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INFANT TEMPERAMENT, MATERNAL EMOTIONAL AVAILABILITY AT BEDTIME, AND INFANT SLEEP FROM 1 TO 6 MONTHS

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ABSTRACT

Infant sleep develops dramatically during the first half year of life, in a dynamic, bidirectional exchange between intrinsic infant characteristics and the caregiving environment. The current study was aimed at examining the relationship between parenting emotional availability (EA) at bedtime, infant temperament, and objectively assessed infant sleep development from 1 to 6 months, as well as how the effect of EA on infant sleep development being moderated by infant temperament. The sample was composed of seventy-one mother and infant dyads, with infant sleep measured by actigraphy at 1, 3, and 6 months, maternal EA coded from bedtime videos at 3 and 6 months, and mothers reporting infants' temperament at 3 and 6 months. Analysis showed marginally significant positive effects of maternal EA at bedtime on developmental changes of infant sleep length. In addition, infant temperamental negative affectivity and surgency moderated EA's impact on infant sleep length development. Results were discussed in terms of the transactional model of infant sleep development, as well as implications for preventions of infant sleep difficulties.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Infant sleep develops dramatically during the first half year of life, manifested by nighttime sleep lengthening and wakings reducing in frequency and duration (Anders & Keener, 1985; Burnham, Goodlin-Jones, Gaylor, & Anders, 2002; Henderson, France, & Blampied, 2011). While infant sleep appears to follow a maturational trend and displays moderate stability over time (Anders & Keener, 1985; Scher, Epstein, & Tirosh, 2004), individual differences in developmental changes of sleep are considerable (Burnham et al., 2002). Drawing from the transactional model of child development (Sameroff, 1989), Sadeh and colleagues proposed that infant sleep develops in a dynamic, bidirectional exchange between intrinsic infant characteristics and the caregiving environment (Sadeh & Anders, 1993; Sadeh, Tikotsky, & Scher, 2010). However, most studies to date have examined parenting practices and infant characteristics in relation to infant sleep either separately or additively, and no study has examined the relationship between parenting emotional availability at bedtime and objectively assessed infant sleep. The present study investigates the influences of bedtime maternal emotional availability and infant temperament as well as their interactive effects on the developmental changes of infant sleep, assessed objectively, from 1 to 6 months of life.

Parenting and Infant Sleep

Parent-child interactive context and intrinsic infant factors are directly associated with infant sleep development, according to the transactional model of infant sleep (Sadeh & Anders, 1993; Sadeh et al., 2010). Parent-infant bedtime interaction is probably most consistently and immediately associated with the origins of infant sleep (Mindell, Sadeh, Kohyama, & How, 2010; Sadeh & Anders, 1993; Sadeh et al., 2010). For example, the presence of parents while infants were falling asleep, high level of parental involvement, shorter parental response time to infant awakenings, and active soothing at bedtime by parents have been related to more frequent infant night wakings (Adair, Bauchner, Philipp, Levenson, & Zuckerman, 1991; Burnham et al., 2002; Johnson, 1991; for review, see Sadeh, Tikotzky, & Scher, 2010). Interventions that instituted a consistent bedtime routine (Mindell et al., 2007; Mindell, Telofski, Wiegand, & Kurtz, 2009) and promoted infant self-regulating by increasing parents' response latency to infant nighttime signals over time (Wolfson, Lacks, & Futterman, 1992) have also been shown to reduce parent-reported frequency of night wakings of infants and toddlers.

Compared to parenting practices, less attention has been paid to the emotional quality of bedtime parenting in relation to infant sleep (Sadeh et al., 2010). Some studies have shown that sensitive daytime mother-infant interactions (Priddis, 2009) and less dyadic tension in the feeding context (Minde, Faucon, & Falkner, 1994) were associated with better quality of infant sleep. Very few studies have specifically examined parenting emotional quality in the framework of emotional availability (EA) in relation to infant sleep. The present study examines maternal EA at bedtime, making use of Biringen's (2000) conceptual EA framework. This framework integrates an attachment perspective, which emphasizes parental sensitivity and their functioning as secure base, and an emotional availability perspective, which emphasizes affective attunement and emotional communication within the parent-child dyad. The EA framework is dyadic and considers the emotional quality of both the parent and the child. Parental EA takes into consideration the appropriateness of parental understanding of the child's signaling as well as parental emotional signaling, and incorporates such dimensions as sensitivity, supportive structuring, and being nonintrusive and non-hostile in parent-child interactions. Parental EA is predictive of child-parent attachment and many aspects of children's socioemotional and cognitive development (Biringen, 2000; Biringen et al., 2005; Dries, Juffer, van IJzendoorn, Bakermans-Kranenburg, & Alink, 2012; Easterbrooks, Bureau, & Lyons-Ruth, 2012; Kertes et al., 2009; Volling, McElwain, Notaro, & Herrera, 2002). The EA framework also incorporates child EA, which reflects the child's affective quality and secure base behavior in dyadic interactions, and consists of dimensions of child responsiveness to and involvement with the parent (Biringen, 2000).

Only two studies, to the author's knowledge, have examined emotional availability in relation to infant sleep. Scher (2001) examined daytime EA during mother-infant interactions and infant sleep in a community sample, finding that infants' EA (responsiveness and involvement) in daytime play, but not maternal sensitivity, was positively associated with infant sleep interruptions assessed by actigraphy at 12 month. Teti, Kim, Mayer, and Countermine (2010) conducted the only study to date that has examined maternal EA at bedtime relating to infant sleep. They found that observed bedtime maternal EA, but not specific parenting practices, was predictive of fewer sleep disruptions as reported by mothers. Interpreted from an evolutionary perspective, Teti et al. (2010) hypothesized that maternal emotional availability at bedtime promotes infants' feelings of security and trust in their sleep environment, which in turn help them adapt to the longest and most challenging daily separation from their attachment figures. Despite its meaningful finding, however, this study only used mothers' report of infant sleep but not objective measures of infant sleep, and had a relatively small (n = 45) cross-sectional sample of families with infants ranging from 1 to 24 months. Therefore, it is necessary to conduct research of bedtime EA's effect on infant sleep that makes use of objective assessments of infant sleep. Indeed, such assessments can capture infant sleep-wake patterns more comprehensively than parental report, whereas parental report could only capture infant night wakings with signaling that parents were able to notice, not to mention that different parents may have different notions about what constitutes a night waking (Anders & Keener, 1985; Anders, Keener, Bower, & Shoaff, 1983; Scher et al., 1992).

Infant Temperament and Infant Sleep

Besides the impact of parenting, the development of infant sleep is likely influenced by infant intrinsic characteristics, such as temperament, maturation, and other biomedical factors (Sadeh & Anders, 1993; Sadeh et al, 2010). Infant sleep typically goes through major developmental changes during the first six months of life, including consolidation of sleep episodes, lengthening of nighttime sleep, and reducing of night wakings (Anders & Keener, 1985; Burnham, Goodlin-Jones, Gaylor, & Anders, 2002; Henderson, France, & Blampied, 2011). Because infant sleep is moderately stable over time (Anders & Keener, 1985; Scher, Epstein, & Tirosh, 2004), the current study controlled for infant sleep at one month to tease out the variance of sleep development explained by baseline levels of sleep maturation.

In addition to maturation, infant temperament is another important intrinsic factor that has been identified as a predictor of infant sleep patterns (e.g., Carey, 1974; Schaefer, 1990; Ednick et al., 2009; Scher, Epstein, Sadeh, Tirosh, & Lavie, 1992; Spruyt et al., 2008; Weissbluth, 1981). Temperament has been variously conceptualized and defined (Buss & Plomin, 1984; Chess & Thomas, 1984; Goldsmith & Campos, 1982; Rothbart & Derryberry, 1981; Rothbart & Bates, 1998), with some attempts to integrate the various perspectives into some common dimensions (e.g., Goldsmith et al., 1987; Shiner et al., 2012). A recent, integrative conceptualization, summarizing different approaches of temperament research, describes temperament as "emerging basic dispositions in the domains of activity, affectivity, attention, and self-regulation", a product of the interactions of genetic, biological, and experiential factors across development (Shiner et al., 2012). The current study follows

Rothbart's conceptualization of temperament, because it emphasizes the hierarchical structure of temperament and has a relatively broad inclusion of temperament factors (Shiner et al., 2012). Rothbart defines temperament as "constitutionally based individual differences in reactivity and self-regulation, in the domains of affect, activity, and attention" (Rothbart & Bates, 1998, p. 100). Infant sleep and infant temperament may thus share a common biological foundation, likely including the organization of infant neural system (Anders & Keener, 1985) especially prefrontal cortex (PFC) (Dahl, 1996). Supporting evidence for this shared biological basis of sleep and temperament is that cardiac functioning, only as assessed during infant sleep at 2 weeks and 2 months of age, but not assessed in daytime, could differentiate later infant temperament (Snidman, Kagan, Riordan, & Shannon, 1995).

