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MATERNAL STRESS AND THE DEVELOPMENT OF INFANT REGULATORY PROCESES

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ABSTRACT

When mother-infant dyads engage in an effective form of communication, one where mother and infant both play an active role, the infant gains an understanding for the emotions that they feel. However, acute stress exposure may challenge the dyad's ability to effectively self-regulate prior to and following a social stressor. According to stress contagion theory, stress can be passed on from mother to infant during social interactions. Through an experimental manipulation of maternal stress, the current study examined relations between maternal stress and infant emotion regulation. The purpose of this study was to determine whether a stressed mother may "transmit" stress to her infant, thus causing infant physiological dysregulation. Forty mother-infant dyads were assessed in the laboratory, using the Still Face Paradigm (SFP), to examine this relationship. Forty mother-infant dyads participated. Infants were examined at 7 months of age, and mothers ranged from 21-38 years old. We were successful in creating a stress response in infants. However, we did not see differences in infant physiological responses between the stress group and the control group, indicating that we were not able to create two significantly different groups. We did see differences in infant heart rate during the second recovery episode of the SFP, where mothers are allowed to interact with their infants after 2 minutes of not responding. Contrary to our hypothesis, we found that mothers exposed to a stressor prior to the SFP had infants with shorter recovery times compared to unexposed mother infant dyads.

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INTRODUCTION

Caregivers act as an external source of emotion regulation for their infants until infants learn independent forms of self-regulation (Tronick, 1989). When mother-infant dyads engage in an effective form of communication, one where mother and infant both play an active role, the infant gains an understanding for the emotions they feel (Tronick, 1989). However, acute stress exposure may challenge the dyad's ability to effectively self-regulate prior to and following a social stressor (Moore & Calkins, 2004). While researchers have examined the relationships between maternal stress and infant emotion regulation (Moore & Calkins, 2004; Conradt & Ablow, 2010), all of the studies thus far are correlational. Experimental approaches would allow us to identify a causal relationship between maternal stress and its impact on infant emotion regulation, which could in turn clarify the etiological factors involved in the expression of infant emotion regulation.

Stress Contagion

Infants may "catch" the emotion of their mother during times of stress. The theory of stress contagion proposes that individuals tend to capture the emotion of someone else while engaging in a social interaction (Hatfield, Cacioppo, & Rapson, 1994). In mother-infant dyads, this stress contagion can be examined by studying maternal emotional signaling, where the mother's emotions could encourage the infant's corresponding behavior (Sorce et al., 1985). For example, Sorce et al. (1985) found that when mothers expressed a negative emotion (e.g., fear or anger) the infant was less likely to cross a visual cliff compared to mothers that expressed a positive emotion (e.g., happiness), demonstrating that a mother's emotions play a role in how infants behave.

Another study, in support of stress contagion theory, found that the manner in which mothers interact with strangers affects the way infants interact with those same strangers (de

Rosnay et al., 2006). De Rosnay et al. found that mothers who acted anxious with a stranger had infants that were more avoidant and afraid of that stranger compared to mothers who acted normally with a stranger. Furthermore, there was a greater positive covariation of mother-infant physiology after mothers met a negative stressor (e.g., fear or anger) compared to a low level stressor (de Rosnay et al., 2006). Therefore, it is possible that negative stress has a more powerful contagion effect on the infant relative to a low level stressor (Waters, West, & Mendez, 2014). In other words, as a mother experiences distress, her infant may experience this distress at behavioral and physiological levels.

Infant Physiological Indices of Emotion Regulation

As a method to measure infant physiological responses to interpersonal stress, the Still Face Paradigm (SFP; Tronick, Als, Adamson, Wise, & Brazelton, 1978) typically induces a stress response in both infants and mothers by breaking the natural flow of social interactions. Infant bids for communication are ignored by the mother, which increases the infant's stress levels (e.g., often by increasing heart rate). The SFP is therefore typically used to examine infant physiological indices of emotion regulation. The SFP consists of a normal play session, a still face session (a period of time where the mother is unresponsive to her infant), and a reunion session where the mother is allowed to resume play with her distressed infant (Tronick et al., 1978).

