

Disposable Diaper Use Promotes Consolidated Nighttime Sleep and Positive Mother-Infant Interactions in Chinese 6-Month-Olds

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The emergence of consolidated nighttime sleep and the formation and maintenance of parent-infant relationships are 2 primary developmental achievements of the infancy period. Despite the development of a transactional model that links parenting behaviors to infant sleep, limited attention has been devoted to examining experimental manipulations of infant sleep that may impact the discrete parent-infant interactions that may form the foundation for emerging attachment relationships. In the present study, infants were randomly assigned to wear high-absorbency disposable diapers or to continue using traditional low-absorbency cloth diapers that necessitate frequent changes and associated disruptions of nighttime sleep. Parents reported on infant sleep before and during the 6-week experimental manipulation; a subset of infants also wore actigraphs. Parents and infants also participated in a parent-infant interaction task both before and near the end of the experimental manipulation. Infants who wore cloth diapers experienced more frequent sleep disruptions overall as well as a greater number of disruptions that did and did not wake the infant from sleep. Infants who wore disposable diapers were rated as experiencing more engagement and positive affect near the end of the intervention relative to infants who wore cloth diapers; mothers of infants who wore disposable diapers were rated as more engaged and sensitive near the end of the intervention relative to mothers of infants who wore cloth diapers. These findings suggest that the disposable diaper manipulation was causally related to characteristics of mother-infant interactions that may form the foundation for emerging attachment relationships.

Keywords: infancy, sleep, interaction, relationships

The infancy period is characterized by numerous developmental achievements, among them the emergence of consolidated nighttime sleep and the formation and maintenance of parent-infant attachment relationships. Specifically, the frequency of infant night waking declines significantly over the first three months of life and remains relatively stable until one year (Anders, Halpern, & Hua, 1992; Burnham, Goodlin-Jones, Gaylor, & Anders, 2002), and the foundation for the parent-infant attachment relationship is established over the first and develops into the second year of life

(Bowlby, 1969/1982). Transactional models of development link parenting behaviors in particular—including those associated with parent-infant interpersonal relationships and bedtime interactions—to measures of infant sleep (Sameroff, 1989; Sameroff & Emde, 1989; see also Sadeh & Anders, 1993; Sadeh, Tikotzky, & Scher, 2010). Yet, experimental manipulations of infant sleep and characteristics of parent-infant attachment have received limited empirical attention. Even fewer studies focus on associations between experimental manipulations of infant sleep and more dis-

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crete parent-infant interactions that may form the foundation for emerging attachment relationships. The goal of the present research was to examine whether an experimental manipulation of infant diaper use would (a) facilitate consolidated nighttime sleep, and (b) promote more positive mother-infant interactions in typically developing 6-month-old Chinese infants.

Most commonly, studies examining infant sleep habits in relation to parent-infant attachment relationships indicate that infant sleep problems are associated with insecure-resistant or -ambivalent behavior profiles¹ (Beijers, Jansen, Riksen-Walraven, & de Weerth, 2011; McNamara, Belsky, & Fearon, 2003; Morrell & Steele, 2003; Zentall, Braungart-Rieker, Ekas, & Lickenbrock, 2012; although see Scher, 2001a, for data indicating that associations between infant sleep and parent-infant attachment may extend beyond traditional cases of insecure-resistant or -ambivalent attachment styles). In the Strange Situation procedure that is used to characterize the attachment relationship, infants who are ultimately assigned the insecure-resistant or -ambivalent attachment classification cling to the mother when she is present and are highly distressed when she leaves the room; once the mother returns, the infant may seek but also attempt to resist contact with her (Ainsworth, Blehar, Waters, & Wall, 1978). In terms of sleep-attachment associations, infants with insecure-ambivalent attachment profiles experience more frequent night wakings (Beijers et al., 2011; McNamara et al., 2003; Morrell & Steele, 2003; Zentall et al., 2012) and are more likely to have a clinically relevant sleep problem relative to infants with other attachment classifications (McNamara et al., 2003).