Early studies relating infant sleep and temperament used parental reports for both. One of the first studies was conducted by Carey (1974), who found that infants who woke up frequently during the night were more likely to be perceived as having a low sensory threshold. Later studies have found that the temperament dimension of "approach" (positive emotion and quick approach toward pleasurable stimuli; Garstein & Rothbart, 2003) was associated with longer night sleep, earlier sleep onset and ending time, and fewer sleep interruptions for infants and toddlers, while negative mood, slow adaptation, and high distractibility were associated with shorter sleep duration (Kelmanson, 2004; Scher et al., 1992; Weissbluth, 1981). Also, rhythmic infants were found more likely to be ready for bedtime and sleep longer (Kelmanson, 2004). In general, "easy" infants (infant characterized by positive mood, high approach, and good regulatory capacity) were found to sleep longer at night or less likely to have sleep problems than "difficult" infants (infants characterized by negative mood, high withdrawal, and poor regulatory capacity) (Atkinson, Vetere, & Grayson, 1995; Minde et al., 1993; Schaefer, 1990; Weissbluth, 1981).

Later, researchers examined associations between infant temperament and infant sleep using more objective assessments of sleep, such as time-lapse video recordings (e.g., Keener, Zeanah, & Anders, 1988) and actigraphy (e.g., Sadeh, Lavie, & Scher, 1994; Scher, Tirosh, & Lavie, 1998; Spruyt et al., 2008). Similar to what was found with maternal reports of both infant sleep and temperament, young children with "easy" temperament had longer sleep duration or better sleep quality, compared with "difficult" infants (Spruyt et al., 2008). Specifically, infants with more positive moods were found to go to bed earlier and have longer sleep duration (Scher, Tirosh, & Lavie, 1998); infants and toddlers who were high in approach were found to sleep earlier or longer at night than the more withdrawn ones (Scher et al., 1992; Spruyt et al., 2008; Halpern et al., 1994); and infants with high sociability, which means seeking and showing pleasure in social interactions, had lower percentages of night waking (Halpern et al., 1994). The above dimensions, though not being the exact dimensions defined by Rothbart and colleagues, appear to map straightforwardly onto Rothbart's conception of the overarching temperament dimension of Positive Affectivity/Surgency (Garstein & Rothbart, 2003), which describes infants who are emotionally positive, physically and verbally active, and easily excited by novel or social stimuli and likely to approach them. However, toddlers who were low on sensory threshold, a dimension similar to perceptual sensitivity under the superfactor of surgency, were shown to display frequent night wakings (Sadeh et al., 1994), similar to the finding of Carey (1974). Therefore, it is still unclear how infant surgency is associated with length and quality of infant sleep.

Besides these dimensions, other studies showed that irritability and inhibition were associated with more awakenings at night (Halpern et al., 1994), and higher infant negative mood was associated with longer diurnal sleep duration (Spruyt et al., 2008). These dimensions appear to map onto Rothbart's dimension of temperamental Negative Affectivity (Garstein & Rothbart, 2003), which describes infants who are often sad, fearful, withdrawn, easily frustrated due to limitations, and difficult to recover from stress. Therefore it is possible that negative affectivity would be associated with poorer infant sleep. In addition, previous research also found that lower infant distractibility was associated with longer 24-hour sleep duration (Spruyt et al., 2008); higher persistence in infants and toddlers was associated with longer 24-hour sleep duration (Spruyt et al., 2008) or better sleep efficiency (Scher et al., 1992); higher soothability was related to longer sleep at night; higher rhythmicity was associated with earlier sleep onset and longer sleep, but also a tendency to sleep less efficiently (Scher et al., 1998); and poor adaptability in toddlers was associated with frequent night wakings (Sadeh et al., 1994). These temperamental factors seem fit within Rothbart's temperament dimension of Orienting/Regulation (Garstein & Rothbart, 2003), which includes the degree to which the infant can focus for a long duration, can enjoy low-intensity pleasure, and can be easily soothed. Thus, these studies suggest that attention/regulation could be related to longer and better infant sleep. These patterns of associations between infant sleep and Rothbart's overarching temperament dimensions, i.e., surgency, negative affectivity, and orienting/regulation, will be explored in the present study.

It should be noted, however, that although associations between temperament and sleep-wake organization have emerged, these associations are weak, especially among non-clinical samples (Halpern et al., 1994; Scher et al., 1998; Van Tassel, 1985). In addition, many of these studies had a small sample size ($n \leq 31$ in the studies by Halpern et al., 1994, Keener et al., 1988, Scher et al., 1992, Scher et al., 1998, and Spruyt et al., 2008; except for that $n = 63$ for Sadeh et al., 1994), which weakened the replicability of the findings and necessitates further research. The modest associations of infant temperament and infant sleep support Sadeh et al.'s (2010) premise that infant sleep is multiply and complexly determined.

Temperament as a Potential Moderator in the Relation of Parenting and Infant Sleep

Rothbart and Bates (2006) proposed that temperament, as a constitutionally based construct, can serve as a potential moderator of socialization experience (Rothbart & Bates, 2006). Indeed, a basic premise in theories of temperament is that children with different temperamental profiles may be differentially sensitive to different types of parenting (Sanson & Rothbart, 1995). Specifically, according to the theory of behavioral activation system (BAS) and behavioral inhibition system (BIS) (Gray, 1991), children with high approach and positive affect are more sensitive to reward, while children with high inhibition and fearfulness are more sensitive to punishment. Consistent with this model, Kochanska (1993, 1997) found that for children differing in fearfulness or inhibition-approach, different socialization strategies are conducive to internalization: gentle discipline that capitalizes on the internal anxiety in fearful children can better foster their compliance, while parental responsiveness and warmth that capitalize on children's positive motivation to accept parental values are especially effective for surgent children. Further, Cipriano and Stifter (2010) found that exuberant toddlers developed better effortful control if their parents used more command/prohibitive statements characterized by positive emotional tone; inhibited toddlers developed better effortful control if parents used more neutral redirection/reason, but the same parenting behavior led to worse effortful control development for exuberant toddlers. The sleep regulatory system overlaps with affect and attention regulatory system in psychophysiological and developmental domains (Dahl, 1996). However, it is unknown whether the patterns of temperamental sensitivity to parenting influences would be similar between the development of sleep and effortful control, such that children with different temperamental characteristics would be differentially responsive to certain dimensions of parenting in terms of sleep development.

Several theoretical models exist that inform hypotheses about temperament as a moderator of the influence of experience (Belsky & Pluess, 2009; Boyce & Ellis, 2005; Monroe & Simons, 1991; Wachs, 1987). Two in particular are germane to the present study. The *diathesis-stress model* proposes that individuals with highly reactive temperamental profiles will be more vulnerable than individuals with less reactive profiles to negative environmental influences (e.g., Monroe & Simons, 1991). The *differential susceptibility hypothesis* expands upon the diathesis-stress model and proposes that temperamentally highly reactive individuals will not only be strongly and detrimentally affected by negative environmental influences but, for the same reason, be strongly and positively affected by favorable environmental influences. In terms of specific temperament factors, negative emotionality has been identified by many studies as either a marker of vulnerability or plasticity in response to rearing influences (for review, see Belsky & Pluess, 2009). Some studies have also shown that exuberance (a combination of high approach and high positive affect, both components of Rothbart's superordinate factor of surgency) and effortful control (including attentional focusing and inhibitory control of behavior) serve as moderators of parenting effects on child socioemotional development and behavior problems (e.g., Cipriano & Stifter, 2010; Lengua, Bush, Long, Kovacs, & Trancik, 2008; Morris et al., 2002; for review, see Kiff, Lengua, and Zalewski, 2011, and Rothbart and Bates, 2006).

Although there have been many studies demonstrating that child characteristics moderate parenting's effects on child socioemotional and cognitive development, there has been no study, to the best of this author's knowledge, investigating the moderating role of infant temperament in the relation between parenting quality and infant sleep development. Such a study is overdue. Infant sleep goes through the most remarkable changes during the first half year of infants' life, with the percentage of infants sleeping through the night rising from over 10%-19% to 67%-84% (Henderson et al., 2011). Rates of sleep maturation, however, are not uniform, as indicated in these studies, which could be related to differences in parenting quality (especially at bedtime), infant temperamental profiles, and their interaction. The current study focuses on the role of infant temperament as a potential moderator of linkages between bedtime parenting emotional availability and objectively assessed infant sleep as it develops from 1 to 6 months of age. The following hypotheses were proposed:

Hypothesis 1: Higher observed maternal bedtime parenting EA would predict increased sleep length and sleep quality from 1 to 6 months above and beyond the effect of maturation.

Hypothesis 2: Infant temperament would predict infant sleep developmental changes from 1 to 6 months. Specifically, we expect that higher negative emotionality would predict decreased sleep length and sleep quality based on previous research (Atkinson et al., 1995; Halpern et al., 1994; Minde et al., 1993; Schaefer, 1990; Weissbluth, 1981). Less clear were predictions linking surgency to infant sleep. Prior work has demonstrated that temperamental components that relate to surgency (positive mood, sociability, and approach) are associated with better infant and toddler sleep. However, highly surgent children, who are also high in perceptual sensitivity in Rothbart's model (Garstein & Rothbart, 2003), are by definition more reactive than children low in surgency , and how this might relate to sleep quality was unclear. Thus, hypotheses regarding surgency's link with the development of infant sleep length and quality were withheld. In addition, based on theory which hypothesizes the overlapping of regulatory systems of sleep, affect, and attention (Dahl, 1996), as well as prior research results (e.g., Carey, 1974; Sadeh et al., 1994; Scher et al., 1992; Spruyt et al., 2008), better orientating/regulation is expected to predict increased sleep length and sleep quality.