Infant cardiovascular responses to stressors like the SFP early in development may set the foundation for more complex levels of emotion regulation (Conradt & Ablow, 2010). Increases in heart rate likely reflect some kind of arousal, whether that be excitement or stress (Conradt & Ablow, 2010). Typically, infants exhibit increases in heart rate during the still face episode of the SFP (Moore & Calkins, 2004; Haley & Stansbury, 2003; Weinburg & Tronick, 1996; Bazhenova, Plonskaia, & Poges, 2001). Following the still face episode, a decrease in heart rate

is usually observed during the reunion phase (Haley & Stansbury, 2003); however, reunion heart rate is still higher than baseline heart rate (Moore & Calkins, 2004). Moore and Calkins also found higher heart rates among infants during reunion than in normal play, although there are some studies that do not find this difference (Weinburg & Tronick, 1996).

While an increase in heart rate in response to stress reflects a response by the sympathetic nervous system, a decrease in heart rate accompanied by an increase in respiratory sinus arrhythmia (RSA) may reflect a parasympathetic nervous system response (Moore & Calkins, 2004). RSA is an index of parasympathetic regulation and reflects the increases and decreases of heart rate as a function of respiratory activity (Beauchaine, 2001). An increase in RSA from baseline is typical during low stress interactions (Conradt & Ablow, 2010). On the other hand, a decrease in RSA is accompanied by increased sympathetic activation and movement in response to stress (Conradt & Ablow, 2010). Studies have found decreases in RSA when infants are engaging in play, but then experience the still face episode (Conradt & Ablow, 2010; Moore & Calkins, 2004; Weinburg & Tronick, 1996; Bazhenova, et al., 2001), and increases in RSA between normal play and reunion (Conradt & Ablow, 2010; Moore & Calkins, 2004).

Many studies have investigated associations between maternal sensitivity and infant physiology in response to the SFP. On average, infant heart rate increases and infant RSA decreases when a mother is unresponsive (Mesman, van IJzendoorn, & Bakermans-Kranenburg, 2009). Another study found that increased maternal sensitivity is related to a lower infant heart rate during the reunion episode (Conradt & Ablow, 2010). Haley and Stansbury (2003) and Conradt and Ablow (2010) found a negative correlation between maternal sensitivity and infant heart rate during the reunion episodes, indicating that more responsive mothers had infants with a slower heart rate during these episodes. Furthermore, less responsive mothers had infants with an increased heart rate during both still face and reunion episodes compared to more responsive

mothers (Haley & Stansbury, 2003). Interestingly, the correlations between maternal sensitivity and RSA were not significant for any of the still face episodes (Conradt & Ablow, 2010). However, mothers with high maternal sensitivity had infants who showed higher levels of RSA during the reunion episode (Conradt & Ablow, 2010), indicating that more sensitive mothers may have been able to soothe their infants adequately.

Present study

The aim of the current study is to determine, using a controlled experimental manipulation of stress in mothers, whether maternal stress exposure is related to infant physiological indices of emotion regulation. We hypothesized that mothers exposed to a stressor prior to the SFP will have infants with higher heart rates and lower RSA during still face than mothers not exposed to a stressor. We also hypothesized that stressed mother-infant dyads will have a longer infant recovery time from the still face episode compared to control dyads. These hypotheses rest on the notion, informed by stress contagion theory, that stress can distract the mother from helping her infant calm down, which would lead to the infant not being adequately soothed, thus experiencing a longer recovery time.

METHOD

Participants

Participants were 40 mother-infant dyads who were part of a longitudinal study, beginning prenatally, that examined the impact of prenatal exposure to maternal emotion dysregulation on infant development. The caregiver-infant dyads came into the lab when infants were between 26-30 weeks old (M = 28.5 weeks, SD = 1.66). Mothers ranged from 21 to 38 years old (M = 28.9 years, SD = 4.32). Consent for the infants was given by the mother.

