Quebec) at baseline, (just prior to the presentation of the stimuli), and at +20 and +40 minutes post-testing [42]. Cortisol assays were performed in the Neurosciences laboratory at St. Joseph's Healthcare, Hamilton, ON. On the day of assay, samples were thawed and saliva was extracted via centrifugation (3,000 RPM at room temperature for 15 minutes). Approximately 200 μl of saliva was obtained. Salivary cortisol measurements were quantified using a high sensitivity enzyme immunoassay kit (Salimetrics, LLC, State College, PA). The correlation between serum and saliva cortisol levels has been shown to be highly significant ($r = 0.91$, $p < 0.0001$) via Salimetrics' in

house testing. The sensitivity of this assay is 0.08 nmol/L, the intra- and inter-assay coefficients of variation were 3.5 and 5.1% respectively.

Mother-infant interactions: Mothers were videotaped individually with their infants for a period of 15-minutes in a private room. Mothers were given the opportunity to feed and change the infant prior to video commencement. Behaviours were later coded from the videotape using the BEST system (Behavioural Evaluation Strategies and Taxonomies, S & K Computer Products, Ontario, Canada). A research assistant blinded to the experimental conditions coded the behaviours. A second RA also trained to code tapes provided inter-observer reliability in coding. Inter-rater reliability was obtained by having two observers code the same 10 videos of mother-infant interactions twice. Inter-rater reliability was highly correlated for all behaviors, with *r* values ranging from 0.80 to 0.96.

The behaviours that were coded included maternal attention (looking at the baby, looking at and over, looking away, en face, looking at magazine), talking to the infant (motherese, adult voice, quiet talk), grooming/caretaking (wiping face, adjusting clothing/blanket) infant activity (waving arms, fussing/crying), affection touching (stroking, palming) proximity (mothers face within 2 inches of infants body) and poking the infant. As the length of the videotaped sessions varied in lengths between 10-15 minutes, all behaviour durations were converted to proportions of total session time.

Questionnaires

Questionnaires assessed mood, physical symptoms, maternal attitudes, as well as demographic information.

Maternal attitude questionnaire: The Child-bearing Attitudes Questionnaire (CAQ) was given to mothers to assess maternal attitudes on aspects of caregiving, and relationships. The CAQ includes 83 items, with a 7-point Likert scale response from disagree strongly (1) to agree strongly (7) We relied on previously established factors from Ruble et al. [43], derived from responses provided by a sample size of 667. From the 83 questions, factors were created through principal component analysis with 20 factors with eigenvalues greater than 1, which explained 58% of the total variance. Next, an iterated principle axis factor analysis with squared multiple correlations for prior communality estimates extracted 20 factors, which were subjected to Promax oblique rotation. Items were then assigned to scales based on factor loadings. The Maternal Attitude factors used in the present study included factors reflecting attitudes such as negativity towards caretaking duties, parental worry, own parental support, and maternal attachment.

Current experience questionnaire: Subjects had to rate 44 current mood, and physical concerns using a scale ranging from 'none' to 'extremely'. Items on this questionnaire covered symptoms, such as depression and anxiety, and physical concerns, such as nausea and headaches. This questionnaire uses a 6 point Likert-type scale ranging from "None" to "Extremely" (1-6, respectively).

Mood state was assessed using factors derived from the Current Experience Questionnaire. These included factors reflecting physical symptoms, depression, anxiety, irritability, feelings of well-being, and fatigue. These mood factors have been found to be reliable and valid for the postpartum population and show consistency over time [15]. Correlations between the current experience scale (CES) and other standardized mood scales (e.g. the MAACL (76) are highly significant, ranging from 0.55 to 0.80 in different studies [15,44].