Relations between parental behavior and infant sleep can be expected to impact not only the attachment relationship as a whole, but the patterns of parent-infant interaction on which attachment is based. Yet, only a handful of studies have examined relations between infant sleep habits and characteristics of daytime parent-infant interactions, and the obtained results have been inconsistent. For example, Scher (2001b) reported that infant sleep habits at 12 months were associated with infant behavior during a 10-min interaction task such that infants who were more responsive during the interaction experienced more frequent night wakings; relations were not found between infant sleep habits and maternal behavior. In their work, Dearing, McCartney, Marshall, and Warner (2001) found that maternal sensitivity at 6 months was negatively associated with infant circadian rhythmicity at 19 months but not at 7 or 31 months.² Other research conducted with infants and older children has indicated positive associations between infant and child sleep habits and characteristics of parent-child interactions. Paret (1983) reported that 9-month-old infants identified as good sleepers and their mothers demonstrated more favorable interaction patterns relative to other infants. In more recent work, Priddis (2009) indicated that mothers of infants with sleep problems were less sensitive when interacting with their infants relative to mothers of infants without sleep problems. Aspects of infant sleep behavior at 4 months of age were also concurrently associated with maternal behaviors in infants born preterm or low birth weight (Schwichtenberg & Poehlmann, 2009). These data suggest that infant sleep problems may be associated with the daily experiences had by infants (for additional work on preschoolers through adolescents, see Bates, Viken, Alexander, Beyers, & Stockton, 2002; Bordeleau, Bernier, & Carrier, 2012; Spilsbury et al., 2005).

Researchers have developed a transactional model of infant sleep that suggests that sleep-wake regulation results from bidirectional intrinsic (such as infant health and temperament) and extrinsic (such as parent functioning or cultural factors) influences (Sadeh & Anders, 1993; Sadeh, Tikotzky, & Scher, 2010; Tikotzky & Sadeh, 2009). This theoretical model suggests that parenting behaviors may impact infant sleep habits and infant sleep habits may impact parenting behaviors. These bidirectional influences have been demonstrated with older children. For example, Bell and Belsky (2008) determined that not only was maternal parenting at third grade associated with change in child sleep habits over time after relevant covariate control, but that child sleep habits at third grade also predicted change in maternal parenting scores associated with negativity, sensitivity, and closeness or conflict. Experimental work with infants also indicates that the modification of infant sleep habits may be associated with changes in patterns of parent-infant interactions. Minde, Faucon, and Falkner (1994) examined the effect of a parent-centered infant sleep intervention on infant sleep, infant behavior, and characteristics of mother-infant interactions in 12- to 36-month-olds. Although the study included infants with and without sleep problems, only infants with sleep problems were subject to an experimental manipulation. Parents of infants with sleep problems received counseling sessions with a social worker to identify a problematic aspect of infant sleep behavior; parents then implemented the recommended suggestions for improving infant sleep problems. The intervention improved the sleep habits of infants with sleep problems and facilitated parent-infant interactions in a behavioral observation task. Specifically, infants who received the intervention received higher ratings on a composite score of organization, attention, and social skills as well as lower ratings on a composite score of dysregulation, irritability, and negative behavior relative to preintervention ratings; dyads also received higher ratings on a composite associated with mutuality and reciprocity and lower scores on dyadic tension after the intervention relative to baseline. Taken together, these findings suggest that child sleep habits are associated with the quality of parent-child interactions that may form the foundation for emerging attachment relationships.

The goal of the present research was to examine whether an experimental manipulation of disposable diaper use would produce measureable effects on (a) consolidated nighttime sleep, and (b) characteristics of mother-infant interactions in typically developing Chinese 6-month-olds without any known sleep problems. We selected 6-month-old infants as participants because of their developing attachment relationships to their parents: infants of this age discriminate between familiar and unfamiliar adults and use their emerging gross motor abilities to maintain contact with preferred caregivers (Bowlby, 1969/1982). We reasoned that if the imposed experimental manipulation was effective, it would facilitate more positive parent-infant interactions. Although not measured in the present research, this, in turn, could lead to the

¹ The different names refer to the same constellation of behaviors (for a review, see Keller, 2011).