Procedure

Following consent, both mothers and infants were attached to heart rate and respiratory equipment (described below). While physiological data was collected for both mother and infant, only infant physiology data will be reported. Infants were then dressed in a gender neutral smock that covered the electrode wires. Infants were seated in a high chair while their mothers sat next to them. The dyads watched a 2 minute Baby Einstein video (© 2002, The Baby Einstein, LLC) to establish a baseline. The "Baby Einstein" assessment was used to determine the infant's resting heart rate and RSA.

Design

There was one independent variable and two dependent variables. The independent variable was maternal stress exposure. Maternal stress was defined as the prompt (control or worry) that the mother was randomly assigned to before the visit. The stress prompt asked mothers to describe a parenting worry that they experienced over the last two weeks. The control prompt asked mothers to describe a quiet moment they had with their child in the past two weeks. The dependent variables were the baby's physiological responses to the Still Face Paradigm as measured by mean heart rate and mean respiratory sinus arrhythmia (RSA).

Stress assessment

Following the baseline measurements for baby's resting RSA and heart rate, mothers were asked to fill out a 10 question survey to assess their own emotions. Questions were in the format "How calm do you feel right now?" Mothers were randomly assigned to one of two writing prompts meant to illicit either a stress/worry group or a control group. The prompts and the surveys can be found in the Appendix. Lastly, after the stressor, mothers were asked to fill out the same 10-item questionnaire as before to assess mother's emotions. This questionnaire also asked how often they thought about the writing task during the social interaction. Infants were allowed to play with toys during this task.

After the writing task, the room was rearranged for the Still Face Paradigm (Tronick et al., 1978). Mother and infant were seated face-to-face with the infant in a high chair. Babies were not allowed toys for this task. Participants were told to play with their baby normally as they would at home for two minutes. Over the intercom, mothers were instructed to turn around and then turn back to face their baby with a still or neutral "poker" face for two minutes. Again, over the intercom, they were instructed to turn around, turn back, and resume normal play for two minutes. A second still face and a second reunion were instructed in the same manner. If at any point the infant grew too fussy, the still face paradigm was paused so the mother could soothe her baby. While some studies use the single still face format (play, still face, reunion), the current study utilized the double still face format (play, still face, reunion, still face, reunion) to induce greater stress compared to the single still face format (Haley & Stansbury, 2003).

Video recordings were set up with one camera focused on the mother and another camera recording the infant. A split-screen generator recorded the interaction with both cameras side-by-side.

Physiological assessment

Infant physiology data were collected with Mindware Electrodes. Experimenters placed electrodes on the right clavicle and the bottom of the left and right ribs while infants were sitting in a high chair. Infants were covered with a smock so they could not tug on the wires, and so that coders could not make assumptions about infant sex. Infants were still able to move. During the writing task and each event of the SFP, physiological channels were continuously recorded. Individual events were recorded using an epoch file. The heart rate data were sampled at 1,000 Hz, and were checked for outliers and artifacts using MindWare Heart Rate Variability software V. 3.3.5 (© 2012, MindWare Technologies, LTD). RSA was derived using the R-R series and

was determined by MindWare Heart Rate Variablity software V 3.3.5 (© 2012, MindWare Technologies, LTD).