Procedure

The protocol was the same for both stimulus conditions. All

mothers received the following: 1) a detailed explanation of the protocol, 2) fitting for heart-rate monitoring, 3) initiation of heart-rate monitoring, 4) completion of mood scales, 5) 2-minute waiting period (for baseline heart rate), 6) 1st saliva collection (baseline), 7) 2-waiting period, 8) 1st cry or control stimulus, 9) rating of affective response (ERS), 10) 1-minute interval, 11) repetition of steps 8,9,10 for total of 4 cries/stimuli, 12) 2nd saliva collection (post 1, 20 minutes post tape onset), 13) 20-minute interval and 3rd saliva collection (post 2, 40 minutes post tape onset), 14) discontinuation of heart-rate monitoring. Thus, heart-rate was monitored prior to, after, and throughout the periods of stimulus presentation. Hormones were assayed prior to, 20 minutes and 40 minutes after stimulus onset. Self-report affective responses to stimuli were obtained after each stimulus presentation. Each cry/control stimulus was 35-seconds in duration. Following each stimulus the ERS was completed over a one-minute period followed by a one-minute interval to the next stimulus presentation. Participants continued to fill out the ERSs. A 15-minute videotaped interaction of the mother and infant took place at the end of the study.

Statistics analyses

Data was analyzed using analyses of variance or analysis of covariance (ANCOVA) with significant *p* values set at p<.05. Factors included in each analysis are described below in the Results section. Degrees of freedom, within an analysis type, reflect the number of subjects or observations that completed the measure being analyzed. Because of the number and complexity of the different outcome measures and the absence of imputation of measures, there was some variation in degrees of freedom across analyses (within n=125 to 140). The effects of order of cries (which were counterbalanced in the design) and hence their carry-over effects, were analyzed, using cry order as a factor in the ANOVA and no significant effects were found for heart rate, cortisol or ERS responses.

Results

Demographics

Chi-square analyses were undertaken on a variety of demographics, including parity, highest education, employment status, marital status and combined income. There were no significant differences between depressed and non-depressed mothers in any of the analyses with the exception of parity (X^2 (df=1)=4.89, p=0.027) and employment status (X^2 (df=5)=13.803, p=0.017); in the depressed group there were more multiparous than primiparous mothers and they had lower rates of employment out of the home, respectively. Independent-samples t-tests on age, of both mother and infant, showed no significant differences between groups (Table 1).

Demographic		Mother	
		Depressed	Non Depressed
Sample Size (N)		47	93
Age	Mother [years, M (SD)]	30.06 (4.68)	31.23(4.83)
	Infant [months, M (SD)]	3.7 (1.62)	3.6 (1.58)
Parity (N)*	Primiparous	17	52
	Multiparous	30	41
Highest Education (%)	Some high school	6.4	4.3
	High school graduate	6.4	7.53
	College/ Tech Training	21.3	17.2
	Tech Training Completed	2.13	4.3
	College/University Grad	61.7	52.7
	Some Grad School	0	1.1
	Graduate degree	2.13	13

Employment Status (%)*	Full time	23.4	51.6
	Part time	17	17.2
	Full time parent	8.5	5.4
	Student	0	1.1
	No occupation	42.6	18.3
	Self employed	8.5	6.5
Marital Status (%)	Single	8.5	6.5
	Married	80.9	80.6
	Separated	2.13	1.1
	Divorced	0	1.1
	Cohabitate	8.5	10.8
Combined Income (%)	$ 0-28,999	12.77	6.67
	$ 29,000-49,999	21.28	16.67
	$ 50,000 or over	61.7	57.78
	$ 100,000 or over	4.26	18.89

Note: * Significant differences between depressed and non-depressed mothers in parity (X^2 (df=1)=4.89, p=0.027) and employment status (X^2 (df=5)=13.803, p=0.017).

Table 1: Description of demographic characteristics of population.