Hypothesis 3: Links between bedtime maternal EA and the developmental changes of infant sleep would be moderated by infant temperament. The following interaction pattern, if emerging, would be compatible with the *diathesis-stress model*: for infants with high reactivity (either high negative emotionality or high surgency) or poor regulatory capacity, low maternal EA at bedtime would predict decreased infant sleep length and quality from 1 to 6 months; for infants with low reactivity or high regulatory capacity, the link between low maternal EA at bedtime and decreased infant sleep length and quality would not exist or be weaker. The following interaction pattern, if emerging, would be compatible with the *differential susceptibility hypothesis*: low bedtime maternal EA would lead to decreased infant sleep length and quality for infants with high reactivity (either high negative emotionality or high surgency) or poor regulatory capacity compared with infants with low reactivity or high regulatory capacity; high maternal EA would lead to better sleep for infants with high reactivity or poor regulatory capacity compared with infants with low reactivity or high regulatory capacity.

METHODS

Participants

Data were drawn from an ongoing longitudinal study of parenting, infant sleep, and infant development, Project SIESTA II (Study of Infants' Emergent Sleep TrAjectories II). 167 families from central Pennsylvania were recruited through local hospitals when mothers were pregnant. Infants and both parents participated in the study when infants were one month old until they were 24 months.

For the current study, all the families that had complete data on the Infant Behavior Questionnaire-Revised (IBQ-R, Gartstein & Rothbart, 2003) and maternal EA at bedtime at both 3 and 6 months and infant sleep actigraphy at both 1 and 6 months were included. One hundred and fifty-four families at 1 month and 143 families at 6 months had infant sleep data assessed by AW-64 actiwatches (Respironics, Inc.). One hundred and six families at 3 months and 105 families at 6 months had bedtime maternal EA scores (reasons for the smaller sample size with available EA scores include families dropping the study, skipping a visit, requesting no video, no video set up due to family emergency, families forgetting to turn on the video camera, baby having falling asleep before the camera was turned on, technical problems, infant sickness, and bedtime videos being too short (shorter than 2 minutes) to code for maternal EA). One hundred and fifty-one families at 3 months and 149 families at 6 months had infant temperament scores by completing the Infant Behavior Questionnaire-Revised (IBQ-R, Gartstein & Rothbart, 2003).

Seventy-one families comprised the final study sample. These were families with complete data for actigraphy, bedtime maternal EA, and infant temperament at each time points. Eighty-seven percent of mothers in the study sample were European American, 4% African American (three mothers), 3% Asian American (two mothers), 1% Latino (one mother), and 4%

other ethnic group (three mothers). Eighty-seven percent of the mothers were married and living with partner at 1 month. Mothers' age ranged from 19 to 41 (*M* = 29.5, *SD* = 5.2). Seventy-nine percent of mothers completed college education or more. Fifty-one percent of mothers were employed at one month. Family annual income ranged from $10,000 to $300,000 (*M* = $73,940, *SD* = $55,546).

Procedures

Families in the larger study were visited at home when the children were 1, 3, 6, 9, 12, 18, and 24 months. At each data collection point, they were visited three times during one full week. Bedtime parenting videos were usually taken on the first night of each week via the cameras set up where babies typically spent bedtime and nighttime. Infant wore the actiwatch on their calves for seven consecutive days at each time point to record their sleep and waking activity. Mothers filled out questionnaires regarding infant temperament at each time point beginning at 3 months, because some temperament dimensions, especially positive emotions, become observable reliably after this time point. For the current study, only data at 1, 3, and 6 months were used.

Measures and Coding

Demographical data. Parents filled out demographical questionnaires at the first visit when infants were 1 month. Information regarding the infant's day of birth, gender, parental age, education, employment, family annual income, ethnicity, number of siblings, etc. was obtained through this questionnaire.

Infant sleep. Infant sleep length and quality were measured objectively by actigraphy, with infants wearing the Mini-Mitter Actigraphy wristwatches (Model AW-64) on their calves throughout the home visit week. This device recorded infant physical activity level, from which information regarding infant sleep and awakenings was derived. After the visit, the recordings from Actigraphy were downloaded onto the project computer and read by the software Actiware version 5.59. Summary scores of infant sleep were calculated by averaging sleep data across the seven days to provide relatively more reliable sleep data than single-day scores. Four sleep indices in current analysis were used to reflect two distinct characteristics of sleep: quantity and quality (Pilcher, Ginter, & Sadowsky, 1997): average infant nocturnal *sleep duration* (the total minutes between sleep onset and final wakeup) and average infant nocturnal *sleep minutes* (total duration of infant sleep subtracted by infant awake minutes between sleep onset and final wakeup) were indices for infant sleep length (quantity), while average infant *sleep fragmentation* (sleep fragmentation = the sum of percent mobile and percent immobile bouts less than 1-minute duration to the number of immobile bouts) and average *number of wake bouts* at night were indices for infant sleep quality.

Infant temperament. Measures of temperament at 3 and 6 months were based on mother-report on the Infant Behavior Questionnaire-Revised (IBQ-R, Gartstein & Rothbart, 2003), the revised version of one of the mostly widely used measurement of infant temperament, Infant Behavior Questionnaire (IBQ; Rothbart, 1981). The IBQ-R is a 191-item, comprehensive measure of infant temperament designed for use with infants under 12 months, yielding three broad-band factors of Surgency/Extraversion, Negative Affectivity, and Orienting/Regulation. The three superfactors were used as summary scores, calculated by averaging scores of primary loading scales, according to Gartstein and Rothbart (2003). The superfactor Negative Affectivity was an average score of subscales of Sadness, Distress to Limitations, Fear, and reverse-scored Rate of Recovery. The superfactor Surgency/Extraversion was the average of subscales of Approach, Vocal Reactivity, High Intensity Pleasure, Smiling and Laughter, Activity Level, and

Perceptual Sensitivity. The superfactor Orienting/Regulation was the average of subscales of Low Intensity Pleasure, Cuddliness/Affiliation, Duration of Orienting, and Soothability. IBQ-R has established good internal consistency and inter-parent agreement, as well as convergent validity with behavioral measurements of temperament (Gartstein & Rothbart, 2003; Parade, & Leerkes, 2008).

Maternal Emotional Availability (EA). Video and audio equipment was set up in the participant families' homes where bedtime and infant sleep usually took place, based on parental input. In most homes, two to four cameras were set up to capture the interaction between parent and infant during bedtime and nighttime. A Bosch Divar XF 8-Channel Digital Versatile Recorder was used for video and audio recording. Infrared security cameras by ARM Electronics (Model No. C420BCVFIR) were used to collect video information. Channel Vision microphones (Model No. 5104-MIC) were used to collect audio information. At least one camera was set up above the infant's crib or bed where infant sleep took place. Other cameras were usually set up to capture the infant's changing table, the chair where parent fed infant, or an overview of the infant's room, according to the information that parents provided to the project staff about the locations of infant's bedtime and nighttime activities. Parents were instructed to turn on the camera about one hour before the bedtime began and turn off the camera after the infant woke up in the morning, thus providing relatively complete recordings of bedtime and nighttime activities centered on the infant.

The current study coded mothers' EA during bedtime using the Emotional Availability Scales (EAS; Biringen, Robinson, & Emde, 1998), a measure aimed at capturing the emotional quality of parenting in parent-child dyadic interactions. There are four subscales in the EAS for assessing parental EA: *sensitivity* (parent's capacity to be aware of, interpret accurately, and give contingent and appropriate responses to child's signals), *structuring* (parent's capacity to support and scaffold child's activities while following child's needs), *nonintrusiveness* (parent's capacity to not be overprotective or interfering in the parent-child interaction), and *nonhostility* (parent's capacity to interact with the child in a patient and peaceful way without anger and irritability). Although the EAS also includes two subscales that assess the child's emotional availability, i.e., responsiveness (the child's ability to positively respond to the mother's bids for interaction) and involvement (the child's ability to initiate and involve the parent in interactions in a non-urgent way), they are not included in the present study, because the behavioral repertoire of infants from 3 to 6 months is too limited for the coders to reliably code EA from. Bedtime videos that were shorter than two minutes were determined by the coders as being too brief to provide sufficient information about parenting emotional quality, so videos equal to or longer than two minutes were coded for EA.

Since bedtime is not the context in which the EAS system was originally developed, the current study used the EA coding system adapted to the bedtime context in our pilot study (Teti et al., 2010). Maternal sensitivity was rated high when the mother detected immediately, interpreted accurately, and responded promptly and appropriately to the infant's signals. Maternal structuring was rated high when the mother engaged the infant in bedtime routine in a quiet, soothing, and organized way that gently induced the infant to sleep. Maternal nonintrusiveness was rated high when the mother did not initiate arousing activities with the baby or other family members which would go against the goal of putting the infant to sleep. Maternal nonhostility was rated high when the mother did not display covert or overt impatience, frustration, or anger during the whole bedtime.