RESULTS

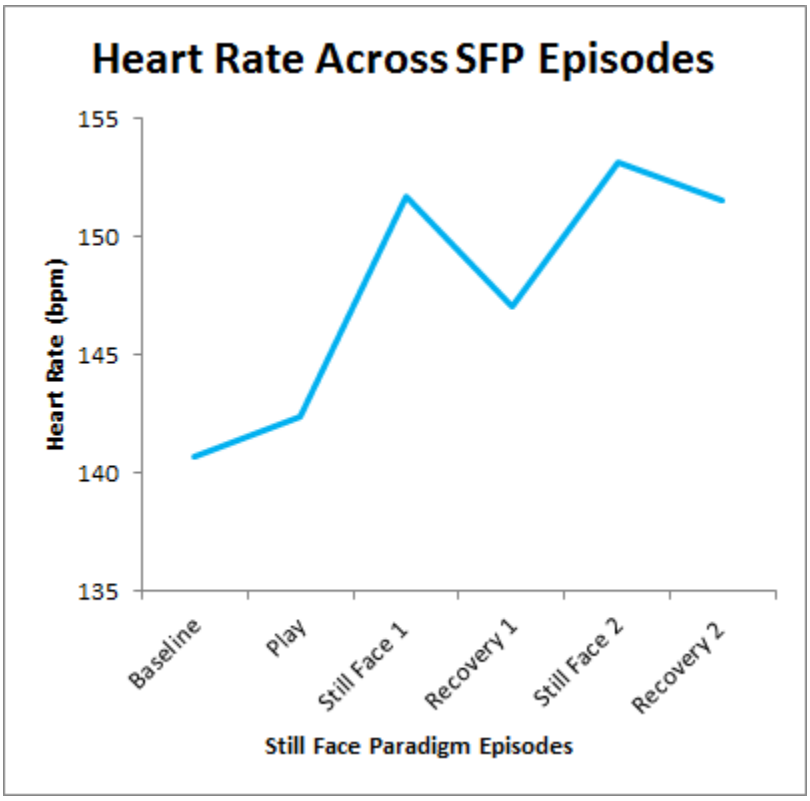
Prior to running the primary analyses, we calculated the grand means for HR and RSA across all episodes of the still face paradigm (Tables 1-2).

Manipulation checks

First, we examined the differences in pre- and post- emotion assessments to determine if there were any differences in maternal self-report of emotional states between the stress and control groups. There were no differences between the experimental groups all *p's >.05*, indicating that the experimental groups did not differ in self-reported emotional states and the manipulation did not work. Regardless, we continued with our analyses as planned.

The purpose of our second manipulation check was to determine whether infants exhibited changes in HR or RSA across the SFP, regardless of experimental condition. A paired samples t-test was used to determine differences between the SFP episodes. As expected, infant HR was significantly higher during the still face compared to the first play episode, regardless of stress condition, $t(38) = -7.04$, $p < .05$. In addition, infant HR was significantly lower during the first recovery episode compared to the first still face episode, $t(35) = 2.45$, $p < .05$. There was also a significant increase in HR between the first recovery episode and the second still face episode $t(33) = -2.45$, $p < .05$. After the second still face episode infant HR remained high. We plotted the HR grand means across the still-face conditions in Figure 1.

Figure 1. Infant heart rate across the Still Face Paradigm episodes, collapsed across experimental condition.



Paired *t* –tests were also conducted to determine whether there were significant differences in RSA across the still-face episodes, regardless of experimental condition. As expected, infant RSA was significantly higher during the still face episode compared to the play episode, regardless of the experimental condition $t(37) = 3.39$, $p < .05$. There were no other significant differences in RSA responses (all p's > .05).

Aim 1 Results

The first aim of this study was to determine whether maternal stress exposure prior to the SFP could impact infant physiological responses to stress. The hypothesis was that mothers who were stressed prior to the SFP would have infants with higher heart rates throughout the SFP. A repeated-measures analysis of variance (ANOVA), with still-face episode as the within-subjects factor and group as the between-subjects factor, revealed that there were no significant differences in infant HR or RSA between the experimental groups (Tables 3-4).

Aim 2 results

The second aim of the study was to determine whether there were differences in recovery times between a stressed group and a control group. The hypothesis was that mothers exposed to a stressor prior to the SFP would have infants who showed a longer time to recover, as evidenced by the theory of stress contagion, wherein an individual tends to capture the emotion of another person in a social interaction. A repeated-measures ANOVA was used to determine whether infants whose mothers were exposed to stress exhibited differences in how they recovered physiologically from the stress of the still-face episode compared to infants whose mothers were not exposed to stress. There were no significant differences between the two groups for both HR and RSA in response to the first recovery episode (N=36), $F(1,34) = 0.05$, $p > .05$. We next examined differences in HR and RSA during the second recovery episode (N=32) across all four, 30-second epochs. We found no significant differences between the two groups $F(1,34) = 0.14$, $p > .05$. Upon inspection of the graph, we noticed larger differences between the two groups during the first three epochs of the second recovery episode. We probed differences in these three epochs between infants whose mothers were exposed to a stressor prior to the still-face paradigm and those whose mothers were not exposed. There was a significant difference in HR between the two experimental groups $F(1,30) = 4.01$, $p < .05$. Figure 2 shows that the stressed group's