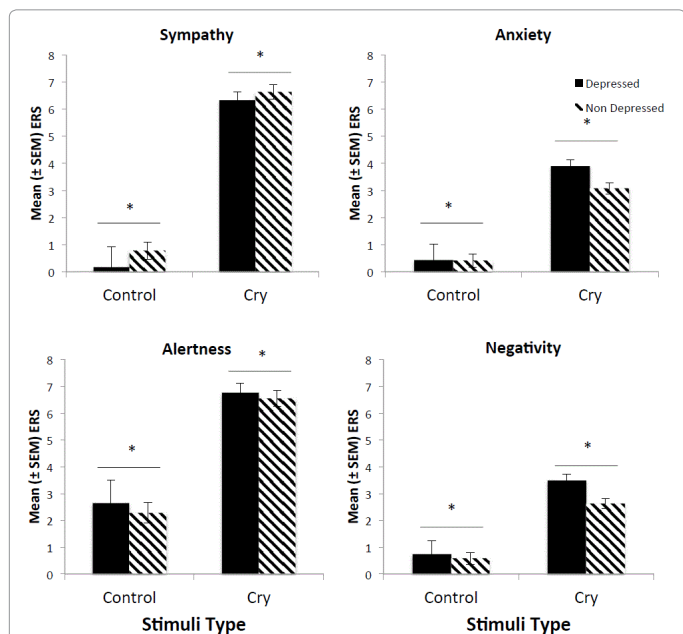**Figure 1:** Mean (± SEM) ERS during different stimuli. There was a main effect of stimuli type. Both depressed and non-depressed mothers show an increase in sympathy, anxiety, alertness and negativity when listening to cries when compared to listening to the control stimuli (p<0.004-0.001). Groups sharing like symbols represents significant effects.

Emotional response to infant cries

Cry stimuli versus control stimuli: To determine whether the cry condition produced higher affective responses than did the control voice condition, a series of multivariate (group: depressed mothers vs. non-depressed mothers) x 2 (condition: cry vs. control stimuli) ANOVAs on ERS responses to averaged cry (average ERS to 2 hunger cries and to two pain cries) and voice (ERS to 4 voice segments) stimuli were undertaken. Parity was included as a covariate. As shown in Figure 1, there was a main effect of stimulus condition (F(4,132)=48.75, p=0.001). Both groups responded with higher scores on sympathy, alertness, anxiety, and negativity to the cry stimuli than to the control stimuli.

Pain versus hunger cry stimuli: To determine if depressed and non-depressed mothers were responding to pain and hunger cries

differently, a series of 2 (group: depressed mothers vs. non-depressed mothers) x 2 (cry type: pain vs. hunger cries) repeated measures ANOVA with parity entered as a covariate, were performed separately for each ERS averaged across the 2 pain cries, and separately across the 2 hunger cries. In this analysis only responses to the cry tapes were included. As shown in Figure 2, these showed a main effect of cry type, with greater intensity of response for the pain cries over the hunger cries for alertness (F(1,92)=16.68, p=0.001), anxiety (F(1,92)=8.75, p=0.004), overall negativity (F(1,92)=7.05, p=0.001), and marginally, for sympathy (F(1,92) =3.5, p=.065). There were also significant interactions, with depressed mothers showing greater feelings of anxiety (F(1,92)=4.48, p=0.04), and increased feelings of overall negativity (F(1,92)=8.35, p=0.005) when presented with the pain cries as opposed to the hunger cries. Whereas both groups are responding differentially to the two cry types, depressed mothers show larger differences to the two types of cry. The parity covariate had a direct effect only with respect to the alertness (F(1,92)=4.58, p<.035), where multiparous mothers were more alerted in response to the less alerting hunger cry than were the first time mothers. There were no parity differences in response to the pain cry, with both groups responding with elevated alertness.