The main coder and the principal investigator of the larger study were trained and certified on EAS (3rd edition; Biringen et al., 1998). The interrator reliability was established between them, with intraclass correlations for absolute agreement for bedtime maternal sensitivity, structuring, nonintrusiveness, and nonhostility at 3 and 6 month ranging from .87 to .99, based on 10% of the sample.

Data Analytic Plan

A series of hierarchical multiple regressions was carried out to predict infant total sleep duration, sleep minutes, sleep fragmentation, and number of wake bouts from 1 to 6 month. Because temperament superfactors were highly correlated between 3 and 6 month time points (see Table 2), and also because aggregated scores may reflect infant temperament more reliably, temperament scores at 3 and 6 months were each converted to z-scores, and then averaged across the two age points to create composite infant temperament scores. Bedtime maternal EA scores at each age point were calculated by first creating the z-scores of the four subscales (sensitivity, structuring, non-intrusiveness, and non-hostility), and then adding them to form a composite EA score for each mother. Based on similar rationale to that for creating composite temperament scores, EA scores at 3 and 6 months were z-scored respectively, and then averaged across the two age points. In order to create interaction terms of temperament and EA, standardized 3-and-6-month temperament scores were multiplied by standardized 3-and-6-month EA scores. Thus the composite 3-and-6-month temperament scores and the composite 3-and-6-month bedtime EA scores, as well as their interactions, served as predictors. As for control variables, since there appeared to be gender differences in some aspects of infant sleep, such as sleep state transitions and efficiency in previous research (Scher et al., 2004), and sleep minutes, sleep fragmentation, and number of wake bouts in the current study (see Table 2), infant gender was statistically controlled. Also controlled were 1-month sleep variables which corresponded to the outcome variables at 6 month. These 1-month sleep variables served as baseline levels, so the analysis will focus on residualized gain scores of infant sleep from 1 to 6 month (how an infant's sleep changed from 1 to 6 months relative to group-level trends of change as predicted by 1-month sleep), rather than raw change scores.

For each regression, infant gender and the 1-month sleep variable corresponding to the 6-month sleep outcome were entered in step 1. Maternal EA at bedtime and all three temperament superfactors were entered in step 2. The three interaction terms of EA multiplied by each temperament superfactor were entered in step 3. If a superfactor, or its interaction with EA, turned out statistically significant, in order to understand which specific temperament dimensions underlying the superfactor are relevant, all the sub-dimensions within that superfactor would be subject to individual multiple regressions. These regressions would use one of the sub-dimensions, EA, and their interaction terms, along with other two temperament superfactors and interaction terms, to predict infant sleep, in the same way as the analysis with the superfactor.

Apart from using the original temperament measure for the analysis, it should be noted that the IBQ-R contains some items directly assessing infant sleep. For instance, item 12 (included in the Activity subscale) asked "during sleep, how often did the baby toss about in the crib", and item 15 (included in the Distress to Limit subscale) asked "after sleeping, how often did the baby fuss or cry immediately". In order to avoid using temperament items which are indeed "sleep items" to predict sleep outcomes, these items were excluded and temperament scores were recalculated. IBQ-R items No.11 to 31 were identified as directly assessing infant sleep and would be excluded from this set of analysis. Four subscales, i.e., Activity Level, Distress to Limit, Rate of Recovery, Sadness, and two superfactors, i.e., Surgency and Negative

Affectivity, contain sleep items and therefore will be recalculated. A set of multiple regressions was rerun using these recalculated scales to ensure any result based on temperament scores derived from the original IBQ-R scale was not biased due to the inclusion of sleep-related items.

RESULTS

The descriptives for infant sleep variables from 1 to 6 months, maternal emotional availability at bedtime, and infant temperament are listed in Table 1. Repeated measures analysis of variance demonstrated that all the infant sleep variables changed significantly over time, according to multivariate test's Wilk's Lamda and univariate tests of within-subjects effects (Table 1). Post-hoc (Bonferroni) comparisons showed that, for the current sample, infant sleep duration and sleep minutes grew longer from 1 to 3 months (ps < .05) and from 3 to 6 months (ps < .001), infant sleep became less fragmented from 1 to 3 months ($p < .001$) and from 3 to 6 months ($p < .001$), while infant's number of wake bouts did not change between 1 and 3 months ($p = 1.00$) but decreased significantly from 3 to 6 months ($p < .01$).

The intercorrelations between infant gender, infant temperament, maternal EA at bedtime, and infant sleep variables are listed in Table 2. In terms of variable stability, three superfactors of infant temperament had strong to very strong stability from 3 to 6 months (rs = .61 ~. 85, ps < .005), and so did maternal EA at bedtime ($r = .63$, $p < .005$). Therefore the average scores of each of these variables across 3 and 6 months were used as predictors. Sleep variables were modestly correlated from 1 month to 6 months (rs = .21 ~. 30, p < .10 or .05) except number of wake bouts ($r = .00$, $p = 1.00$). In terms of correlations between the control variable, predictors, and outcome variables, infant gender (1 = male, 2 = female) was modestly correlated with 6-month infant sleep variables ($r = .32$ for sleep minutes, $r = -.31$ for sleep fragmentation, $r = -.33$ for number of wake bouts, ps < .01), indicating that female infants tended to have longer sleep minutes, slept less fragmentedly, and woke up less frequently at 6 months than male infants. Infant temperament factors were not correlated with infant sleep at 6 months, while higher 3-month surgency was correlated with shorter 1-month sleep minutes (r = -.34, p < .005) and lower sleep fragmentation (r = -.24, p < .05), and higher 6-month surgency was correlated with more 1-month wake bouts (r = -.28, p < .05). Three-month maternal EA at bedtime was positively correlated with 6-month infant sleep duration (r = .25, p < .05).

After preliminary correlational analysis, hierarchical multiple regression analysis (see Table 3) was conducted to test the hypotheses regarding main effects of maternal EA at bedtime and infant temperament on developmental changes of infant sleep from 1 to 6 months, as well as how the effect of maternal EA at bedtime might be moderated by infant temperament.

Infant gender and the 1-month sleep variable corresponding to each 6-month outcome sleep variable were entered in the first block as controls, and they explained significant portions of variance in outcome variables. Specifically, female infants tended to have longer sleep minutes, sleep in a less fragmented fashion, and wake up less frequently than male infants (β = .32, -.33, -33, p < .01). Levels of 1-month sleep duration, sleep minutes, and sleep fragmentation all were positively associated with 6-month sleep variables respectively (β = .24 ~ .35, p < .05 except for number of wake bouts. These controls remained the same significance pattern after maternal EA at bedtime, temperament superfactors, and their interaction terms were entered into the regressions in later steps.

Hypothesis 1: Higher Observed Maternal Bedtime EA Would Predict Increased Sleep Length and Sleep Quality From 1 to 6 Months.

Before interaction terms were entered into regressions, higher 3-and-6-month bedtime maternal EA composite scores marginally predicted longer 6-month infant sleep duration and sleep minutes ($\beta = .25$, $p = .07$; $\beta = .22$, $p = .08$) (see step 2 in Table 3) above and beyond the influences of 1-month infant sleep baseline levels and infant gender. In order to understand the specific dimensions (sensitivity, structuring, nonhostility, and nonintrusitiveness) under the EA umbrella that were contributing to EA's effects, regressions were conducted with EA replaced by one of the four EA sub-dimensions each time (the sub-dimensions were not entered in the same equation to avoid high collinearity). It was found that higher structuring significantly ($\beta = .27$, $p < .05$), and sensitivity and non-hostility marginally significantly ($\beta = .24$, $\beta = .23$, *p*s < .10) predicted increased infant sleep duration from 1 to 6 months, and that higher non-hostility significantly predicted increased infant sleep minutes ($\beta = .26$, $p < .05$).

However, after interaction terms of EA and temperament were entered, the main effects of EA on the two indicators of sleep length were no longer significant ($\beta = .01$, *ns*; $\beta = .04$, *ns*) (see step 3 in Table 3). In addition, maternal EA at bedtime did not predict changes of infant sleep fragmentation and number of wake bouts from 1 to 6 months, regardless of the entering of interaction terms.

Hypothesis 2: Infant Temperament Would Predict Infant Sleep Development From 1 to 6 Months.

Except for the finding that infant 3-and-6-month orientating/regulation marginally and positively predicted the change of infant sleep duration from 1 to 6 months ($\beta = .33$, $p = .06$) after interaction terms were entered in the regression, none of 3-and-6 month infant temperament superfactors predicted the changes of infant sleep length or quality from 1 to 6 months.

Hypothesis 3: The Links Between Bedtime Maternal EA and Developmental Changes of Infant Sleep Will Be Moderated by Infant Temperament.

Results of multiple regression analyses showed that the interaction between maternal EA at bedtime and surgency, as well as the interaction of EA and negative affectivity, significantly predicted changes of infant sleep duration (EA×surgency: $\beta = .50$, $p < .01$; EA× negative affectivity: $\beta = -.39$, $p < .005$) and sleep minutes (EA×surgency: $\beta = .38$, $p < .05$; EA× negative affectivity: $\beta = -.26$, $p < .05$) from 1 to 6 months, but not sleep fragmentation or number of wake bouts. Simple slope tests were conducted to follow up on these interactions (Aiken & West, 1991).