² Given our interest in examining characteristics of mother-infant interaction in relation to the diaper manipulation, information about developmental change across administrations of the interaction task independent of group assignment is not reported here but can be obtained from the first author upon request.

development of more positive attachment relationships over time. The experimental manipulation consisted of the introduction of high-absorbency disposable diapers that do not need to be changed during the period of nighttime sleep. Though common in many countries, they are not in regular use in major areas of China. Instead, in China, the traditional and prevailing custom is use of cloth diapers that are not intended to absorb or retain waste for extended periods. The traditional Chinese cloth diaper usually consists of a thin piece of cloth cut out from discarded garments and is held in place by an elastic band around the waist. The plastic diaper covers that are commonly placed over cloth diapers in the West are virtually unused in China. The result is that the cloth diapers must be changed during nighttime sleep. Parents are often close by, since the prevalence of bed sharing or cosleeping in China ranges from 10% to 79% before the school years (see Huang, Wang, Zhang, & Liu, 2010, for a review). However, this activity that frequently results in infant waking and thus interferes with consolidated nighttime sleep. Consistent with this suggestion, relative to infants from predominantly Caucasian countries, parents from predominantly Asian countries indicate that infants experience later bedtimes in the evening, later rise times in the morning, and shorter durations of nighttime sleep. Moreover, parents of infants from predominantly Asian countries also perceive that their infants experience more problematic sleep relative to parents of infants from predominantly Caucasian countries (Mindell, Sadeh, Wiegand, How, & Goh, 2010; see also Chou, 2007; Jiang et al., 2007). We expected the introduction of disposable diapers to result in improved infant sleep, relative to that of infants wearing traditional cloth diapers. We conducted the experimental manipulation of sleep for six weeks in order to maintain consistency with the intervention reported in Morrell and Steele (2003).

In the present research, 6-month-old Chinese infants were randomly assigned to continue wearing traditional cloth diapers or to use provided disposable diapers at night for a 6-week period. Parents provided information on the nighttime sleep habits of their infants over the course of the 6-week diaper manipulation; a subset of infants also wore actigraphs for a portion of the manipulation. In addition, infants and their mothers engaged in a play-based interaction task before the imposition of the diaper manipulation and near its completion. This interaction was expected to inform the question of whether infant sleep is predictive of characteristics of parent-infant interactions that form the foundation for emerging attachment relationships. We predicted that disposable diaper use would be associated with reductions in the frequency and duration of nighttime sleep disturbances. Based on previous research, we also expected that disposable diaper use would be related to increases in infant engagement and positive affect relative to the first administration of the task and relative to infants who wore traditional cloth diapers (Minde et al., 1994). We also anticipated that the mothers of infants who wore disposable diapers would display more engagement and sensitivity after the 6-week manipulation relative to mothers of infants who wore cloth diapers (Priddis, 2009).

Method

This research was supported by private industry. The sponsor's representative participated in the conceptual design of the study

and in enabling the logistics for study execution. He did not participate in defining the specific measures included in the study or in the reduction, analysis, or interpretation of the results. The first and anchor authors (academics unassociated with private industry) had complete control and decision-making authority regarding those aspects of the study.

Participants

Eighty-two 6-month-old infants (mean age = 6 months, 2 days; range 5 months, 13 days to 6 months, 18 days; 39 girls) participated. Three additional infants were enrolled but did not complete the study (one family moved, one infant was withdrawn due to grandfather discomfort with the procedure, and another infant was withdrawn but no reason was provided). Families were enrolled by a recruitment agency from the cities of Jinzhou ($n = 43$ infants; 20 girls) and Shenyang ($n = 39$ infants; 19 girls) in the Liaoning province of northeastern China.

Families were recruited by a paid agency, using hospital birth records. Parents were invited to participate if their infants met the following criteria: full-term birth (40 ± 4 weeks gestational age); experiencing an apparently normal course of development with no known mental or physical conditions or disorders; routinely wore cloth diapers, and wore them exclusively during the seven nights prior to the recruitment interview; and experienced at least four sleep disruptions per night for diaper changes or infant toilet training (the Chinese commonly attempt to toilet-train infants who are no more than a few months old; Chou, 2009). Infants were excluded from participation if their parents reported that they had experienced any perinatal complications, if they had any chronic health conditions, or if they had previously participated in a study involving the use of disposable diapers. Parents of infant participants were provided with monetary incentives or infant toys (approximately \$75 per family).

