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Cortisol Reactivity, Maternal Sensitivity, and Infant Preference for Mother's Familiar Face and Rhyme in 6-Month-Old Infants

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Abstract

This study investigated how cortisol (stress) reactivity and mothers' behavioral sensitivity affect familiarity preferences in 6-month-old infants. Relations between sensitivity and stress were explored using saliva samples taken from mothers and infants before, and 20-min after, two preferential looking experiments. Photographs and voice recordings from infants' mothers were incorporated into standard visual preference tasks. Sensitivity was assessed by determining the degree of behavioral synchrony between mother and infant from a 10-min interaction period preceding the preferential looking experiments. Results showed that decreasing infant cortisol reactivity and greater maternal sensitivity were associated with familiarity preferences for mother's face stimuli. For the experiment with voice stimuli, a sex difference was obtained in the relationship between the directionality of cortisol reactivity and familiarity preferences. Results are related to a parallel study with 3-month-old infants (Thompson & Trevathan, 2008), and issues are discussed in terms of infants' developing emotional independence from mother.

Keywords

Cognitive; Infant; Social Interaction; Mothers; Quantitative

Infants' ability to recognize caregivers' faces and voices is important for the development of attachment (Bowlby, 1969). Numerous studies have investigated the newborn infant's preferences for, and ability to discriminate, their mother's face and voice. For example, research has shown that newborn infants look for longer periods of time at their mother's face compared to a stranger's face (Bushnell, Sai, & Mullin, 1989; Pascalis et al., 1995; Walton, Bower, & Bower, 1992). In the auditory recognition domain, newborn infant's ability to recognize their mother's voice is a well-established finding (Spence & Freeman, 1996). Newborns can also discern the native tongue of their mother's voice (Mehler et al., 1988), and, at just 3 days of age, discriminate between unfamiliar, and familiar, story passages that were spoken by their mothers during the last trimester of prenatal development (e.g., DeCasper & Spence, 1986). At four months, event-related potential (ERP) studies show enhanced arousal and a clear memory template for mother's voice compared to an unfamiliar voice (Purhonen et al., 2005). By eight months, infants are able to preserve information about talker identity when exposed to the same talker over a 2-week time interval (Jusczyk, Hohne, Jusczyk & Redanz, 1993).

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¹To establish whether or not there was a difference in cortisol reactivity between those infants with usable looking time data and those without, two-tailed paired samples t-tests were conducted between log₁₀ T1 and T2 values for infants whose looking time data could not be analyzed, separately for the faces and rhymes experiments. As was the case in the larger sample, log₁₀ T1 and T2 values for the infants whose looking time data could not be included were not significantly different from each other, for both the faces and the rhymes experiment (*p*'s > .05).

Research has delimited some boundaries in these early abilities. For instance, in one study, 4- to 6-week-old infants preferred their mother's voice to the voice of a stranger only when the mother's speech contained the prosodic and intonational characteristics of her normal speech (Mehler, Bertoncini, Barriere, & Jassik-Gerschenfeld, 1978). In another, 6-month-old infants discriminated mothers' and strangers' faces when they were dissimilar from each other, however when the face of a stranger was similar to the infants' own mothers' faces, they showed no evidence of recognizing their mothers (de Haan & Nelson, 1997). Thompson, Madrid, Westbrook, and Johnston (2001) found that 7- and 8-month-old infants' ability to discriminate female faces (all strangers) depended on the amount of modification made to the original photograph. Using a computer graphics program, the jaw lines of the photos were lengthened and shortened, thereby altering the spatial relations between internal facial features, specifically, the eyes and the mouth and chin. Those photos with only slight adjustments were not discriminated by babies, but those with 3 mm or greater adjustments (from a total face length of approximately 20 cm) were discriminated. Bhatt, Bertin, Hayden, & Reed (2005) also manipulated the spatial relations between features of the face, while holding the size of the face frame constant. When habituated to the modified version of a face, and then tested with a face pair using both the novel (nonmodified) and modified version of the face, 5-month-olds, but not 3-month-olds, were able to discriminate the faces. Unlike older infants, neonates do not seem to use a mechanism that encodes the internal structure of the face; rather, they rely on the hairline and outer contour of the face (Pascalis et al., 1995). These results suggest that infants greatly extend the range of faces recognized by implementing a face processing mechanism used to encode second-order relational information (Diamond & Carey, 1986).

Hidden in reports of perceptual abilities of same-aged infants is a sample population of individuals with varying motivations and cognitive abilities for discriminating and remembering, presumably, even their own mothers' faces and voices. Psychologists have studied individual differences in infant cognition from a variety of perspectives, including behavioral, cognitive neuroscience, and biobehavioral perspectives. To address individual differences in infant cognition from a behavioral perspective, Rose, Futterweit, and Jankowski (1999) measured overall mood, the amount of time smiling, and the duration of infants' longest looks in 5- to 9-month-olds, and found that faster learning was associated with neutral affect and short looks to photographs. Findings from several labs over the past 15 years have consistently shown that infants who look for longer periods of time at stimuli seem to process the information more slowly (e.g., Freese, Columbo, Coldren, 1993). The general advantage for "short-lookers" has been found using a variety of tasks with infants tested during the first year (e.g., Columbo, Mitchell, Coldren, & Freese, 1991; Columbo, Richman, Shaddy, Greenhoot, & Maikranz, 2001; Frick & Columbo, 1996; Frick, Columbo & Saxon, 1999). Using face stimuli, 12-month-old "short-lookers" showed better recognition of "fractured" faces (Rose, Jankowski, Feldman, 2002). From a cognitive neuroscience perspective, individual differences in ERP have been associated with novel and familiar face encodings in infants (Snyder, Webb & Nelson, 2002). Results from 6-month-old infants have shown that individual differences in infant proximity seeking are correlated with the Nc component of ERP when mother's face is presented (Swingler, Sweet & Carver, 2007). From a biobehavioral/cognitive neuroscience perspective, ERP and infant cortisol have been found to be linked in 12-month-old infants, where those infants with higher normative ERP patterns showed lower cortisol levels and better attachment behaviors (Gunnar & Nelson, 1994).

Our research investigates differences between infants in lower-level cognitive processes, such as encoding, discrimination, and short-term memory abilities, from a biobehavioral perspective. More specifically, do differences between infants' psychophysiological reactions and/or differences in mothers' responsiveness to their infants partially account for individual differences in infant cognitive processing? Experiential variation with mother during mother-infant attachment formation, and differences amongst infants in emotional reactivity should

contribute some of the variation in early infant cognition. Our research concerns how maternal sensitivity and infant adrenocortical functioning might affect infant cognitive processing during the first year of life.