Predicting Developmental Changes of Infant Sleep Duration From 1 to 6 Months (see Figure 1)

For highly surgent infants, higher maternal EA at bedtime predicted increased sleep duration with a significant slope ($B = 23.77$, $t(71) = 3.09$, $p < .005$); for less surgent infants, maternal EA at bedtime did not influence the development of sleep duration ($B = -23.20$, $t(71) = -1.56$, *ns*). Post-hoc comparisons of endpoint values of the slopes (denoting the sleep durations for infants who were ±1 standard deviation on surgency scores and whose mothers were ±1 standard deviation on EA scores) showed that, with mothers that were less emotionally available at bedtime, infants with higher levels of surgency developed significantly shorter sleep duration from 1 to 6 months than infants with lower levels of surgency; however, with mothers that were highly emotionally available at bedtime, the development of sleep duration did not differ for infants with different levels of surgency. Therefore highly surgent infants may be more vulnerable to negative influences of low emotional-quality maternal care at bedtime in terms of sleep duration development. This pattern was compatible with the diathesis-stress model

(Monroe & Simons, 1991), with high surgency being a constitutionally vulnerable factor. Additional analysis of sub-dimensions underlying the surgency superfactor showed that Vocalization, Smile and Laughter, and Perceptual Sensitivity moderated the effect of maternal EA on sleep duration development (βs = .36 ~ .41, *p*s < .05 or .01). For infants who were more likely to vocalize, to smile and laugh, or were more sensitive in perception, lower emotional availability of their mothers at bedtime was associated with lower total sleep duration at 6 months while controlling for 1-month sleep duration ($B = 22.59 \sim 25.42$, $t(71) = 2.83 \sim 3.71$, $p < .01$). For infants with lower levels on these temperamental characteristics, maternal EA at bedtime did not affect their sleep duration ($B = -17.26 \sim -11.15$, $t(71) = -1.11 \sim -.81$, *ns*).

Meanwhile, for infants with lower levels of negative affectivity, better maternal EA at bedtime predicted longer sleep duration ($B = 23.18$, $t(71) = 2.51$, $p < .05$) from 1 to 6 months; for infants with higher levels of negative affectivity, however, higher maternal EA marginally predicted shorter sleep duration ($B = -22.60$, $t(71) = -1.81$, $p = .07$). Post-hoc analysis comparing endpoints of the slopes showed that, with mothers being less emotionally available at bedtime, infants with lower levels of negative affectivity developed significantly shorter sleep duration at 6 months when controlling for 1-month sleep duration, compared with infants with higher levels of negative affectivity; with mothers being highly emotional available at bedtime, infants' levels of negative affectivity did not relate to sleep duration development. Therefore the interaction pattern appeared compatible with the diathesis-stress model (Monroe & Simons, 1991), and low levels of negative affectivity served as a vulnerability factor in terms of sleep duration development. Further analysis found that the sub-dimensions underlying the negative affectivity superfactor that moderated the relation between maternal EA and infant sleep duration were Sadness and Distress to Limit ($\beta = -.40$, $p < .005$; $\beta = -.50$, $p < .001$). For infants who were less likely to be sad, or were less distressed when their behavior was restrained, levels of maternal EA at bedtime were positively associated with development of their total sleep duration from 1 to 6 months (B = 24.99, $t(71) = 2.65$, $p < .05$; B = 26.13, $t(71) = 2.89$, $p < .01$). For infants who were more likely to be sad, or more distressed when they were restrained, higher maternal EA at bedtime marginally significantly, or significantly predicted shorter sleep duration (B = -21.23, $t(71) = -1.78$, $p = .08$; B = -31.61, $t(71) = -2.36$, $p < .05$) at 6 months when controlling for 1-month sleep duration.

Predicting 6-Month Infant Sleep Minutes (see Figure 2)

For highly surgent infants, higher maternal EA at bedtime predicted longer sleep minutes (B = 22.88, $t(71) = 2.65$, $p < .05$); for less surgent infants, maternal EA at bedtime did not influence sleep minutes (B = -18.00, $t(71) = -1.07$, *ns*). Post-hoc comparisons of end points of the slopes showed that, however, for infants with different levels of surgency, if they both received similar levels (either low or high) of emotional quality of maternal care, their developmental changes of sleep minutes did not differ. In other words, the only difference in developmental changes of sleep minutes took place between surgent infants with highly emotional available mothers at bedtime and surgent infants with less emotionally available mothers. Additional tests of individual sub-dimensions underlying the surgency factor indicated that Activity Level, Vocalization, and Smile and Laughter moderated the effect of maternal EA on sleep minutes (βs = .32 ~ .40, ps < .05). For infants who were highly active, tended to vocalize, or smiled and laughed a lot, highly emotionally available maternal care at bedtime promoted longer sleep minutes at 6 months (B = 23.08 ~ 30.55, $t(71)$ = 2.88 ~ 3.46, $p < .01$); for infants who had relatively low levels of these attributes, bedtime maternal EA did not have significant influence on sleep minutes (B = -25.48 ~ -19.63, $t(71)$ = -1.36 ~ -1.48, *ns*).

Meanwhile, for infants with lower levels of negative affectivity, better maternal EA at bedtime marginally predicted longer sleep minutes ($B = 19.62$, $t(71) = 1.88$, $p = .06$); EA did not predict sleep minutes for infants with higher levels of negative affectivity ($B = -14.74$, $t(71) = -1.05$, *ns*). Post-hoc comparisons of end points of the slopes found that, however, for infants with different levels of negative affectivity, if receiving maternal care with similar levels (either low or high) of EA, the developmental changes of sleep minutes did not differ. In other words, the only marginal difference of developmental changes of sleep minutes took place among infants who had lower levels of negative affectivity, but cared by mothers with different levels of bedtime EA. Further analysis of sub-dimensions underlying the negative affectivity superfactor revealed that Sadness (marginally) and Distress to Limitations significantly moderated the effect of maternal EA on sleep minutes development ($\beta = -.24$, $p = .05$; $\beta = -.35$, $p < .05$). For infants who were less sad, or were less distressed when their behavior was restrained, high maternal EA at bedtime marginally significantly, or significantly predicted longer sleep minutes from 1 to 6 months ($B = 20.11$, $t(71) = 1.89$, $p = .06$; $B = 23.20$, $t(71) = 2.25$, $p < .05$); for infants who had relatively high levels of these attributes, bedtime maternal EA did not have significant influence on sleep minutes development ($B = -11.21$, $t(71) = -.82$, *ns*; $B = -23.74$, $t(71) = -1.56$, *ns*).

Reanalysis After Dropping Sleep-Related Temperament Items

With the goal of avoiding potential bias caused by using sleep-related temperament items in IBQ-R to predict infant sleep, a new set of multiple regression analysis was conducted based on temperament scores which were recalculated after dropping items identified by the author as directly assessing infant sleep (for details, see data analytic plan).

Predicting infant sleep duration changes from 1 to 6 months, the patterns of surgency and its sub-dimensions moderating the effect of maternal EA at bedtime on infant sleep duration development were consistent before and after dropping sleep-related temperament items. Negative affectivity also stayed as a significant moderator, with the same moderation pattern. However, the moderation pattern of sub-dimensions of negative affectivity partly changed after sleep-related items were dropped. For infants who were less sad, or less distressed when their behavior was restrained, high maternal EA still predicted longer infant sleep duration ($B = 24.05$, $t(71) = 2.41$, $p < .05$; $B = 25.31$, $t(71) = 2.43$, $p < .05$); but for infants who were more sad, or more distressed when her behavior was restrained, maternal EA at bedtime was no longer associated with infant sleep duration development ($B = -17.43$, $t(71) = -1.39$, *ns*; $B = -20.73$, $t(71) = -1.50$, *ns*).

In terms of predicting infant sleep minutes' changes from 1 to 6 months, the patterns of surgency and its sub-dimensions moderating the effect of bedtime EA on sleep minutes were again unchanged after dropping sleep-related temperament items. Negative affectivity also still significantly moderated the effect of maternal EA on infant sleep duration, with the same moderation pattern. However, only one of its sub-dimensions, Distress to Limit ($\beta = -.31$, $p = .07$), but not Sadness, remained a marginally significant moderator of EA's effect on infant sleep minutes.

DISCUSSION

The current study is among the first that examined whether observed maternal emotional availability at bedtime and infant temperament influenced objectively measured infant sleep development additively, as well as whether the influence of bedtime EA on infant sleep development was conditioned by infant temperament. As such, the present study represented an attempt to study determinants of infant sleep development from the perspective of the transactional model of child sleep (Sadeh & Anders, 1993; Sadeh et al., 2010), which posits that infant sleep is ecologically based and multiply and complexly determined. Our study found some but insufficient support for the main effects of 3-and-6-month maternal EA at bedtime and infant temperament on developmental changes of infant sleep length and quality during the first half year of infants' life. Instead, and consistent with the transactional model of infant sleep, maternal EA at bedtime was found to predict infant sleep development differentially for infants with different temperament characteristics.