Cortisol responses to infant cries

To evaluate whether there was a difference in hormonal responses to the cry stimuli versus control stimuli, between depressed and non-depressed mothers, pre-stimulus cortisol (baseline) were compared to post-stimulus cortisol levels (post 1 and post 2) in a 2 (group: depressed mothers vs. non-depressed mothers) x 2 (condition: cry vs. control stimuli) x 3 cortisol (time points: baseline, post 1, post 2) repeated measures MANOVA. In the multivariate analysis, there was a 3 way interaction between depression, stimuli, and time (F(2,130)=3.158, p=0.05), with a quadratic form (F(1,131)=6.257, p=0.014). In response
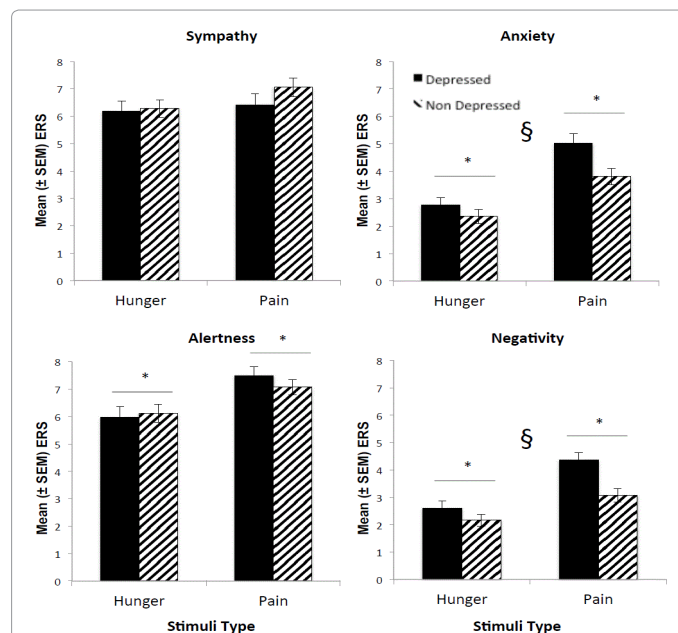

Figure 2: Mean (± SEM) ERS during different cry stimuli. There was a main effect of cry type. Both depressed and non-depressed mothers show an increase in alertness, anxiety, and overall negativity when listening to pain cries when compared to listening to hunger cries (p<0.01). Groups sharing like symbols represents significant effects. There were also significant interactions (§). Depressed mothers show higher levels of anxiety and overall negativity when presented with pain cries versus hunger cries than non-depressed mothers (p<0.04-0.005).

to the control stimuli, depressed mothers showed greater elevations to the stimuli at the first post stimulus, followed by a decline at 40 minutes. Non-depressed mothers showed no change across time (Figure 3). In response to the cry stimuli, the opposite pattern was seen with non-depressed mothers showing a slight increase across time in cortisol levels, whereas depressed mothers showed a blunted response. Co-varying parity (see below) did not attenuate these findings.