Relevant evidence linking maternal sensitivity and cognitive processing points in the expected direction. For example, attachment security has been linked to cognitive processes in toddlers (Belsky, Spritz & Crnic, 1996; Farrar, Fasig & Welch-Ross, 1997; Jacobsen, Edelstein, & Hofmann, 1994), as has maternal synchrony and infant intelligence (Feldman, Greenbaum, Yirmiya, & Mayes, 1996). Tamis-LeMonda, Bornstein, and Baumwell (2001) found a relationship between mothers' responsiveness to their infants and infant language development in 9- and 13-month-olds. Infants whose mothers responded contingently to their behaviors scored higher on various measures of early language ability. Maternal sensitivity could be shown to affect infant cognition directly, and it also could plausibly exert its effect indirectly, by affecting infant adrenocortical functioning, which may then directly affect infant cognitive functioning.

Studies relating infant psychophysiological parameters and cognitive development also exist, but it is too early for a clear understanding (Haley, Weinberg, & Grunau, 2006; Thompson & Trevathan, 2008). In this vein, Haley et al. (2006) reported an investigation of cortisol secretion in 3-month-old infants and its relationship to infant learning and memory. This study, conducted in the infants' homes, found that, while cortisol reactivity was not related to learning or short-term retention, a moderate increase in cortisol was associated with better long-term memory in infants, that is, memory for an association formed 24-h earlier. Cortisol is a glucocorticoid (GC) hormone secreted from the adrenal glands, and is produced by the L-HPA (limbic-hypothalamic-pituitary-adrenocortical) system, which is a component of the stress response system. Cortisol is often used as a measure of physiological arousal and emotional stress in infants and mothers (e.g. Fleming, Steiner, & Anderson, 1987; Fleming, Steiner, & Corter, 1997; Gunnar, et al. 1996; Haley & Stansbury, 2003). Cortisol, a steroid hormone, is released from the adrenal glands in the fourth step of a process that begins when the brain perceives a stressor, which is followed by the release of corticotropin-releasing hormone (CRF) from the hypothalamus, which in turn stimulates the pituitary gland to release adrenocorticotrophic hormone (ACTH), which is followed by the release of cortisol from the adrenals into the bloodstream, through which it travels throughout the body and into the brain, where it is known to affect the functions of the hippocampus and other cortical structures (Sapolsky, 1992). Prolonged or severe stress negatively affects learning and memory processes and health (e.g., Flinn & England, 2003).

Our research investigation is guided by findings in two domains of research, involving both child and adult populations. In the child domain, research is beginning to support the general thesis that the development of emotional and cognitive control processes proceeds concurrently (e.g., Posner & Raichle, 1994), and may involve common brain areas, specifically the anterior cingulate and prefrontal cortices (Posner & Rothbart, 2000; Rothbart, Posner, & Kieras, 2006). This position has received recent support in the literature, where for example, in toddlers, better attention regulation and response inhibition were associated with better emotional regulation (Posner & Rothbart, 2000) and lower cortisol levels (Watamura, Donzella, Kertes, & Gunnar, 2004). The link between the control of emotional and cognitive processes has also been made apparent in studies of at-risk preterm infant populations. For example, Tu, et al. (2007) found that higher levels of basal cortisol levels were associated with poorer quality of focused attention during a toy exploration task in a specific subgroup of 8 month-old corrected age infants tested. It remains unclear whether these linkages can be found in full-term infant populations, however. Tu et al. (2007) studied a reference group of full-term infants and did not find an association between cortisol levels and focused attention. In the adult domain, the release of GC hormones has been found to have a deleterious effect on the retrieval of

previously learned material (DeQuervain, Roozendaal, Nitsch, McGaugh, & Hock, 2000; Elzinga & Roelofs, 2005; Kirschbaum, Wolf, May, Wippich, & Hellhammer, 1996), although GC release may improve certain aspects of cognitive performance such as long-term memory consolidation (Buchanan & Lovallo, 2001; Cahill, Gorski, & Le, 2003).

Based upon previous findings and Rothbart and colleagues' claims (e.g., Rothbart et al., 2006), our general expectation is that infants who can manage their emotional response to a moderately stressful situation would be more likely to display discrimination ability during an experiment than infants who manage their emotional response less well. Moreover, in line with other researchers, we assume that cortisol elevations reflect a failure of the infant's behavioral coping system (e.g., Gunnar et al., 1996; Levine & Wiener, 1988; Spangler & Grossman, 1993), and further, that a maternal separation episode constitutes a challenge to the 6-month-old infant's emotional response system (e.g., Ahnert, Gunnar, Lamb, & Barthel, 2004). Lastly, evidence supports the claim that prolonged or severe stressors interfere with encoding and memory processes (e.g., Heffelfinger & Newcomer, 2001). Taken together, past theoretical and empirical work implies that if the infant is left to cope without the physical presence of his/her mother while simultaneously experiencing a novel experimental task, failures in emotion coping may be associated with reductions in infants' capacities for discriminating between relevant classes of stimuli during an experiment.

We recently reported an investigation of the influence of both maternal behavioral responsiveness and mother and infant cortisol reactivity, on learning of speech/visual object correspondences in 3-month-old infants (Thompson & Trevathan, 2008). First-time mothers and their infants came to the laboratory, and first participated in a 10-min videotaped interaction period, during which mothers interacted with their infants in any way that they felt comfortable. Saliva was collected from both mother and infant after the videotaped interaction period, two times, once prior to a learning experiment and again, 25 minutes later. The experiment involved infants attending for 90-sec to their mother's voice saying "Oh! Look at that block!" Her voice was emitted from a speaker immediately above a monitor on the infant's left and right sides, displaying a red block on one side and a yellow block on the other side, both moving in a wave-like manner across the screens. The voice was paired with one block color. In the retention phase, both monitors again showed the moving blocks, but no maternal voice stimuli were presented. Infants whose cortisol increased during the session showed no learning or memory of the voice/object association. In contrast, infants whose cortisol levels declined during the experiment showed attention to, and short-term memory for, the maternal voice/object association. Using the coding scheme of Isabella and Belsky (1991), the degree of synchronous dyadic interactions, characterized by mutually rewarding and reciprocal exchanges by the mother and infant, were coded from the 10-min interaction period in our previous study. An association between mother-infant synchrony and infant cortisol reactivity was not shown. However, mothers with greater decreasing cortisol reactivity showed higher degrees of sensitivity to their infants in the videotaped interaction period.

As in our previous investigation, our primary objective is to better understand how infant stress reactivity and maternal responsiveness affect the infant's ability to discriminate and remember patterns of stimulation that infants experience very frequently—those involving the infant's own mother's face and voice. The present experiment extends our previous investigation to 6-month-old infants and their first-time mothers. The developing infant, with three additional months of experience in relationship to mother, is more familiar with her, and may be less dependent on her for emotional regulation. One might expect that infant maturational development in the first year would involve increasing divergence from mothers' psychophysiological response patterns, in conjunction with an increasing dependence on behavioral caregiving response patterns. Consistent with this view, Feldman (2007) in a recent review of biobehavioral research on parent-child relationships and infant development,

provided an important and timely conceptual framework with which to understand the development of infant regulation. In general, she argues that “Development is thus grounded in relationships and this initial dependence of the infant on the mother's body opens the lifelong neurobiological possibility that one person can serve an ‘external regulatory’ function to the physiological systems of another through timely adaptation to distress and social cues” (p. 331).