Previous literature has investigated the contribution of parenting (e.g., Scher, 2001; Teti et al., 2010) or infant temperament (e.g., Halpern et al., 1994; Sadeh et al., 1994; Scher et al., 1992; Scher et al., 1998; Spruyt et al., 2008) separately or additively, but seldom attempted to integrate these two forces and examine how the former's influence might be moderated by the latter. As a result of the limitation of the main effect analytic approach used in most previous studies, complex relations between parenting, temperament, and infant sleep may not have been truly revealed. Indeed, if applying only "main effect" analyses on the current sample, one could conclude that there were marginal effects of maternal EA at bedtime and infant temperament on infant sleep development from 1 to 6 months. This conclusion may be based on current findings of sporadic significant first-order correlations between temperament superfactors and sleep variables (e.g, 3-month surgency and 1-month infant sleep variables), and between bedtime EA and sleep variables (3-month EA and 6-month sleep duration), as well as marginally significant effects of EA on developmental changes of infant sleep duration and sleep minutes in step 2 of multiple regressions. However, by further exploring the moderating effects of temperament on the parenting–infant sleep links, most of the direct associations between bedtime EA and infant sleep developmental changes, and between infant temperament and infant sleep developmental changes were qualified after accounting for interactional effects of EA and temperament.

Main Effects of EA

Results revealed a positive correlation between 3-month maternal EA at bedtime and 6-month sleep duration, as well as marginally significant positive effects of EA composite scores on the developmental changes of infant sleep length, i.e., sleep duration and sleep minutes from 1 to 6 months. These results partly supplement Teti et al.'s (2010) finding of an association between higher maternal EA at bedtime and mothers' reports of fewer infant sleep disruptions (sleep quality), and together imply a likely positive impact of emotional available parenting at bedtime on infant sleep development. There are several differences between the two studies, however, that are worth noting. First, the present study found a marginal effect of EA on infant sleep length, while Teti et al. (2010) found EA's association with infant sleep quality, indicated by sleep disruptions. Second, the current study used actigraphy to record infant sleep, whereas Teti et al. (2010) used maternal reports, which might be biased by mothers' memory errors, or might have omitted infant awakenings that were unnoticed by mothers. Third, the current study is longitudinal, focusing on sleep developmental changes during the first half year of infants' life, beyond the influences of initial individual differences in sleep maturation indicated by 1-month sleep variables, while Teti et al. (2010) study examined a cross-sectional sample of infants ranging from 1 month to 24 months old.

Main Effects of Infant Temperament

First, in terms of Pearson correlations, the current sample did not reveal a predictive correlation from early temperament to later sleep variables, but show some negative associations between longer sleep and better early sleep quality at 1 month with lower levels of surgency at 3 or 6 month. These correlations, however, should be interpreted with caution. This is because infant temperament could not be reliably assessed before 3 months, and thus we cannot examine relations between infant sleep and temperament at 1 months. The lack of assessments of infant temperament at a timing as early as measures of infant sleep doesn't mean that infant sleep shapes infant's emotionality and behavioral tendency rather than the other way around. Second, in terms of multiple hierarchical regressions, results showed that most of 3-and-6-month infant temperament superfactors did not predict changes of infant sleep length and quality from 1 to 6 months, except for that infant orienting/regulation marginally predicted 6-month infant sleep duration in the final regression model. This is not incompatible with past literature, because although some patterns of associations between infant temperament and infant sleep have emerged, these associations tend to be modest and inconsistent across studies (Halpern et al., 1994; Scher et al., 1998; Van Tassel, 1985). In addition, the current study used the IBQ-R to assess infant temperament, which has been rarely used in previous research examining temperament and sleep, so the use of different measures might have also affected differences in results.

Infant Temperament Moderating the Influences of Bedtime EA on Infant Sleep

Results highlighted the moderating role of infant temperament, especially surgency and negative affectivity, in the links between maternal EA at bedtime and infant sleep developmental changes. This is in line with the transactional model of child development (Sameroff, 1989) and infant sleep (Sadeh & Anders, 1993; Sadeh, Tikotsky, & Scher, 2010), as well as the proposition that individuals carrying different temperamental profiles are differentially sensitive to parenting (Sanson & Rothbart, 1995).

Analyses showed that highly surgent infants, but not less surgent infants, were responsive to the positive effect of maternal EA at bedtime in terms of developing longer sleep duration and sleep minutes after controlling for 1-month sleep lengths. The interaction pattern predicting sleep duration development is mainly driven by a smaller increase of sleep duration among infants with high levels of surgency and receiving less emotionally available maternal care at bedtime. So the pattern is compatible with the diathesis-stress model (Monroe & Simons, 1991), with high-level surgency functioning as a vulnerability factor in terms of negative impacts of low EA at bedtime on sleep duration changes. The interaction pattern predicting sleep minutes development, however, did not fit into either the diathesis-stress model or the differential susceptibility model. This is because, although the slope for less surgent infants was significant, infants receiving similar levels of EA but with different levels of surgency did not differ in outcome values. These patterns, as well as the patterns associated with sub-dimensions of surgency, remained robust after dropping sleep-related temperament items.

Prior work indicates that surgent children, who are characterized by positive affect and high tendency to approach novel or social stimuli (Garstein & Rothbart, 2003), are sensitive to parenting characterized by responsiveness and warmth in the development of compliance and effortful control (Kochanska, 1993, 1997; Cipriano & Stifter, 2010). Even though emotional availability is not identical to a combination of warmth and responsiveness, it encompasses these dimensions as well as affective attunement in the parent-child dyad. Surgent infants, identified by their levels of activity, vocalizations, positive affect, and perceptual sensitivity, might require higher levels of parental attention and responsiveness to fulfill their physical, communicative, and emotional needs at bedtime. Parents who were able to be emotionally available to these infants would also need to keep up with infants' positive affect. Thus parental emotional availability may be more crucial for highly surgent infants' sleep development than it is for less surgent infants. High EA of these parents might foster among surgent infants a stronger orientation toward the parent and greater compliance with parental efforts to put infants to bed, which may help lead to their increased sleep duration and sleep minutes from 1 to 6 months. On the other hand, highly surgent infants who received maternal care of low emotional quality might become restless at nighttime, because of their high activity level and reactivity, resulting in their sleep not as lengthened from 1 to 6 months as other infants.

Infant negative affectivity also served as a moderator for bedtime EA's effect on infant sleep length development from 1 to 6 months. For infants with lower levels of negative affectivity, if they received less emotionally available maternal care at bedtime, their total sleep durations were shorter, and their sleep minutes were marginally shorter at 6 months, after controlling for 1-month sleep length. For infants with higher levels of negative affectivity, maternal EA at bedtime was marginally and negatively predictive of changes in sleep duration overtime, but not predictive of changes in sleep minutes. It may be worth mentioning here that negative affectivity is not the bipolar opposite of positive affectivity (e.g., Putnam & Stifter, 2005), and in our sample, negative affectivity was not correlated with surgency (see Table 2). Therefore infants with low levels of negative affectivity may not be the infants with high levels of surgency, and thus both temperament moderators may be unique moderators of parenting's effects on infant sleep. The interaction pattern of negative affectivity and EA predicting sleep duration changes is somewhat compatible with the diathesis-stress model (Monroe & Simons, 1991), with low negative affectivity functioning as a risk factor in terms of negative effects of low EA. On the other hand, the interaction pattern predicting sleep minutes development is more ambiguous, because the slope of infants with low negative affectivity was just marginally significant, and comparisons of end points did not reveal significant differences. It should be noted, however, that since sleep minutes indicate the actual time that the infant was in the sleep status, sleep minutes may be more informative with regard to infant sleep length compared to sleep duration. Therefore the ambiguous interaction between negative affectivity and maternal EA on sleep minutes development may, to some degree, qualifies further interpretation about the moderating role of negative affectivity in the links between EA and infant sleep length development from 1 to 6 months.

It is somewhat difficult to explain why infants who had lower levels of negative affectivity were more responsive to maternal EA's effect on infant sleep length development, and why infants with low levels of negative affectivity and receiving low-EA maternal care did not increase in sleep duration from 1 to 6 months as much as other infants. It is possible that infants, regardless of levels of negative affectivity, would to some degree benefit from high maternal EA in terms of sleep development. This is because high EA may cultivate in infants a sense of security and trust in their sleep environment (Teti et al., 2010), which might be conducive for maintaining their sleep state. However, the current study only examined sleep developmental changes from 1 to 6 months; after 6 months, how infants with different levels of negative affectivity would be influenced by maternal EA at bedtime remains unknown, and is in need of further investigation. The possibility could not be ruled out that negative affectivity, often identified as a vulnerability or plasticity factor of environmental influences (Belsky & Pluess, 2009), might moderate effects of maternal EA at bedtime on child sleep development in later stages.