HR decreased more than the control group, which was contrary to our hypothesis. RSA differences in the second recovery episode were not significant $F(1,30) = 0.13$, $p > .05$.

Figure 2. Differences of infant heart rate between experimental groups during the first 90 seconds of Recovery 2.

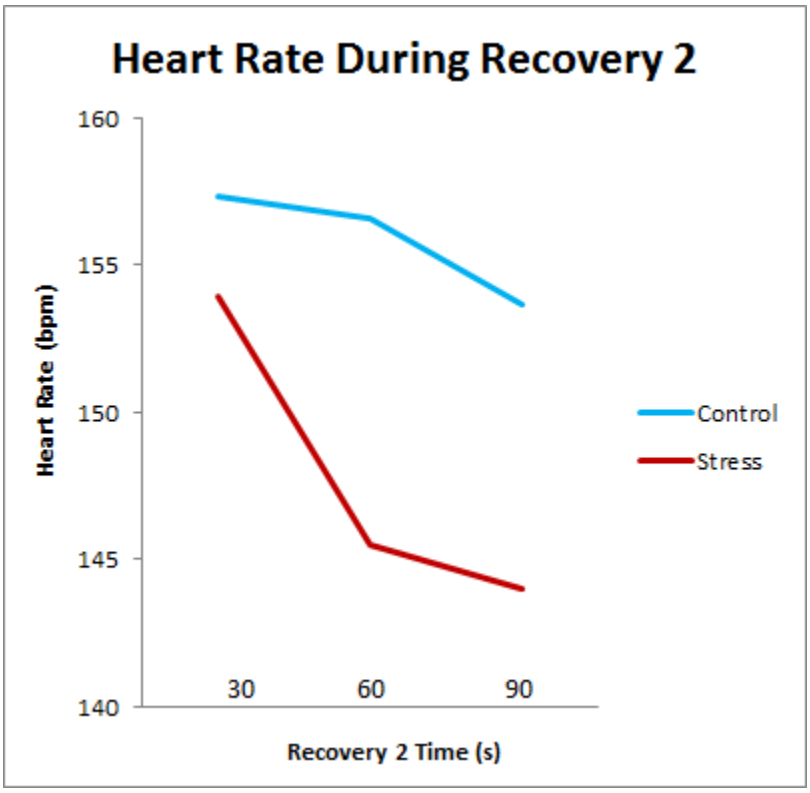


Table 1

Grand Means and Standard Deviations for Infant Heart Rate

Still Face Episode	Stress		Control	
	M	SD	M	SD
Baseline	137.57	10.38	143.48	13.93
Writing	145.99	13.00	148.91	10.03
Play	139.95	13.28	145.50	13.17
Still Face 1	154.30	12.77	156.08	15.60
Recovery 1	148.48	17.84	149.65	12.83
Still Face 2	151.24	14.75	155.10	15.59
Recovery 2	146.72	14.71	155.04	14.79

Table 2

Grand Means and Standard Deviations for Infant Respiratory Sinus Arrhythmia

Still Face Episode	Stress		Control	
	M	SD	M	SD
Baseline	3.71	0.96	3.39	1.00
Writing	3.10	0.72	3.09	1.01
Play	3.70	1.06	3.49	0.8
Still Face 1	3.21	0.82	3.00	1.22
Recovery 1	3.21	1.11	3.36	1.28
Still Face 2	3.50	1.21	3.36	1.2
Recovery 2	3.33	1.12	3.47	1.15