Materials, Measures, and Procedures

The following procedures were approved by Institutional Review Boards at the Procter and Gamble Company, an American university, and a Chinese hospital. Parents signed informed consent statements before participating in the study with their infants.

Group assignment. Families were randomly assigned times to attend their enrollment interviews. After the interview was complete, infants who were eligible to participate were assigned to either the cloth diaper group or the disposable diaper group. The first enrolled infants of each sex were assigned to the cloth diaper group; the next infants of each sex were assigned to the disposable diaper group; and so on, until the complete sample was realized.

The diaper manipulation. At the start of the 6-week diaper manipulation, parents of infants in the disposable diaper group were given a live demonstration of how to apply disposable diapers and were informed of their properties. In particular, parents were told that disposable diapers are more absorbent and less prone to leakage than are cloth diapers, such that they are able to absorb all of the urine emitted by an infant throughout the night; parents were not provided with any other direction about the need to reduce or eliminate nighttime sleep disruptions. This information session was provided by the recruitment agency and was necessary because the parents were generally unfamiliar with disposable diaper application and use.

Parents of infants in the disposable diaper group were provided with free supplies of high-absorbency disposable diapers (Pampers Baby Dry manufactured by the Procter & Gamble Company) and were instructed to use them on their infants each night for the following six weeks; instructions were not provided concerning daytime diaper use (parents were provided with enough diapers for both daytime and nighttime use). Parents of infants in the cloth diaper group were not provided with any information about disposable or cloth diapers; they also did not receive any free supplies of cloth diapers.

Home visit questionnaires. Study personnel visited the homes of enrolled families 14 times during the course of the study. One baseline visit was completed before the initiation of the diaper manipulation to assess the frequency of sleep disruptions the previous night for diaper changes or other reasons. The other 13 visits occurred during the 6-week diaper manipulation. At these visits, study personnel asked parents to report (a) whether their infant wore the appropriate type of diaper the previous night, (b) the frequency of sleep disruptions the previous night for the purposes of diaper changes, and (c) the frequency of sleep disruptions the previous night for reasons other than diaper changes. Study personnel also provided additional free diapers to families in the disposable diaper group and reminded parents about their properties.

Nighttime sleep diaries. Parents completed detailed nighttime sleep diaries about the sleep habits of their infants for three consecutive nights during either the fourth or fifth weeks of the 6-week diaper manipulation. Nighttime sleep reports were made during either the fourth or the fifth weeks of the diaper manipulation in order to coincide with the actigraph recordings, as described below. A 3-day recording period was chosen as previous research has indicated that this duration is optimal when asking parents to complete detailed daily diaries concerning infant behavior patterns (St. James-Roberts & Plewis, 1996; see also Bernier, Carolon, Bordeleau, & Carrier, 2010). Parents were asked to indicate (a) when their infant was put to bed at night and when the infant woke the next morning, (b) the frequency of sleep disruptions the previous night and whether the infant woke as a result of the disruption, and (c) the duration of nighttime sleep disruptions, again differentiating between when the infant was and was not woken from sleep. Parents were asked to record each event immediately after its occurrence, thereby allowing for the most accurate self-report measure possible.

Actigraphy. A subset of 38 infants (19 infants from the disposable diaper group and 19 infants from the cloth diaper group; 18 girls) were randomly selected to wear an actigraph (Actiwatch16, Respironics, Inc., Bend, OR) around their left ankle during either the fourth or fifth weeks of the 6-week diaper manipulation. The recordings occurred over the course of two separate weeks due to the number of actigraphs available for use. Actigraphs are commonly used to record infant sleep habits since the collected data are more objective than those gathered through parent-report (Sadeh, 1996, 2007) and are generally in agreement with records obtained through polysomnography (Sadeh, Lavie, Scher, Tirosh, & Epstein, 1991).