In addition to investigating individual differences in infant cognition attributable to mother-infant synchrony and infant cortisol reactivity, the present study explores the nature of development of mothers' and infants' patterns of emotional reactivity exhibited while participating in the experimental event. One possible consequence of infants' increasing dependence on an external behavioral regulatory framework over the first year of life (Feldman, 2007) might reasonably be proposed to include a reduction in infants' dependence on a physiological regulatory framework that might be made manifest in indicators of synchronous activities which are rooted in the functioning of the neuroendocrine system. If so, mothers' and infants' cortisol levels should show less similarity at this age than when the infants were 3 months of age. In our previous study, 3-month-old infants' cortisol levels were significantly positively correlated with their mothers' when they arrived at the laboratory (Time 1; T1), however after the voice/object mapping experiment during which time they were separated from their mothers (25 min later; T2) their cortisol levels were no longer correlated. The pattern of mother-infant correlated cortisol values at T1, subsequently becoming uncorrelated at T2, suggests that infants played a role in their own psychophysiological coping experiences during a learning event. A maturational pattern of greater divergence between mothers' and infants' emotional reactivity between 3 and 6 months would be indicated if 6-month-old infants' and mothers' cortisol levels were not correlated at either T1 or T2. Our research is the first to include maternal cortisol measures to examine possible links between maternal sensitivity, infant cortisol, and infant cognition.

It is important to make explicit the time course of events in the experiment before stating our predictions, because this helps to establish what aspects of psychophysiological functioning are reflected in mothers' and infants' cortisol values. Mothers drove to the laboratory, and upon entering the laboratory, settled in for a period of approximately 20 minutes before the first saliva sample (T1) was taken. During the final 10 minutes prior to T1 sampling, the 10-min videotaped free-play mother-infant interaction period occurred. The Faces Experiment then took place, followed by a short break, which was then followed by the Rhymes Experiment. During the experiments, the infant was placed in an infant seat in front of the monitors, while the mother disappeared from her infant's view behind a partition. The duration of these experiments varied slightly, but the total time that elapsed prior to T2 saliva sampling averaged 21 minutes. As in our previous study, we make the assumption that T1 cortisol levels are primarily reflective of infants' and mothers' physiological and emotional responses to the lab context as experienced in each other's physical presence. We further assume that the difference in cortisol levels between T1 and T2 ($\Delta T1-T2$) reflects infants' reactions to both maternal separation and the novel experiment situation. Finally, we used the same conservative criterion for determining cortisol change categories as we used in our previous study, specifically, a one-half standard deviation difference in cortisol levels between T1 and T2.

Regarding individual differences in infant cognition, we make hypotheses similar to our previous study, and include some additional hypotheses extending some of our earlier findings. More specifically, we predict that infants who show declining cortisol levels during the experimental session will: (a) show recognition of their own mother's face, by looking at it longer than photos of other adult female faces, (b) use second-order relational features of the face to discriminate between mothers' modified and nonmodified faces, and (c) will discriminate between familiar and unfamiliar rhyme recordings spoken by their mothers. We

also hypothesize that infants who experience no change in cortisol levels will not make these discriminations. A finding that increasing cortisol levels is associated with better discrimination would be consistent with Haley et al.'s (2006) long-term memory findings, but would be inconsistent with results both in adults showing cortisol-induced impairments of working memory (Elzinga & Roelofs, 2005) and in infants with a pattern of increasing cortisol reactivity showing short-term memory deficits (Thompson & Trevathan, 2008). Moreover, since we found in our previous study that gender was correlated with T2 cortisol values, specifically, boys' cortisol values were lower than girls', we will explicitly test the hypothesis that gender may interact with the direction of cortisol change during the preferential looking experiments in the present study.

We also hypothesize that mothers who demonstrate greater behavioral synchrony with their infants will have infants who will make these discriminations of mother's face stimuli, while infants of mothers with lower levels of synchrony will not. We did not hypothesize an effect of behavioral synchrony on infants' preference for rhymes, due to the fact that the mothers and infants always experienced an additional, non-coded, interaction period that preceded the Rhymes Experiment. In contrast, the 10-min interval that was coded always immediately preceded the Faces Experiment, so this interval was considered to be a better predictor of infant learning in the first, rather than the second, experiment in the sequence.

And finally, we investigate potential links between infants' and mothers' stress reactivity and maternal sensitivity. Haley and Stansbury (2003) investigated parent responsiveness and its relation to 5- and 6-month-old infant abilities to regulate stress, using both physiological and behavioral measures of stress regulation in infants. The heart rate and infant affect results were consistent with the conclusion that infants of more responsive parents could regulate their own stress better than infants of less responsive parents. However, they found no correlation between parent responsiveness and infant cortisol reactivity, and they did not measure cortisol reactivity in parents. We found previously that mothers exhibiting lower levels of cortisol reactivity had higher levels of behavioral synchrony with their 3-month-old infants. Consequently, we will examine this potential link in first-time mothers of 6-month-old infants. Lastly, since behavioral synchrony and infant cortisol reactivity are predicted to have similar effects on infant cognition, they are predicted to be correlated with each other.

Method

Participants

The final sample of 94 6-month-old infants (M age = 182 days; SD = 6.7 days; 51 females, 43 males) and their first-time mothers (M age = 24.8 years; SD = 6.5 years) came from a larger set of 124 participating mother-infant pairs. Of the final sample, twenty-seven sets had participated in our earlier study (Thompson & Trevathan, 2008). Mother's ethnicity data was collected; 42.7% self-identified as Hispanic and 57.3% as non-Hispanic (the majority were Caucasian), approximating the ethnic composition of the region. Infants were full-term at birth, and were free of any known neurological or sensory impairments. They were recruited by radio and newspaper advertisement, and by posting fliers at daycare centers and business establishments. Thirty infants were eliminated from the larger sample due to insufficient amounts of saliva in one or both samples (22), cortisol levels more than 3 SD above the mean (4 infants, 1 mom) or equipment error in filming the 10-min observation period (3). Of the 94 remaining mother-infant pairs in the final sample, cortisol, preferential looking time, and behavioral synchrony data for 77 mother-infant pairs were analyzed for the Faces Experiment and 74 mother-infant pairs for the Rhymes Experiment. The reasons for this further reduction in these two data sets were due to equipment problems, infant fussiness, and side biases. All of the experimental procedures complied with the Code of Ethics of the World Medical

Association (1964 Declaration of Helsinki) and the standards of the New Mexico State University Internal Review Board.