Table 3

One Way Repeated Measures ANOVA of Infant Heart Rate During the Still Face Paradigm

Still Face Episodes		Sum of Squares	df	Mean Square	F	Sig.
Baseline	Between Groups	348.19	1	348.19	2.27	0.14
	Within Groups	5822.81	38	153.23		
Writing	Between Groups	88.04	1	88.04	0.66	0.42
	Within Groups	5225.83	39	134.00		
Play	Between Groups	300.04	1	300.04	1.72	0.20
	Within Groups	6471.74	37	174.91		
Still Face 1	Between Groups	31.52	1	31.52	0.16	0.7
	Within Groups	7719	38	203.13		
Recovery 1	Between Groups	12.34	1	12.34	0.05	0.82
	Within Groups	8209.72	34	241.46		
Still Face 2	Between Groups	126.93	1	126.93	0.55	0.46
	Within Groups	7369.50	32	230.30		
Recovery 2	Between Groups	554.57	1	554.57	2.55	0.12
	Within Groups	6528.3	30	217.61		

Table 4

One Way Repeated Measures ANOVA of Infant Respiratory Sinus Arrhythmia

Still Face Episodes		Sum of Squares	df	Mean Square	F	Sig.
Baseline	Between Groups	1.03	1	1.03	1.06	0.31
	Within Groups	36.72	38	0.97		
Writing	Between Groups	0.001	1	0.001	0.001	0.98
	Within Groups	30.15	39	0.77		
Play	Between Groups	0.42	1	0.42	0.48	0.49
	Within Groups	31.34	36	0.87		
Still Face 1	Between Groups	0.42	1	0.42	0.39	0.53
	Within Groups	40.84	38	1.08		
Recovery 1	Between Groups	0.2	1	0.20	0.14	0.71
	Within Groups	48.86	34	1.44		
Still Face 2	Between Groups	0.17	1	0.17	0.12	0.74
	Within Groups	46.72	32	1.46		
Recovery 2	Between Groups	0.17	1	0.17	0.13	0.72
	Within Groups	39.00	30	1.30		

DISCUSSION

Past research investigated associations between maternal stress and infant physiological measures, but none have examined whether maternal stress may cause changes in infant physiology in response to stress. The results from this study are the first to investigate this causal relationship in mother-infant dyads using an experimental manipulation of maternal stress prior to the still-face paradigm.

The results of the manipulation of maternal mood indicate that the writing task did not create any differences of emotional states between the two groups. This demonstrates that our task may not have been a sufficient manipulation of emotion to elicit a stress response in mothers. While it may be the case that the responses from our participants were not emotionally distressing to recreate a stressed response, past research may provide some other possible explanations for this result. Kross and Ayduk (2008) found that when distanced from a negative event that participants were asked to recall, negative emotions were often reduced during recall. While we asked our participants to recall an event in the past week, they may have been too distanced from the isolated event to fully experience the negativity of the event. In addition, a resolution within the recalled story reduces the negative emotions associated with the event (Pasupathi, Billitteri, & Mansfield, 2015). The stressful moment that our mothers recalled may have been resolved before they wrote about the event, a hypothesis that we will test for in future research. Thus, our insignificant results may have been due to the insufficient maternal stress manipulation.

However, the infant physiological indices of emotion regulation were consistent with past research results (Moore & Calkins, 2004; Haley & Stansbury, 2003; Weinburg & Tronick, 1996; Bazhenova, Plonskaia, & Poges, 2001). In our study, we showed that infants became distressed

when their mother was unavailable (i.e., did not respond to her infants' bids for attention). We saw in increase in HR and a decrease in RSA between the play episode and the still face, which indicated that infants were activating their sympathetic nervous system, and reducing their parasympathetic nervous system in response to stress. In addition, we showed that an infant became less distressed as the mother resumed normal interactions. There was decreased HR during the first recovery episode, indicating that infants were being soothed. Lastly, we saw an increase in HR during the second still face, indicting another stress response. These findings suggest that we were able to create both a distressed state in infants and a recovery state, in which the infants effectively regulated their emotions with the aid of their mother.