Heart rate responses to infant cries

To determine whether depressed and non-depressed mothers differ in their heart rate, we averaged three consecutive 5 second intervals before the stimuli (baseline) and three 5 second intervals after the onset of the stimuli (reactivity). The repeated measures ANOVA analysis consisted of a 2 (group: depressed moms vs. non-depressed moms) × 2 (stimuli condition: cry vs. control stimuli) x 4 (heart-rate intervals: baseline and 3 post-stimulus) analysis. Using absolute heart-rate responses, there were no main effects of depression, nor did depression interact with any other factor. When proportional change scores from baseline to the onset of the cries was explored, there was a marginal effect of depression ($F_{(1,108)}$=2.95, p=0.04 (1 tailed)), where depressed mothers showed greater reductions in heart rate during the early phases of the tapes than did non-depressed mothers (not shown).
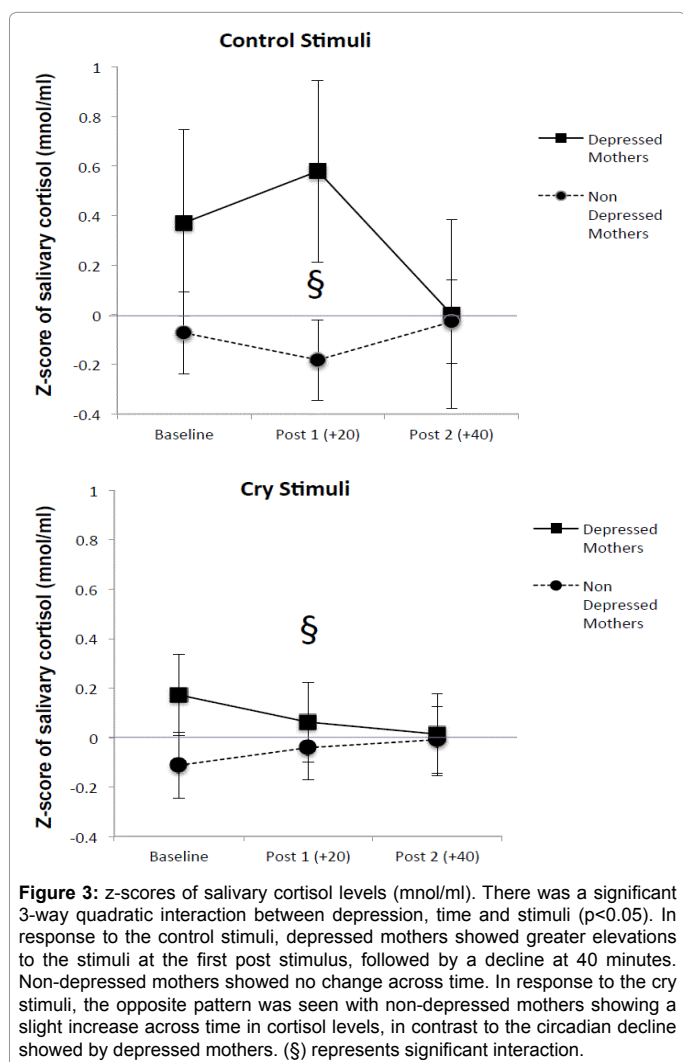
Figure 3: z-scores of salivary cortisol levels (mnol/ml). There was a significant 3-way quadratic interaction between depression, time and stimuli (p<0.05). In response to the control stimuli, depressed mothers showed greater elevations to the stimuli at the first post stimulus, followed by a decline at 40 minutes. Non-depressed mothers showed no change across time. In response to the cry stimuli, the opposite pattern was seen with non-depressed mothers showing a slight increase across time in cortisol levels, in contrast to the circadian decline showed by depressed mothers. (§) represents significant interaction.

Maternal Attitudes	Depressed	Non-depressed	
7-pt scale (Strongly disagree-strongly agree)	Mean (SEM)	Mean (SEM)	P Value
Parental Worry	3.90 (0.163)	3.12 (0.109)	0.001
Self-confidence in the mothering role	4.86 (0.163)	5.54 (0.109)	0.004
Negative feelings about care taking activities	2.30 (0.231)	2.12 (0.156)	0.534
Feelings about infants in general	5.02 (0.163)	5.58 (0.110)	0.005
Attachment to own infant	5.88 (0.113)	6.17 (0.076)	0.004
General attitudes			
Interest in Sex	2.56 (0.194)	2.97 (0.130)	0.091
Feelings about partner	3.97 (0.212)	4.97 (0.142)	0.001
Feelings about their mothers	4.87 (0.250)	5.39 (0.167)	0.097
Feelings about their fathers	4.45 (0.223)	5.11 (0.149)	0.001
Negative feelings towards the self	4.17 (0.179)	2.861 (0.120)	0.002
Mood			
Negative Mood	3.88 (0.125)	2.43 (0.084)	0.001
Positive Mood	2.56 (0.120)	3.16 (0.081)	0.001
Physical Complains	2.32 (0.086)	1.75 (0.058)	0.001

Table 2: Mean (SEM) results for maternal attitudes towards infant, other infants and caretaking in general as well as current experiences.

Maternal attitudes and current experiences

6.5.1 Attitudes towards motherhood and infants: Based on responses to the Maternal Attitudes Questionnaire, depressed mothers reported higher feelings of parental worry ($F_{(1,134)}$ =12.12, p<0.001), reduced self-confidence in the mothering role ($F_{(1,134)}$=8.56, p<0.004), and more negative attitudes towards infants in general ($F_{(1,134)}$=6.62, p<.005). They also described themselves as less attached to their own infants ($F_{(1,134)}$=8.5, p<.004). However, when asked about their feelings about caretaking activities, the extent of negative feelings in relation to caretaking did not differ between the two groups.