Preferential Looking Experiment: Faces

Each mother was photographed at a constant distance and lighting, and wore no make-up or jewelry. Their hair was drawn back so that their faces were in full view, but several had bangs on their foreheads. Photos were scanned into a computer and transported into image processing software. Each photo-image was scaled to a common interpupil distance, and “touched up” by smoothing out skin blemishes or shadowing. These are referred to as the “nonmodified” stimuli. In order to have a variety of faces for infants to view, four different face categories were used. One was the infant's mother. A second was another infant's mother, chosen because it looked similar to the infant's mother. A third was an infant's mother that looked very different from the infant's mother. (These determinations were made by one experimenter who based her judgments primarily on face shape, skin color, and hairstyle.) A fourth category was a stimulus face of a young woman that every infant saw. For the four “nonmodified” images, two “modified” versions were also created by either adding (lengthened stimuli) or splicing out (shortened stimuli) several narrow horizontal sections of the interior region of the face, between the bottom of the nose and the top of the mouth, and between the bottom of the mouth and the chin. A smooth, natural-looking jaw line was brushed in using the software tool. All other features of the face were left intact. The size of the face as it appeared from the infant's position on the computer monitor was approximately life size. Example photographs used in the experiment appear in Figure 1.

Design—There were four different randomized orderings of 16 trials, with approximately equal numbers of infants viewing each ordered set. Within each pair, a modified and a nonmodified version of the same face were presented simultaneously. There were four pairs containing a lengthened modified face and four pairs containing a shortened modified face, and each face pair was shown two times. Each trial pair always included a nonmodified face displayed on one side, and that same face modified displayed on the other side. For example, a pair on one trial might include mom modified on one side and mom nonmodified on the other. The modified version of each pair was presented once on the baby's right side and once on the left side. The only constraints in ordering the sets were that no fewer than two trials occurred between presentations of the same face pair, and that the normal versions of the faces appeared equally often on the right and left sides.

Apparatus and procedure—A standard two-monitor visual preference paradigm was used (Kemler Nelson et al., 1995), a common tool used in investigating visual processing abilities (e.g., Thompson, et al., 2001). Pairs of face stimuli appeared on two color computer monitors positioned on the infant's left and right sides at 45 degree angles to the infant. The infant sat alone in an infant seat, mounted on a stool. A small red light also appeared at midline at the infant's eye level. This light flashed on and off between trials, and, along with a ringing cowbell, was used to orient the infant toward center prior to the beginning of every trial. The infant controlled the beginning of each trial by orienting toward the center for two full seconds.

The 8-sec trial length, stimulus advancement, and data recording were controlled by computer. One experimenter stood behind a booth at the center and looked through a one-way mirror at the infant, recording the amount of time the infant looked toward the right, center, or neither position. The recording was done by hand held switches. The experimenter who operated the switches could not see the displays that the infants were viewing and was unaware of the stimulus conditions. Mothers stood out of view behind the booth so that they could not see the stimuli and potentially influence the looking preferences of their infants.

We obtained interobserver reliability of visual-fixation scoring by having two experimenters view 75% of the prerecorded infant sessions, scoring the infants' looking times to their right and left sides across all trials in both the Faces and Rhymes experimental session. The average of the reliabilities was .97, using Cronbach's alpha.

Preferential Looking Experiment: Rhymes

The Rhymes Experiment always took place after a 1-2 min break after the Faces Experiment. Two modern nursery rhymes served as stimuli in this experiment. They were chosen because they were pleasant, lyrical, and approximately the same length. Half of the mothers read one of the rhymes, while the other half read the other rhyme, to their infant as often as they wished during a two-week interval prior to coming to the experimental session. The purpose of allowing this amount of variability in rhyme reading was twofold. We wished to investigate whether the effort mothers put into reading frequency would be correlated with behavioral synchrony, and we also wanted to determine if rhyme reading frequency would be correlated with the degree of discrimination between familiar and unfamiliar rhymes shown by infants. Mothers kept track of the number of times they read the rhyme. This is referred to as the Familiar rhyme, while the one they did not read to their infants at home is the Unfamiliar rhyme. The Familiar and Unfamiliar rhymes were digitally recorded by the mother in the lab at least two weeks prior to the experimental session, who was instructed speak as if she were speaking to her baby. The digital recordings were approximately the same length and loudness across mothers and rhymes. Mothers were not given the Unfamiliar rhyme to read to their infants during the 2-week interval.

Using a standard preferential looking paradigm for auditory stimuli (Hirsh-Pasek et al., 1987), four trials were presented to each infant, two consisting of the infant's mother's voice speaking the Familiar, and two of her speaking the Unfamiliar, rhymes. They were presented in counterbalanced order, with half of the infants hearing the first rhyme on the right speaker on the first trial, and half on the left speaker. Half of the infants received the Familiar rhyme first. A trial began with the infant looking center for two seconds. A light would then appear above the speaker for the upcoming rhyme presentation. As soon as the infant saw the light, the speaker emitted the rhyme. The rhyme played until the infant looked away for one second. An experimenter, wearing headphones that played masking auditory stimuli, used hand-held switches to record the infant's fixations toward the left speaker, the right speaker, and neither location.

Video-Recording and Observational Coding

As in our previous study with 3-month-old infants (Thompson & Trevathan, 2008) we used a modification of the methods developed by Belsky, Isabella and their colleagues (Isabella, Belsky, & Von Eye, 1989; Isabella & Belsky, 1991). In their study, observations of mother-infant interaction were made in their homes as mothers were asked to "go about their daily routines" (Isabella & Belsky, 1991, p. 375). In our study, these observations were made during a 10-min free-play session in an area of the lab consisting of a small couch, a rug, a table with magazines on it, and a basket of toys. Mothers were asked to "play with, or just be with, your baby as you normally would at home." We included 11 of the 12 maternal behaviors and 10 of the 11 infant behaviors that Isabella and Belsky used in their study. The only behaviors of theirs not included were the 3-step interactions, which we determined could not be reliably coded in the 10-sec sampling period we used. The 10-min videotaped interactions were digitized and imported into the Observer software program (Noldus Corporation). Two individuals who were extensively trained on Isabella and Belsky's maternal-infant interaction coding system separately coded mother and infant. The 10-sec sampling period was prompted by a timer. The same two individuals reviewed every interval where their codes differed, and

all discrepancies were resolved by discussion. Prior to discussion, the percentage of observations receiving the same codes across trained raters was always above 90%.

Synchronous dyadic interactions are characterized by mutually rewarding and reciprocal exchanges by the mother and infant, while asynchronous interactions are those that seem one-sided, unresponsive, or intrusive on the part of the mother. For a synchronous exchange to occur, the mother responded to the infant in a manner that was sensitive and contingent upon the infant's behavior. For example, if the infant vocalized and the mother's response appeared to be contingent on that vocalization, by soothing and/or making some other sensitive behavioral response to that vocalization, the dyadic interaction was classified as *synchronous*. On the other hand, if the infant explored and the mother stimulated, aroused, or vocalized to the infant, those were seen as *asynchronous* in that her behavior interfered with the infant's independent exploring. Co-occurrences not listed in the tabled categories were considered *neutral* and were used only in the denominator representing total numbers of behaviors coded. Two individuals not involved in behavioral coding independently determined the synchrony category (synchronous, asynchronous, neutral) for each pair of codes for mother and infant. The percentage of synchronous behaviors (number of synchronous behaviors divided by the total number of intervals coded, times 100) served as the final measure of behavioral synchrony. The maternal and infant behaviors and their synchronous and asynchronous classifications appear in Appendix A.