Apart from the theoretical merit of modelling the interactional effects of EA and temperament on infant sleep, the present study also had some methodological strengths. First, different sources of information were obtained for assessing predictors and outcomes: infant sleep was measured by actigraphy, maternal EA at bedtime was observed by coders blind to other measures of the families, and infant temperament was reported by mothers. This served to reduce shared method variance (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003). Second, in order to avoid the common variance shared between sleep-related temperament items and infant sleep measures, those items were dropped from IBQ-R and regression analyses were conducted again based on “purified” temperament measures. Patterns of how infant temperament moderated maternal EA’s effect on infant sleep development remained mostly unchanged in the second set of analysis, which assured the robustness of the results. Third, most past studies only examined first-order, cross-sectional or longitudinal correlations between parenting, infant temperament, and infant sleep, but did not investigate developmental changes of infant sleep (e.g., Sadeh et al., 1994; Scher et al., 1992; Scher et al., 1998; Spruyt et al., 2008). In the current study, 1-month infant sleep variables were controlled in regressions, thus making the analyses target on predicting residualized gain scores of infant sleep variables, which indicated how an infant’s sleep developed relative to the group level of development from 1 to 6 months.

Nevertheless the current study also had several limitations. First, although recruitment efforts were made to oversample participants from ethnic minority groups and diverse socioeconomic backgrounds, the current sample was predominantly white and reasonably well-educated. Second, due to missing data, the current sample (n = 71) was small, although it is relatively larger than most previous studies with actigraphy measure of infant sleep (Halpern et al., 1994; Scher et al., 1992; Scher et al., 1998; Spruyt et al., 2008). These sample characteristics qualify the generalizability of the results. Third, only infant sleep development from 1 to 6 months was examined. It remained unknown what patterns would be between maternal EA, infant temperament, and infant sleep in later phase of development. Fourth, although maternal EA at bedtime has provided important insight on the quality of mother-child interactions relevant to infant sleep, emotional quality of parenting during nighttime might also be worth considering in terms of affecting infant sleep. Unfortunately, these data was not available in the current study. Finally, from a family system perspective, the dyadic interactions between mothers and their partners, their partners and infants, as well as triadic interactions between mothers, partners, and infants, were not included in the present analyses. Although there were fathers that took care of infants at bedtime in our sample, paternal EA and coparenting data at bedtime were too scarce to be included in the current analysis. Future research can benefit from using a larger, more ethnically, socially, and economically diverse sample, testing later developmental stages, expanding the examination of parenting quality to the context of nighttime, and incorporating partners of mothers, and perhaps other bedtime and nighttime caregivers such as grandparents into the ecological context of infant sleep.

The current study is among the first studies that attempted to examine the complex, transactional relations between maternal emotional availability at bedtime, infant temperament, and developmental changes of infant sleep from 1 to 6 months, by exploring the moderating role of temperament in the relation between EA and infant sleep development. Results lend partial support to the positive impact of EA at bedtime on the development of infant sleep length, and showed sporadic evidence for main effects of temperament on infant sleep. Moderation analyses revealed that for infants with high surgency and infants with low negative affectivity, maternal EA at bedtime was likely to promote increases of sleep duration and sleep minutes from 1 to 6 months, above and beyond the influence of sleep maturation levels at 1 month. These interactive patterns indicate that infant sleep interventions may benefit from not only improving parenting emotional availability at bedtime, but also considering infant temperamental characteristics and thus infants' varied levels of responsiveness to the influence of parenting emotional quality. Finally, while the current study provides support for the transactional pattern between infant characteristics and parenting emotional quality at bedtime in the developmental process of infant sleep, further studies that examine later developmental phases, consider other aspects of infant constitutional factors and ecological factors, and utilize a larger, diverse sample, are definitely warranted.

APPENDIX:

Tables and Figures

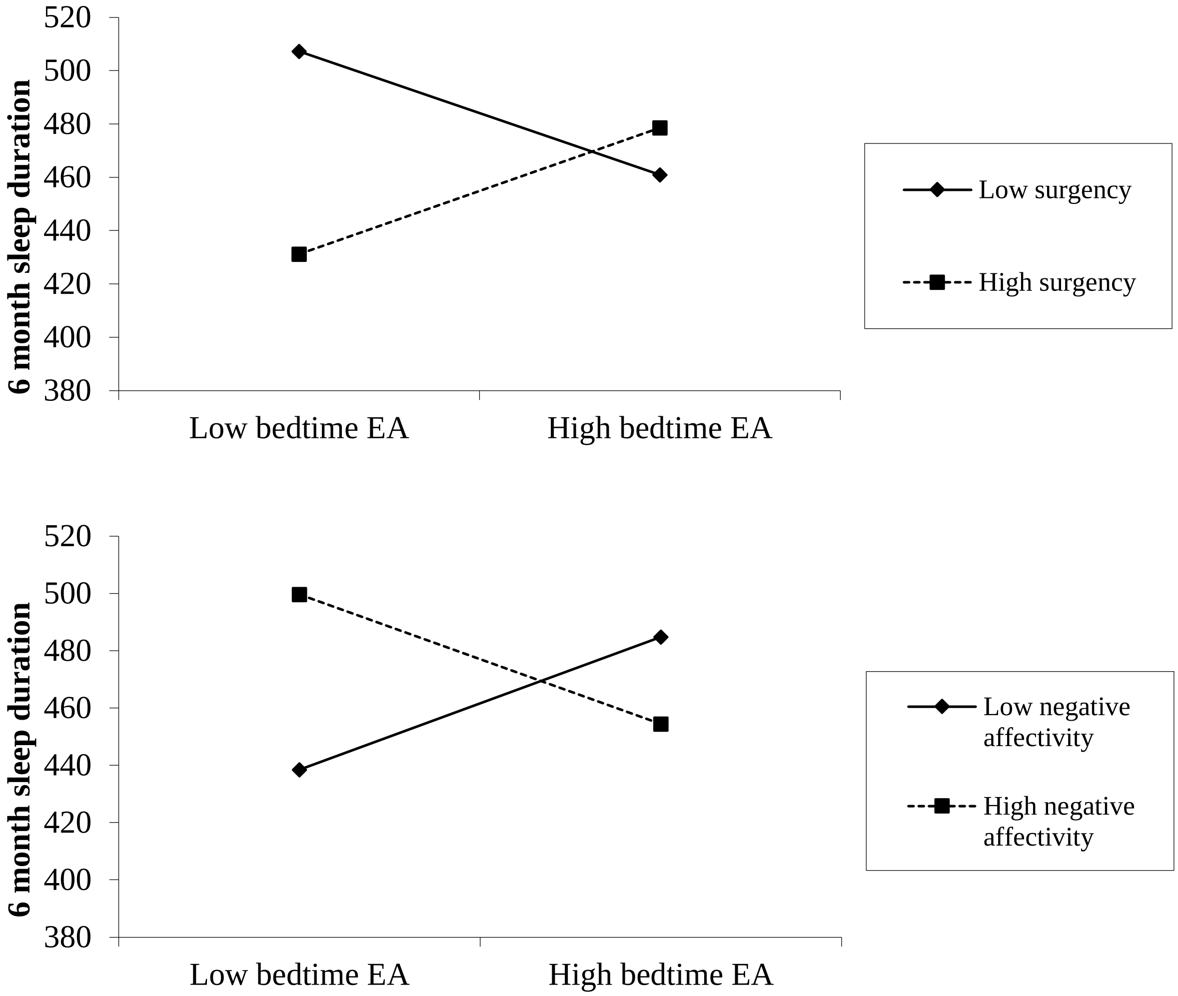

Figure 1. Predicting 6-Month Infant Sleep Duration After Controlling for 1-Month Sleep Duration: Simple Slopes for Interaction of Maternal EA at Bedtime and Infant Surgency, and Interaction of Maternal EA at Bedtime and Infant Negative Affectivity.