The results of the second aim suggest that mothers exposed to a stressor prior to the SFP have infants with shorter recovery times, which was opposite of what was hypothesized. An important caveat to these results is that we looked specifically at the first 90 seconds (out of 120 seconds) of the second recovery episode for HR only. While we did see HR differences, we did not see a corresponding RSA response between the experimental groups. A limitation to this result is that several infants did not complete the second recovery in its entirety or, in some cases, at all, thus reducing the sample size further for the second recovery episode.

While the results were inconsistent with our hypothesis, these results lead us to speculate about maternal stress and infant emotion regulation. It may be the case that stress experienced by the mother may alter maternal sensitivity and affect the way infants develop their growing sense of emotion regulation. In light of this study, it is possible that stress may facilitate more sensitive parenting, rather than distract the mothers from their parenting. In addition, the prompt we use for mother's stress manipulation asks them to think about their infant in a stressful context. This may cue the mother to her parenting worries, thus increasing her maternal

sensitivity. Future research could examine behavior during the SFP in addition to the physiological measures in order to better understand how stress affects maternal sensitivity.

The results of this study help to understand the effects of maternal stress on infant physiological responses. We found that stressed mothers were able to better soothe their infants than control mothers. This study provides opportunity to further investigate how maternal stress affects infants' physiological responses. A look into maternal behavioral responses as well as infant physiological responses could help pinpoint these effects.

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APPENDIX

Stress prompt: All new mothers worry about some aspect of their parenting. Identify the biggest worry you had as a parent in the last week. Write in detail about what it was that you were worried about, how it made you feel about yourself as a mother, how it made you feel about your baby, and how it made you feel about the future.

Control prompt: All new mothers experience quiet moments with their children. Identify the quietest moment you had with your child in the last week. Write in detail about what it was that made it quiet, how it made you feel about yourself as a mother, how it made you feel about your baby, and how it made you feel about the future.

Pre-prompt questions: Please rate to what degree you currently feel for each of the emotions listed using the following rating scale. Do you feel the emotion: (1) not at all (2) a little (3) moderately or (4) very strongly?

Question	Not at all	A little	Moderately	Very strongly
1. How anxious do you feel right now?				
2. How worried do you feel right now?				
3. How nervous do you feel right now?				
4. How sad do you feel right now?				
5. How happy do you feel right now?				
6. How calm do you feel right now?				
7. How mad do you feel right now?				
8. How overwhelmed do you feel right now?				
9. How scared do you feel right now?				
10. How content do you feel right now?				

Post-prompt questions-Stress: Please rate to what degree you currently feel for each of the emotions listed using the following rating scale. Do you feel the emotion: (1) not at all (2) a little (3) moderately or (4) very strongly?

Question	Not at all	A little	Moderately	Very strongly
1. How anxious do you feel right now?				
2. How worried do you feel right now?				
3. How nervous do you feel right now?				
4. How sad do you feel right now?				
5. How happy do you feel right now?				
6. How calm do you feel right now?				
7. How mad do you feel right now?				
8. How overwhelmed do you feel right now?				
9. How scared do you feel right now?				
10. How content do you feel right now?				
11. How much did you think about the parenting worry during the face-to-face interaction?				

Post-prompt questions - Control: Please rate to what degree you currently feel for each of the emotions listed using the following rating scale. Do you feel the emotion: (1) not at all (2) a little (3) moderately or (4) very strongly?

Question	Not at all	A little	Moderately	Very strongly
1. How anxious do you feel right now?				
2. How worried do you feel right now?				
3. How nervous do you feel right now?				
4. How sad do you feel right now?				
5. How happy do you feel right now?				
6. How calm do you feel right now?				
7. How mad do you feel right now?				
8. How overwhelmed do you feel right now?				
9. How scared do you feel right now?				
10. How content do you feel right now?				
11. How much did you think about the quiet moment during the face-to-face interaction?				