Cortisol Collection and Analysis

The experiment was conducted at times when it was most convenient for the mother, although the majority of mothers came to the lab in the morning hours. We used the same sequence of activities as was used in our previous study (see Table 1). Mothers usually drove to the laboratory, during which time infants may have napped. We attempted to control for alertness level by interacting with infants during a 10- to 15-min interval as mothers and infants were "settling in" to the laboratory setting, prior to the videotaped observation period. Saliva samples were collected from the mother and infant twice: at the end of the videotaped observation period (T1) and 20-25 min ($M = 21$ min) after the experiment was initiated (T2). If the mother needed to feed her infant ($n = 3$), we waited at least thirty minutes from feeding to take the first sample (Spangler, 1991). Mothers chewed on a cotton dental roll, the roll was placed in a tube, stored at -20°C , and shipped to Salimetrics, Inc. for radioimmunoassay analysis (Fleming et al., 1997). The roll or braid was applied to the tongue, cheeks and gums of the infant (Lewis & Ramsay, 1995). Duplicate assays were performed at the lab, with an intraassay coefficient of variation of 7.60%. Duplicate samples deviated from each other an average of 0.0011 $\mu\text{g/dl}$.

Results

Infant Cortisol Reactivity, Behavioral Synchrony, and Familiarity Preferences

As in our research with 3-month-old infants (Thompson & Trevathan, 2008), the present study investigated how discrimination processes in 6-month-old infants are affected by short-term changes in cortisol, or cortisol reactivity, from T1 (prior to the face and rhyme preferential looking experiments) to T2 (post-experiments), and by mother-infant behavioral synchrony. We also investigated possible additional correlations between mothers' and infants' T1 and T2 cortisol levels, and between behavioral synchrony and mothers' cortisol reactivity, due to their significance in our previous study.

First, Pearson R tests were conducted to explore relations between study variables (preferential looking at mother's face stimuli during the Face Experiment, preferential looking at the familiar rhyme during the Rhyme Experiment, degree of behavioral synchrony, $\log_{10}$ cortisol values at T1 and T2) and potentially confounding variables (gender, mother's age, ethnicity, education,

and income). Interestingly, the same correlation was obtained in the present study as was obtained in the 3-month-age group (Thompson & Trevathan, 2008): boys' T2 cortisol values tended to be lower than girls' T2 cortisol values ($r(93) = .23, p = .026$). In the present study, boys' cortisol levels at T1 were also lower than girls' ($r(93) = .25, p = .012$).

T1 and T2 cortisol values that were ± 3 SD from the mean for each sample were discarded. This left usable T1 and T2 values for 97 mother-infant pairs, but since there were equipment problems with three of the videotaping sessions of these pairs, 94 full sets of cortisol data with accompanying synchrony data were used in the final analysis (see Table 2). Because the raw cortisol values were not normally distributed, the raw scores were transformed to $\log_{10}$ scores. As in our previous research (Thompson & Trevathan, 2008), we established the $\Delta T1$ -T2 cortisol change category for each mother and infant by determining if the T2 value was 0.5 SD higher (cortisol increased; infant $n = 24$, mother $n = 1$) or 0.5 SD lower (cortisol decreased; infant $n = 15$, mother $n = 11$) than the T1 value. If neither was the case, then $\Delta T1$ -T2 was unchanged for that individual (infant $n = 55$, mother $n = 82$). As in other studies, time of day for saliva collection was not correlated with infant cortisol values (Haley et al., 2006; Ramsay & Lewis, 2003; Thompson & Trevathan, 2008), and was not considered in the preferential looking analyses (p 's $> .05$). However, mothers' T1 cortisol values were significantly higher earlier in the day than later ($r(93) = -.41, p = .0001$), consequently, time of day was used as a covariate in correlational analyses involving mothers' cortisol values.

From the set of 94 mother-infant pairs with usable synchrony and $\Delta T1$ -T2 values for mothers and infants, 17 infants' data were discarded from the Faces Experiment and 19 from the Rhymes Experiment due to fussiness, left or right side biases, or equipment problems.¹ For the Faces Experiment, this resulted in the following numbers of infants in each $\Delta T1$ -T2 change category: cortisol increased, $n = 20$ (13 females, 7 males), cortisol decreased, $n = 14$ (9 females, 5 males), and cortisol no change, $n = 43$ (21 females, 22 males). For the Rhymes Experiment, this resulted in $n = 18$ infants (11 females, 7 males) in the cortisol increased category, $n = 9$ infants (4 females, 5 males) in the cortisol decreased category, and $n = 48$ infants (23 females, 25 males) in the cortisol no change category.

Given that boys' cortisol values were significantly lower than girls at both T1 and T2 in the present study, and also at T2 in our previous study with younger infants (Thompson & Trevathan, 2008), gender was included as a variable in the preferential looking analyses for both experiments. To test whether gender would significantly interact with cortisol change category in the Faces Experiment, a three-way ANOVA was conducted on infants' looking times with gender (2 levels) and cortisol change category (3 levels: increased, decreased, no change) as between-subjects factors and face type (mother nonmodified, mother modified, and other infants' mothers' faces) as a within-subjects factor. Since there was no main effect for gender and gender did not interact with the other variables, results were averaged across gender and separate planned t-tests were conducted on each cortisol change group's data to test the hypotheses.

To test whether infants would look longer at their own mothers' faces (nonmodified versions) as compared to other infants' mothers' faces (three categories of nonmodified versions, averaged), separate one-tailed t-tests were conducted on the difference in infants' looking times across these two categories of faces, for infants who fell into each $\Delta T1$ -T2 cortisol change category separately. Two additional comparisons were of interest. Two-tailed t-tests were also conducted on the difference in average looking times between the infants' own mothers' modified (lengthened and shortened, averaged) and their mothers' nonmodified faces. As a comparison where no difference was expected in looking times across categories, average looking times were compared for the modified and nonmodified versions of the female stimulus seen by every infant (termed the "other female"). Data were averaged across all stimuli in each

face category. Average looking times for each type of stimulus and for infants in each cortisol change category are presented in Figure 2.

In the decreased $\Delta T1-T2$ cortisol group, infants looked significantly longer at their own mothers' faces compared to other infants' mothers' faces ($t(13) = 1.94, p = .038$), but showed no preferential looking between "mother" modified and nonmodified faces, and "other female" modified and nonmodified faces ($p's > .05$). For the no change cortisol category, and for the increased $\Delta T1-T2$ cortisol group, none of the three t-test comparisons reached statistical significance ($p's > .05$).