Interaction task. Infants participated in a 5-min interaction task with one of the adults who accompanied them to the test site both before the initiation of the diaper manipulation and near its completion (mean delay between interactions = 42 days; range

from 42 to 46 days); the analyses in the present report are limited to mothers who participated in the interactions with their infants at both time points. In previous research, the duration of interaction tasks ranged from 3–5 min (Priddis, 2009) to 15 minutes (Dearing et al., 2001). During the interaction task, infants sat in a Bumbo chair or infant walker directly across from their caregiver, who was seated on a padded floor. Once the caregiver and infant were seated, one camera was directed toward the infant and another was directed toward the caregiver. The cameras were focused so that they recorded both the infant and the caregiver as well as the activities in which they were engaged. The images for both cameras were recorded onto the same disk using picture-in-picture technology; the larger picture was devoted to the infant and the smaller picture was devoted to the caregiver. Once the cameras were positioned, the caregivers were given a plastic bucket that contained three age-appropriate infant toys that were commercially available in the United States but not in China. The selection of toys featured a plastic caterpillar with rings that could be moved along the length of its body, an octopus with moveable tentacles, and a small plastic abacus.

Caregivers were asked to interact with their infants as they usually did when playing at home. After the instructions, the video cameras were set to record and a researcher started timing the interaction period. The researcher left the room until the interaction period ended.

Data Reduction

Home visit questionnaires. The primary variable of interest from the home visit questionnaires was the frequency of nighttime sleep disturbances. This measure was calculated separately for the one baseline night before the initiation of the diaper manipulation and for the final night of data collection during the diaper manipulation. Parents also reported the number of times they placed their infants in the assigned type of diaper each night.

Nighttime sleep diaries. Variables concerning the frequency and duration of nighttime sleep disruptions were created from the nighttime sleep diaries. Sleep disruptions were operationalized as diaper changes, feedings, or other parent-reported manipulations of and/or interactions with the infant as he or she slept. Frequency measures were the cumulative number of times infant sleep was disturbed, the number of times infants were disturbed and woken from sleep, and the number of times infants were disturbed but not woken from sleep. Duration measures were the cumulative amount of time infant sleep was disturbed, the amount of time infants were disturbed and woken from sleep, and the amount of time infants were disturbed but not woken from sleep. Mean values were created for both the frequency and duration measures by averaging responses across the three reported nights.

Actigraphy. Variables concerning the frequency and duration of nighttime sleep disturbances were reduced from the actigraph recordings through the use of a commercially available data reduction program (Actiware, Respironics, Inc., Bend, OR). The frequency measure was the number of nighttime sleep disturbances experienced during the night. Duration measures were the total duration of time spent awake, the mean duration of wake episodes, the total duration of time spent asleep, the mean duration of sleep episodes, and the total duration of the sleep period, or the amount of time the parent indicated that the infant was in bed; the percent

of time spent asleep during the night also was computed. Mean values were created by averaging records across the three reported nights.

Interaction task. Because of our interest in examining mother-infant interaction as a function of group assignment, we excluded from data analysis the cases in which the mother was not the interaction partner. In addition, only mother-infant dyads with a minimum of 3 min of interaction at both sessions were included in data coding and analysis. These constraints resulted in elimination of (a) eight infants who participated in the interaction task with someone other than their mother (a grandmother or father commonly served as the partner in these instances), (b) five infants who had at least one interaction session that was less than 3 min in duration, and (c) two infants who did not participate in the mother-infant interaction task. The data from an additional nine infants were excluded due to procedural error or recording equipment failure. The resulting sample was 29 infants from the disposable diaper group (14 females) and 29 infants from the cloth diaper control group (13 females). For these participants, the mother-infant interaction lasted an average of 4 min, 14 s at the first administration (range from 3 min, 49 s to 6 min); at the second administration, the interaction task lasted an average of 4 min, 8 s (range from 3 min, 30 s to 5 min, 50 s). The lengths of the interaction periods did not differ between administrations.

The data from the first and second administrations of the mother-infant interaction task were coded by four undergraduate students who were unfamiliar with the hypotheses of the study or the group to which each infant was assigned. Three of the coders were native Mandarin speakers, and the third coder learned Mandarin when she was young and still spoke the language daily at the time of coding. All of the students indicated that their comprehension abilities ranged from above average to excellent, and none of the coders reported difficulty understanding the dialect spoken by the mothers or the phrases that were used during the interactions.