General attitudes: Depressed mothers reported more negative attitudes about their partners ($F_{(1,134)}$=25.52, p<.001), and their fathers ($F_{(1,134)}$=14.6, p<.001), but not their mothers, than did non-depressed mothers. There were also differences in negative feelings towards the self ($F_{(1,134)}$=10.1, p<.002).

Mood: In their responses to the Current Experience Scale, in comparison to non-depressed mothers, depressed mothers reported experiencing more negative mood ($F_{(1,134)}$=200, p<.0001), less positive mood ($F_{(1,134)}$=34, p<.001), and had more physical complaints ($F_{(1,134)}$=20.194, p=0.001) (Table 2).

Maternal behaviour

Comparisons were made between depressed and non-depressed mothers in the duration of maternal behaviours during interactions with their infants. Depressed mothers spent less time attending to ($F_{(1, 127)}$=3.52, p<0.06), and less time affectionately touching, their infants ($F_{(1,127)}$=4.67, p<.032). There were no differences in caretaking responses (adjusting clothes, blankets, etc.) or in the frequency or durations of vocalizations (not shown). Covarying parity eliminated the attending to infant cues, but made no difference to the affectionate touching pattern. Women with two or more children spent less time attending to the infant than did those with only one.

Discussion

This study shows that depressed mothers were reported feeling more anxious and negative when listening to infant cries and responded more strongly to the pain as opposed to the hunger cries

compared to non-depressed mothers. These results are consistent with the observation that elevated anxiety and negativity are frequently associated with depression [45-47] and, in fact, anxiety is a frequent complaint in depression [48]; not surprisingly, anxiety items are in general included in depression scales (e.g. the EPDS; [49]. The State-Trait Anxiety Inventory (STAI) also shows high correlation with the EPDS [50]. Increased negative parenting has also been reported in mothers experiencing heightened depressive symptoms [51]. The fact that depressed mothers were particularly responsive to pain, as opposed to hunger cries, suggests that depressed mothers may be more responsive to high intensity and more aversive stimuli. Hunger cries are easier to identify and to alleviate and are likely more familiar to mothers than are pain cries. Postpartum depressed mothers may be less able to cope with the irritation and difficulty of alleviation associated with pain cries, as evidenced by executive function irregularities [52]. Furthermore, inconsolable infant crying has been shown to be associated with postpartum depressive symptoms [53]. This differential response to cry type suggests that depressed mothers can accurately distinguish between pain and hunger cries and respond differentially to cries with different properties, similar to their non-depressed counterparts. In terms of other affective responses to the cries, the two groups did not differ. Not surprisingly, both groups expressed more sympathy and alertness when hearing cry stimuli than when hearing control stimuli.

On self-report questionnaires, depressed mothers responded more negatively to many attitudes that do not directly reflect affective state, regardless of the substantive content of those factors. This suggests there may be a reporting bias in depressed mothers, as has been previously reported [44]. However, there were some factors that the two groups did not differ on including their feelings about negative aspects of caretaking activities and in terms of their attitudes to their own mothers. In general, the overall negativity expressed by depressed mothers is consistent with previous research that shows that postpartum negative emotions and appraisals are higher in women with depression [54-56].

Cosisitent with previous findings, depressed mothers demonstrated higher overall cortisol levels compared to non-depressed mothers [57-60]; however, the non-depressed mothers had a slight increase in response to the cries, whereas the depressed mothers had a blunted response to the cries. This dampening of depressed mothers' cortisol responses to 'salient' stimuli (infant cry), is consistent with other recent results comparing peripartum depressed and non-depressed [35-37]. Increased cortisol reactivity has been associated with fewer symptoms of anxiety and depression [61].

The opposite pattern was found for the control stimulus (non-stressful stimuli) with non-depressed women showing no cortisol reaction, whereas depressed mothers had an increased cortisol response.