Behavioral synchrony quartiles were determined from the set of infants with usable preferential looking data in the Faces Experiment. Average looking times for infants in the highest and lowest synchrony quartiles and for the three face categories appear in Figure 3. The same t-tests as described above were conducted separately on the sets of infants from the lowest and highest synchrony quartiles. In the lowest synchrony quartile set ($n = 19$), none of the three t-tests revealed significant differences in looking times ($p's > .05$). However, in the highest synchrony quartile group, infants looked significantly longer at their own mother's faces compared to other infants' mother's faces ($t(17) = 1.72, p = .052$). The comparisons between nonmodified and modified versions of "mother's" and "other female's" faces did not reach significance, however ($p's > .05$).

Preferential looking data for the Rhymes Experiment were first examined to determine if there was a relationship between the number of times mothers reported reading the rhyme to their infant prior to the experiment, and infants' preferences for the familiar rhyme during the experiment. A Pearson R correlation was conducted on these two variables, and no significant correlation was revealed ($r(72) = -.02, p = .88$). Thus, the number of times mothers read the rhyme was not used as a covariate in the subsequent ANOVA. An ANOVA was conducted on the looking time data in the Rhymes Experiment, using gender (2 levels) and cortisol change category (3 levels: increased, decreased, no change) as between-subjects factors and rhyme type (familiar, unfamiliar) as a within-subjects factor. In contrast to the Faces Experiment, a three-way Gender X Rhyme Type X Cortisol Change Category was obtained, $F(2, 69) = 5.20, p = .008$. To test the hypothesis that infants would show preferential looking at the speaker emitting their mother's voice saying the familiar rhyme, as compared to the speaker emitting their own mother's voice saying the unfamiliar rhyme, one-tailed t-tests were conducted on averaged data for stimuli in the two conditions. Hypotheses were tested within each cortisol change category group separately for boys and for girls.

The analyses conducted on the boys' looking data show the following. There were no differences in looking time between familiar and unfamiliar rhymes for male infants in both the unchanged and the decreased $\Delta T1-T2$ cortisol group ($p's > .05$). However, boys in the increased $\Delta T1-T2$ cortisol group showed significantly longer looking at the speaker emitting the familiar rhyme, compared to the unfamiliar rhyme, $t(6) = 6.59, p < .0005$. In contrast, girls in the unchanged and increased $\Delta T1-T2$ cortisol group did not discriminate between rhymes, while the girls in the decreased $\Delta T1-T2$ cortisol group looked significantly longer at the familiar rhyme, $t(3) = 2.72, p = .036$. Boys' and girls' data are plotted in Figure 4. This somewhat unexpected gender difference will be discussed later in the paper.

Finally, as in our previous study with 3-month-old infants and their mothers, preliminary tests were conducted to determine if covariates should be included in correlational tests. Cortisol responses are subject to the Law of Initial Values (LIV; Wilder, 1956), which is the concern that greater increasing $\Delta T1-T2$ cortisol reactivity should occur in a system that is at a lower level of activity at T1 than when the system is at a higher level of activity. Gunnar and White (2001) explain that two conditions must be met before the LIV should be of concern: (a) there

must be a significant difference between cortisol values at T1 and T2, and (b) T1 and T2 values must be significantly positively correlated. Consequently, a test of the correlation between infant $\log_{10}$ T1 and T2 values was conducted. As we found previously this correlation was significant ($r(96) = .69, p < .0001$). However, a matched pairs t-test showed no significant change between infants' $\log_{10}$ T1 and T2 values ($t = -0.51; p > .05$). Thus, infant $\log_{10}$ T1 values were not included as a covariate in the correlation between infant cortisol reactivity and mother-infant behavioral synchrony. However, as in our younger sample, no correlation between mother-infant behavioral synchrony and infant cortisol reactivity was obtained ($p > .05$).

Secondary Analyses

While using time of day for cortisol sampling as a covariate, mothers' initial $\log_{10}$ T1 values were also significantly negatively correlated with mothers' $\log_{10}$ T2 values ($r(93) = -0.82, p < .0001$). Further, mothers' $\log_{10}$ T2 values were significantly lower than their $\log_{10}$ T1 values ($t = -5.68, p < .0001$). Including both mothers' initial $\log_{10}$ T1 values and time of day as covariates, there was no correlation between mother-infant behavioral synchrony and mothers' Δ T1-T2 cortisol reactivity ($r(89) = -0.18, p > .05$). This finding contrasts with our previous study with 3-month-old infants and their first-time mothers, where the correlation was obtained. Interestingly, there was a significant negative correlation between degree of behavioral synchrony exhibited in mother-infant pairs and the number of times mothers spoke the Familiar rhyme to their infants prior to participating in the experimental session ($r(74) = -0.26, p = .028$). Finally, we investigated the relationships between mothers' and infants' cortisol levels at T1 and T2, to assess the extent to which mothers and babies experienced similar levels of stress both before the experiment began, and/or in reaction to the experiment itself. With time of day as a covariate, mothers' and infants' $\log_{10}$ T1 ($r = .08$) cortisol values were unrelated ($p > .05$). Likewise, using time of day and mothers' $\log_{10}$ T1 values as covariates, mothers' and infants' $\log_{10}$ T2 ($r = .04$) cortisol levels were unrelated in our 6-month-old sample ($p > .05$).

Discussion

Cortisol Reactivity and Infant Familiarity Preferences

Consistent with our prediction, 6-month-old infants whose cortisol levels declined from T1 to T2 showed significantly greater looking times to their own mothers' faces compared to other mothers' faces, while infants whose levels remained the same or increased across the interval showed no such discrimination. In addition, girls in the declining cortisol category discriminated between familiar and unfamiliar rhymes spoken by their mothers, while the other two categories of girls did not. Boys, on the other hand, showed a different pattern of results in the Rhyme Experiment—those whose cortisol levels increased discriminated the rhymes while boys in the other two cortisol change categories did not. Our results in the Face Experiment, and the result for girls in the Rhyme Experiment, are consistent with our previous findings obtained with 3-month-old infants (Thompson & Trevathan, 2008). The result for boys in the Rhyme Experiment, however, is consistent with Haley et al.'s (2006) results. While no effects of cortisol reactivity occurred for recognition memory, they showed an effect for long-term memory, in that 3-month-old infants with greater increasing cortisol reactivity were more likely to remember the association between kicking their feet and crib mobile movement one day after they learned it.

Several methodological and statistical factors could reasonably account for these disparate findings across studies, and perhaps across gender in the Rhyme Experiment. First, the results Haley et al. (2006) obtained may hold true only for tests of long-term memory, which our study did not address. Some studies of memory consolidation in adult human populations have also found an association between GCs and enhanced long-term memory (e.g., Buchanan &

Lovullo, 2001; Cahill et al., 2003). Second, infants in our study were tested in a laboratory setting, while infants in the Haley et al. (2006) study were tested at home. Infants in our study were thus exposed to a wider repertoire of new and potentially stressful experiences, perhaps beginning their experimental sessions with higher levels of arousal and emotional stress than they would have at home. Based on the Yerkes-Dodson Law (Yerkes & Dodson, 1908), one might expect that a cortisol decrease from a higher-than-normal baseline level in our study and an increase from a normal baseline in the Haley et al. (2006) study would be associated with better discrimination. The fact that boys in our Rhyme Experiment had lower cortisol levels than girls, and also exhibited a similar relationship to learning as was found in Haley et al.'s (2006) experiment lends credibility to this line of reasoning. Third, the methodological paradigm used by Haley et al. (2006) involved infants making gross motor movements, while infants in our experiments were far less physically active. They simply sat in an infant seat and looked at computer monitors. Physical activity alone is associated with increases in cortisol in both child (e.g., Cielslak, Frost, & Klentrou, 2003) and adult (e.g., Kirschbaum, Wust, & Hellhammer, 1992) populations.