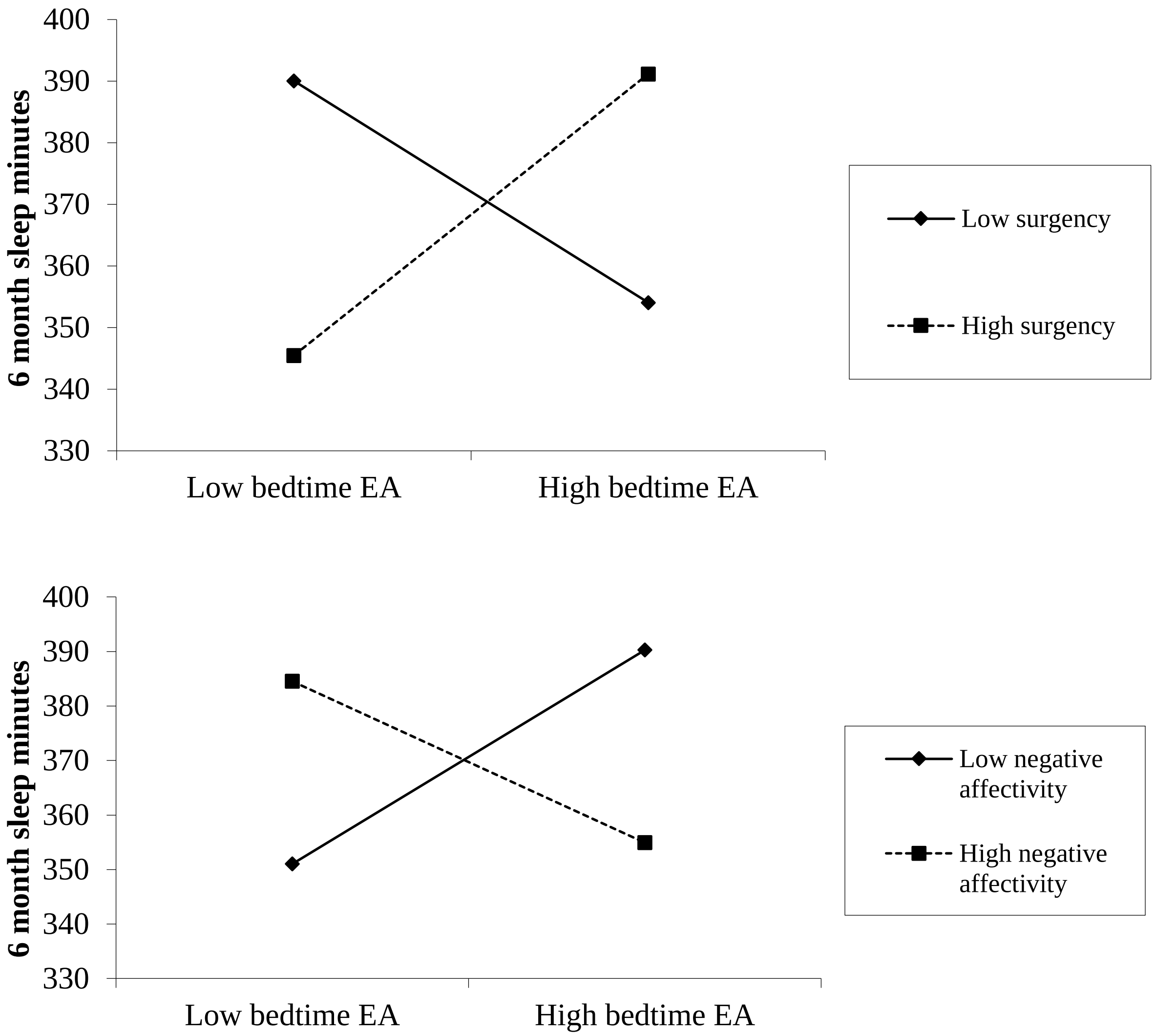

Figure 2. Predicting 6-month infant sleep minutes after controlling for 1-month sleep minutes: simple slopes for interaction of maternal EA at bedtime and infant surgency, and interaction of maternal EA at bedtime and infant negative affectivity.

Table 1

Means and Standard Deviations for Infant Sleep, Maternal Emotional Availability at Bedtime, and Infant Temperament, and Repeated Measures ANOVA (Including Post Hoc (Bonferroni) Comparisons[a]) of Infant Sleep From 1 to 6 Months

	Infants' Age (months)			Wilk's Lamda	Within-subjects Effects
	1	3	6		
Variable	*M* *(SD)*	*M* *(SD)*	*M* *(SD)*	*F(2, 67)*	F^{b}
Sleep Duration (minutes)	560.56^{1} (68.29)	580.79^{2} (68.63)	614.42^{3} (56.85)	20.62^{***}	23.24^{***}
Sleep Minutes (minutes)	389.41^{1} (82.02)	410.04^{2} (65.82)	490.64^{3} (65.41)	68.16^{***}	71.46^{***}
Sleep Fragmentation	84.19^{1} (14.83)	74.92^{2} (10.48)	57.71^{3} (9.62)	149.76^{***}	126.42^{***}
Number of Wake Bouts	42.23^{1} (14.40)	41.33^{1} (8.92)	37.25^{2} (8.51)	5.24^{**}	4.64^{*}
Surgency		3.97 (.85)	4.83 (.69)		
Negative Affectivity		2.76 (.48)	2.98 (.59)		
Orientating/Regulation		4.95 (.54)	5.05 (.51)		
Emotion Availability					
Sensitivity		6.45 (1.40)	6.22 (1.50)		
Structuring		3.70 (.64)	3.63 (.80)		
Non-intrusiveness		4.74 (.53)	4.78 (.43)		
Non-hostility		4.74 (.74)	4.71 (.63)		

[a] The post hoc comparison results were indicated by superscripts of the means. Same number denote insignificant difference and different numbers denote significant difference.

[a] Sleep duration and sleep minutes did not violate the assumption of sphericity, therefore the *F*s of within-subjects effects were calculated under the sphericity-assumed condition. Sleep fragmentation and number of wake bouts violated the assumption of sphericity, so the *F*s were calculated with the Greenhouse-Geisser correction.

$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .005$.

Table 2

Intercorrelations Between Infant Gender, Infant Temperament, Maternal Bedtime Emotional Availability, and Infant Sleep

		Infants' age (months)															
		Surgency		Negative Affectivity		Orientating /Regulation		Emotion Availability		Sleep Duration		Sleep Minutes		Sleep Fragmentation		Number of Wake Bouts	
Variable	Month	3	6	3	6	3	6	3	6	1	6	1	6	1	6	1	6
Gender		.16	.20	.05	-.05	.09	.13	-.19	-.01	.16	.16	.01	.32**	-.08	-.31**	-.04	-.33**
Surgency	3	–	.85***	.11	.15	.64***	.54***	-.41***	-.28*	-.21†	-.16	-.34***	-.09	-.24*	-.09	-.18	-.10
	6		–	-.05	.09	.59***	.68***	-.47***	-.28*	-.15	-.08	-.19	.05	.09	-.20	-.28*	-.10
Negative Affectivity	3			–	.66***	-.19	-.17	-.10	-.07	.06	-.01	.02	-.02	.10	.07	.03	.08
	6				–	-.09	-.34***	-.21†	-.24*	.00	-.02	-.10	-.16	.21†	.19	.03	.23†
Orientating /Regulation	3					–	.61***	-.02	.01	-.14	.10	-.17	.10	.08	-.06	-.10	-.07
	6						–	-.20†	-.08	-.14	.03	-.09	.14	-.11	-.15	-.11	-.12
Emotion Availability	3							–	.63***	-.08	.25*	.06	.15	-.11	.16	.12	.16
	6								–	-.16	.09	-.13	.13	-.02	-.12	.16	.01
Sleep Duration	1									–	.30*	.69***	.33**	-.12	-.16	.14	-.10
	6										–	.28*	.77***	-.06	.01	-.04	.11
Sleep Minutes	1											–	.35***	-.68***	-.17	-.19	-.08
	6												–	-.19	-.47***	-.13	-.38**
Sleep Fragmentation	1													–	.21†	.13	.18
	6														–	.06	.77***
Number of Wake Bouts	1															–	.00
	6																–

Note. For infant gender, 1 = male, 2 = female.

† $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .005$.

Table 3

Predicting 6-Month Infant Sleep From Averaged 3-And-6-Month Infant Temperament, Maternal Bedtime Emotional Availability at Bedtime, and Their Interactions

	Infants sleep at 6 months															
Step and	Sleep Duration Overall $F(9,61) = 3.79^{***}$				Sleep Minutes Overall $F(9,61) = 4.20^{***}$				Sleep Fragmentation Overall $F(9,61) = 1.80^{\dagger}$				Number of Wake Bouts Overall $F(9,61) = 1.33$			
Predictors	F	β	R^2	ΔF	F	β	R^2	ΔF	F	β	R^2	ΔF	F	β	R^2	ΔF
Step 1			.10	3.92*			.23	9.91***			.15	6.08***			.11	4.28*
Gender	1.01	.12			8.88***	.32			8.67***	-.33			8.55**	-.33		
1mo sleep	5.87*	.28			10.78***	.35			4.45*	.24			.01	-.01		
Step 2			.19	1.81			.28	1.29			.20	.89			.15	.80
Gender	1.51	.14			8.95***	.32			7.06**	-.30			7.30**	-.32		
1mo sleep	6.79*	.31			11.64***	.39			4.85*	.26			.14	-.04		
EA	3.50†	.25			3.13†	.22			.16	-.05			.38	.08		
SE	.50	-.14			.07	.05			2.41	-.31			.09	-.06		
NA	.55	.09			.05	-.03			1.81	.17			2.52	.21		
OR	1.29	.21			.30	.10			1.00	.19			.02	.03		
Step 3			.36	5.21***			.38	3.28*			.21	.35			.16	.24
Gender	.84	.10			7.83**	.29			5.91*	-.29			6.76*	-.31		
1mo sleep	8.49***	.32			13.99***	.41			4.49*	.26			.04	-.02		
EA	.00	.01			.07	.04			.41	-.11			.00	-.01		
SE	2.02	-.27			.03	-.03			2.46	-.33			.21	-.10		
NA	1.29	.13			.00	-.01			1.28	.16			2.50	.21		
OR	3.64†	.33			1.10	.18			1.01	.19			.09	.06		
EA×SE	7.66**	.50			4.55*	.38			.28	.11			.72	.18		
EA×NA	10.19***	-.39			4.49*	-.26			.20	.06			.25	-.07		
EA×OR	.88	-.15			.14	-.06			.21	-.08			.51	-.13		

Note. $n = 71$. For infant gender, 1 = male, 2 = female. 1mo sleep = the levels of the corresponding sleep outcome variable at 1 month, e.g., 1mo sleep = sleep duration at 1 month, in the equations predicting 6 month sleep duration. EA = maternal emotional availability at bedtime. SE = surgency/extraversion. NA = negative affectivity. OR = orienting/regulation.

† $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .005$.

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