This suggests that similar to the attitudinal data, the groups have differential physiological responses to the stimuli, with non-depressed mothers showing an expected arousal response to the cries whereas depressed mothers have a blunted response. These results are similar to what we recently reported for teenage mothers who, although not depressed, did not show cortisol elevations to the cry stimuli [30]. Both depressed adult mothers [31,62] and teen mothers [63] have been shown to demonstrate decreased executive function and attention, and these effects may be mediated through the HPA axis. This work contrasts with previous studies of pregnant mothers in which depressed mothers showed an increased HPA reactivity during pregnancy in response to infant distress [64]. It is possible that postnatally the salience of infant cries is higher and more disruptive. Alternatively it is possible that

that cortisol during the two times reflect different internal states (high chronic cortisol during pregnancy does not necessarily reflect stress) and, as a result, may have different functions in response to an infant salient stressor.

In contrast to the cortisol results, there were no differences between depressed and non-depressed mothers in their heart-rate responses either at baseline or in response to the cry stimuli. In fact, both groups showed elevated responses to the cries and differed in their responses to cry versus control stimuli. These results were not expected since our earlier work indicates that mothers who are more sympathetic have higher baseline heart-rates and more reliable elevations with the onset of each cry [34], effects not seen for this population of mothers. However this earlier study did not examine depressed mothers. No differences in heart rate in teen motherswhen compared to teen non-mothers were also reported even with higher levels of reported responsivity in the teen mothers [30]. The fact that we did not find a larger effect of depression on autonomic responses was surprising since heart-rate can be quite a sensitive measure of motivation and endocrine status and we find depression related differences in both of these domains. Bleichfeld and Moely [28] found, for instance, that hearing unfamiliar infant crying elicited heart rate accelerations among newly parturient women and decelerations among non-pregnant women. Moreover, in the Bleichfeld and Moely study, multiparous women had greater accelerations than primiparous women, but only if they were not newly parturient [28]. In other words, parity (experience) made no difference in heart rate response among newly parturient women, but did for mothers later in the postpartum period. These findings suggest an interactive hormonal and experiential effect on autonomic processes [31,65]; hormones may modulate the effect of experience on heart rate response [34,66]. These relations were not found in the present study.

Similar to previous findings [15,17,18,24,25,67-69] depressed mothers were less behaviorally affectionate during interactions with their infants than were non-depressed mothers and were, in general, less attentive to them. Covarying parity eliminated the attending to infant effects, but made no difference in affectionate touching pattern. Women with two or more children spent less time attending to the infant than did those with only one.

Responsive and sensitive care from a mother is essential for optimal child development. During infancy and beyond, the basic needs of infants such as warmth, comfort, protection, and stimulation, are principally provided by a parent. These parental challenges are optimally managed when the mother has sufficient support and is herself emotionally stable. A significant proportion of mothers experience postpartum depression severe enough to affect their ability to parent [14,70]. Depression has been associated with increased negativity [51], and less responsive and stimulating parenting [55,71], as well as altered acoustical cues in maternal infant directed speech [72]. As infants are reliant on their mothers for their basic needs, cognitive stimulation and social interaction, they are vulnerable to the impact of maternal depression for their development. Although many of the negative effects of post-partum depression on maternal behavior usually resolve by 6 months [6,9], there is growing evidence that difficulties in maternal responses to the infant may have implications for the long term development of the child even after the mothers' depression remits, although evidence on this is varied [54,71]. For instance, Murray [73] followed children of depressed and control mothers up to the age of 18 months and found that the infants of depressed mother performed less well on object concept tasks and were more insecurely attached, however they found no effect on infants' general cognitive and language

development. In other studies, lower levels of infant-focused speech and more negative face-to-face interactions at 2 months were associated with poorer infant outcome at 9 and 18 months, particularly for boys [74]. Isabella and Belsky [75] found that mother-infant dyads that had lower rates of interactional synchrony at 3 and 9 months developed less secure attachments. At 19 months, significantly lower levels of sharing and sociability were found in infants of depressed mothers and, to a lesser extent, in infants of mothers who had recovered from depression [16]. Taken together, these studies indicate that PPD is a difficult time for the mother and has an enormous impact on her interactions with her offspring; these, in turn, can have substantial effects on the infant's social and emotional development.

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