Another big difference across studies to consider is the method for determining the category of cortisol change for an individual. In Haley et al.'s (2006) experiment, any amount of change, no matter how minute, warranted placing an individual into an increasing or decreasing cortisol change category (see also Spangler, Schieche, Ilg, Maier, & Ackermann, 1994). In our study, a conservative change of 0.5 SD $\mu\text{g/dl}$ from the group mean was needed for categorization. We believe that our procedure is preferable, for two reasons. First, variation in cortisol levels across sampling periods should be at least as wide as the coefficient of variation in the assays, in order to ensure that the differences can be safely attributed to physiological and not measuring variability (Gunnar & White, 2001). Our conservative change of 0.5 SD from T1 to T2 was nearly equivalent to the coefficient of variation in the assays obtained in our study samples. Secondly, requiring a 0.5 SD change across sampling periods establishes a third category, specifically, no change in cortisol levels, that can be included in hypothesis testing. No change in cortisol implies a steady state in psychophysiological functioning that may be indicated in situations where discrimination is not happening, while a change in either direction might be associated with discrimination, depending on baseline levels. It is noteworthy that in our study, the number of individuals exhibiting no change in cortisol was always at least twice the number of individuals whose cortisol increased or decreased, thus there was more power to obtain significant differences, yet, the "no change" category has not yielded evidence for discrimination in our experiments. Granted, any interpretation of gender differences in preferential looking associated with cortisol reactivity must be made with caution due to the low sample size in the resulting cortisol change categories.

Recently, Lewis and Ramsay (2005) conducted a study with 6-month-old infants using the still face procedure (e.g., Tronick, et al., 1978), examining the relationship between cortisol response and infant emotional response to goal blockage. Goal blockage was assumed to occur when infants' behavioral responses to their mothers' still faces failed to reestablish interaction with their mothers. Infants displaying anger or neutral responses in their facial expressions to their mothers' still faces did not show increases in cortisol reactivity, however, infants displaying sadness in the still face condition evidenced increases in cortisol reactivity. Could the difference in results between our studies and the Haley et al. (2006) study be related to the specific emotion felt by infants when separated from their mother's attention? Future studies examining these possibilities are called for.

In two studies using similar alterations of photographs of female faces, 5-month-old (Bhatt, et al., 2005) and 7- and 8-month-old infants (Thompson et al., 2001) were able to discriminate between modified and nonmodified versions. Two predictions were made in the present study but were not supported; specifically, infants with declining cortisol, and those whose mothers

were in the highest quartile of behavioral synchrony, would show discrimination between modified and nonmodified versions of their mother's faces. The logic of these predictions is that the ability to discern differences between prototypical and atypical spacings of internal facial features is built upon a foundation of experience encoding spatial metric information from faces seen most often by infants, which in most cases, includes their own mother. And further, those infants who would begin this process earliest would be infants with decreasing stress reactivity and more sensitive mothers. There could be many reasons for failing to find any category of infant able to make this discrimination. One possibility is that the inclusion of the infants' mothers' faces in the repertoire of faces viewed by infants made the task into a "search for mother" task by infants, rather than a more impersonal task of inspecting only strangers' faces. Another possibility is that they were simply too young to reliably show the effect.

Gender Differences in Cortisol Values

In both our 3-month-old sample at T1 (Thompson & Trevathan, 2008), and in this sample of 6-month-old infants at T1 and T2, we found that, although there were no sex differences in cortisol reactivity, boys' cortisol levels were lower than girls'. While sex differences in cortisol reactivity have been reported for both neonates (Davis & Emory, 1995) and adults (Kirschbaum et al., 1992), our finding contrasts with previous reports in the literature of a lack of reported gender differences in cortisol levels in 6-month-old infants (Buss et al., 2003; Haley & Stansbury, 2003). While Haley and Stansbury (2003) reported lower heart rates in 5- and 6-month-old boys than girls, the direction consistent with lower cortisol, they found no gender differences in cortisol. The only gender difference in levels we are aware of was obtained in a study of infants and toddlers in child care settings (Watanura, Donzella, Alwin, & Gunnar, 2003), where girls had slightly higher cortisol values than boys in the afternoon. One possible explanation for these disparate findings could be sample size. For example, our sample size of 94 infants may have achieved enough power to uncover an effect of gender, compared to, for example, Haley and Stansbury's (2003) sample of 43 infants. Their reported post-experiment cortisol value is comparable to those obtained in our studies, however, it is not known whether the direction of the gender differences are the same. While not a particularly noteworthy finding as an isolated effect, as noted above, it should be considered in interpreting gender differences in infant cognition or emotional reactions that could occur in situations of mild stress.

Maternal Sensitivity and Infant Familiarity Preferences

Our results were also in line with our prediction that greater behavioral synchrony between mother and infant would be related to infants' greater looking times at their mothers' faces compared to other female faces. A positive relationship between maternal sensitivity and infant language or cognitive development is predicted by the Feldman's (2007) conceptual framework and has been revealed in several previous studies (Belsky et al., 1996; Farrar et al., 1997; Feldman et al., 1996; Jacobsen et al., 1994; Tamis-LeMonda et al., 2001). What is unique about our findings is that our stimulus set included photographs made from the infants' mothers. Thus, we have contributed results showing that maternal sensitivity, as reflected in higher mother-infant behavioral synchrony scores, impacts infants' cognitive processing of mother-specific face patterns. A more forthright way to put it is that infants whose mothers display less sensitivity pay less attention to their mothers when they are not in their presence.

Why Are Maternal Sensitivity, Infant Cortisol Reactivity, and Mother Cortisol Reactivity Unassociated?

Our motivation for including both a measure of maternal sensitivity and a measure of infant psychophysiological stress response in both of our studies was twofold. We aimed to explore their potential independent effects on infant discrimination, and further, whether maternal

sensitivity and infant psychophysiological responding are correlated with each other. If correlated, this would have justified further exploration into a possible causal link between aspects of parental care that could serve to induce an adrenocortical stress regulation response in infants in new learning situations. Using an even more stress-inducing procedure, Haley and Stansbury (2003) also did not find an association between parent responsiveness to infants in the still face experiment and infant cortisol reactivity. Since they found affect and heart rate were affected by parental responsiveness, a general statement about a lack of relationship between parental sensitivity and infant stress reactivity is unwarranted. Possibly, a causal link may only be uncovered in future research using psychophysiological measures of responses expressed in a targeted region of the infant's body (face, heart) that occur in a very short window of time after the infant has experienced stress-inducing, or pleasant, parenting experiences. Cortisol levels reflect a stressful or arousing experience that occurred approximately 20 minutes previous to saliva collection, and when measured in saliva, reflect the interactive effects of multiple body systems. Taken together, our results reveal that infants' adrenocortical systems are more responsive to the experimental stimulus event itself than to mothers' sensitive caregiving that occurred immediately prior to an experimental event.

Our studies are the first to examine relations between mothers' and infants' cortisol reactivity in the context of infant familiarity preferences. As stated earlier, we predicted further divergence between mothers' and 6-month-old infants' cortisol response patterns than was exhibited by three-month-old infants and their mothers, and this prediction was confirmed given the lack of significant correlations between mothers' and infants' cortisol levels both at T1 and T2 in the present study. There are numerous implications of the results. Tentatively, it can be stated that the developmental pattern shows less mother-infant adrenocortical response similarity between 3- and 6-months of age, a maturational pattern that would be the expected outcome as infants gain increasing psychophysiological independence from their mothers. This conclusion is further supported by the fact that in our previous investigation with 3-month-olds a link between psychophysiological and behavioral aspects of caregiving was found, in that mothers with less cortisol reactivity exhibited higher levels of sensitivity. In other words, caregiving behaviors of first-time mothers of 3-month-old infants were related to their own, but not their infants', adrenocortical activity, and further, no relation between mother's sensitivity and mother's cortisol reactivity was evidenced in first-time mothers of 6-month-old infants. However, continuing research could reveal circumstances or ethnic differences where mothers and infants show more similarity in their psychophysiological responsiveness than we found in our experimental paradigm. For example, mothers and infants living in collectivist cultures, in contrast to the American individualistic culture, may exhibit more concordant adrenocortical activity. We are currently conducting a longitudinal study incorporating the same broad experimental design but using different types of infant cognition measures. It will be interesting to more directly investigate relationships between maternal-infant synchrony, cortisol reactivity, and infant cognition as they unfold in the same set of mother-infant pairs.

In conclusion, the primary contribution of this research is demonstrating that both maternal sensitivity as exhibited in greater levels of mother-infant behavioral synchrony, and changes in infant cortisol levels experienced during stressful or emotionally arousing experiences, are both associated with the 6-month-old infants' ability to discriminate stimuli during preferential looking tasks. For the most part, the results align with our previous findings with a younger age group, and show that greater maternal sensitivity and a pattern of decreasing cortisol reactivity are linked to better cognitive performance. The findings further substantiate the hypothesis of concurrent development of emotional and cognitive processes (e.g., Posner & Rothbart, 2000), given that infants who showed better emotional self-regulation also showed a preference for auditory and visual mother-specific face and voice stimuli. The one instance where increasing cortisol reactivity was associated with better discrimination may be a reflection of the phenomenon sometimes found in young adult cortisol studies, that males may

be more sensitive to cortisol increases than females (Wolf et al., 2001), although, clearly more research needs to be done to understand the mediating factors of baseline cortisol levels and gender.

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Appendix A

Maternal and Infant Behaviors Coded, and Their Inclusion Into Synchronous and Asynchronous Categories (modified only slightly from Isabella and Belsky, 1991)

Maternal behaviors		Infant behaviors	
1. no behavior		A. Sleep/drowsy	
2. leisure activity		B. No behavior	
3. leisure and attend to infant		C. Explore	
4. attend to infant		D. Look at mother	
5. vocalize to infant		E. Vocalize	
6. stimulate/arouse		F. Vocalize and look at mother	
7. stimulate/arouse, and vocalize to infant		G. en face interaction	
8. en face interaction		H. Response/explore	
9. response to infant vocalization		I. Fuss/cry	
10. soothe		J. Response/explore and en face	
11. response to vocalization and soothe			
Synchronous behaviors:		Asynchronous behaviors:	
Infant	Mother:	Infant	Mother
C	8	A	5, 6, 7
E	9, 11	B	5, 6, 7
F	9, 11	C	6, 7
G	5, 6, 7, 8, 9, 10	E	1, 2, 3, 4, 5, 6, 7
H	6, 7, 8, 9, 10, 11	F	1, 2, 3, 4, 5, 6, 7
I	10, 11	I	1, 2, 3, 4, 5, 6, 7, 8, 9
J	9, 10, 11		

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Figure 1.

A photograph of an infant's mother that was used in the experiment (middle photo). The photograph on the left was lengthened, and the photograph on the right was shortened. Color images were shown to infants on computer monitors.

Figure 2.

Average looking times to infants' mothers' nonmodified and mothers' modified faces, and to other female nonmodified faces, for all three cortisol change categories of infants (bars = 1 SE).

Figure 3.
Average looking times to all three categories of faces for infants in the highest and lowest quartiles of behavioral synchrony with their mothers (bars = 1 SE).

Figure 4.

Average looking times to familiar and unfamiliar rhymes spoken by the infants' own mothers, for boys (top graph) and girls (bottom graph) in all three cortisol change categories (bars = 1 SE).

Table 1

Sequence of Events During an Experimental Session

Event	Duration	Events Reflected in Cortisol
Car ride to lab	variable	
Enter lab		
Settling in	10 – 15 min	
Videotaped observation	exactly 10 min	
Total time before T1	20 – 25 min	
T1 saliva sampling		Response to new lab context in presence of mother
Faces Experiment	variable	
Short break	1 - 2 min	
Rhymes Experiment	variable	
Wait	variable	
Total time T1 to T2	20 – 25 min ($M = 21$ min)	
T2 saliva sampling		New learning situation & mother separation

Table 2

Means, Standard Deviations and Ranges of the Cortisol Values of Mothers and Infants

Measure	n (%)	Raw Mean (SD)	Raw Range	Log-Transformed Mean (SD)
Infants				
T1 Cortisol in µg/dl	94 (100)	.24 (.17)	.05 – .96	–.69 (.24)
T2 Cortisol in µg/dl	94 (100)	.25 (.18)	.07 – .93	–.68 (.26)
ΔT1-T2 Cortisol (µg/dl)	94 (100)	.01 (.14)	–.54 – .44	
ΔT1-T2 Cortisol increased	24 (25.5)			
ΔT1-T2 Cortisol decreased	15 (16.0)			
ΔT1-T2 Cortisol no change	55 (58.5)			
Mothers				
T1 Cortisol in µg/dl	94 (100)	.20 (.10)	.05 – .55	–.75 (.21)
T2 Cortisol in µg/dl	94 (100)	.17 (.07)	.05 – .39	–.82 (.19)
ΔT1-T2 Cortisol (µg/dl)	94 (100)	–.03 (.05)	–.18 – .13	
ΔT1-T2 Cortisol increased	1 (1.1)			
ΔT1-T2 Cortisol decreased	11 (11.7)			
ΔT1-T2 Cortisol no change	82 (87.2)			

Note: Cortisol values are presented as raw values and log-transformed to base 10. Statistical analyses were conducted with the transformed data.