The data from each session were coded using the coding scheme for mother-infant interactions described in the NICHD Study of Early Childcare (NICHD Early Child Care Research Network, 1997). Behaviors were coded on 4-point scales for each 5-min interaction period. The infant variables were positive affect, negative affect, activity level, sociability, and sustained attention. Maternal variables were responsiveness to distress, responsiveness to nondistress, intrusiveness, detachment, stimulation of development, positive regard for the infant, negative regard for the infant, and flatness of affect. Because the coding scheme required coders to make qualitative judgments about the behavior in question based on the coding rules, primary coders scored the data in pairs. One student was responsible for coding all of the sessions, whereas two other students each coded approximately 50% of the overall sample with her. For each interaction, the coders rated each behavior independently and then compared their responses. Codes that were the same for both coders were retained and differences were reconciled through discussion and review of the video records. The fourth undergraduate student then independently viewed and coded the videos for approximately 25% of the sample included in data analysis ($n = 16$; 8 infants in each group). Two-way mixed intraclass correlations (ICC) computing absolute agreement across sessions are listed below.

We subjected the coded data to separate principal components analyses by participant (mother or infant) with varimax rotation in

order to reduce the number of variables under investigation. Principal components analyses only included data from the first administration of the assessment, given our hypothesis that data from the second administration of the assessments would be impacted by the 6-week diaper manipulation. Maternal responsiveness to distress was not included in the factor analysis for mothers given the low incidence of infant distress at both the first and second administrations of the mother-infant interaction (12 mothers had data at the first administration and 9 mothers had data at the second administration). Two factors emerged for infants: infant engagement and positive affect included codes for negative affect (reverse-scored), positive affect, sociability, and sustained attention (ICC = .88); the second factor included only infant activity level (ICC = .79). Three factors emerged for mothers: maternal engagement and sensitivity included codes for intrusiveness (reverse-scored), positive regard for the infant, responsiveness to nondistress, and stimulation of development (ICC = .70); maternal indifference included codes for detachment and flat affect (ICC = .75); the third factor included only maternal negative regard for the infant (ICC = .34). The lower ICC value for the third factor may have resulted from the restricted range of the coded scores, since there was 91% agreement between the coders on this factor. Mean factor scores were created based on these classifications and were subject to analysis as described in the Results section.

Results

Demographic information for the cloth diaper and disposable diaper groups is provided in Table 1. Chi-square analyses were used to examine group differences on dichotomous variables; analyses of variance were conducted on continuous variables. Group differences were not found on any of the demographic variables.

We determined which background characteristics to include as covariates in the following analyses by conducting correlations between the demographic variables shown in Table 1 and the sleep data obtained during the diaper manipulation as reported on (a) the home visit questionnaires, and (b) the nighttime sleep diaries. Analyses revealed that test site (coded as 0 = Shenyang and 1 = Jinzhou), infant sex (coded as 0 = male and 1 = female), and whether infants woke during nighttime diaper changes (coded as 0 = no and 1 = yes) were correlated with at least two sleep variables obtained during the course of the diaper manipulation; test site and whether infants woke during nighttime diaper changes were also correlated. Given these relations, test site and infant sex were initially included as dichotomous covariates in analyses of variance but were removed from the models if $p \geq .10$; the presented correlations were also conducted controlling for the influence of test site and infant sex. Significant findings are presented when $p \leq .05$.

Sleep Measures

Home visit questionnaires. The data from the home visit questionnaires are shown in Table 2. We examined relations between group assignment and nighttime sleep disruptions by conducting analyses of covariance with group assignment as a between-subjects variable and administration (baseline and 6-week) as a within-subjects variable, since this is the strongest test of the effect of the diaper manipulation.²

Table 1
Demographic Characteristics of Infants Enrolled in the Cloth Diaper and Disposable Diaper Groups

	Cloth diapers (<i>n</i> = 41)	Disposable diapers (<i>n</i> = 41)	Group differences		
			Statistic	<i>p</i> -value	Effect size
Percent girls	44	51	$\chi^2 = .44$	.51	<i>r</i> = .07
Percent from Shenyang	49	46	$\chi^2 = .04$	.83	<i>r</i> = .02
Percent of infants fed by breast	73	63	$\chi^2 = .90$	.34	<i>r</i> = .10
Percent of infants fed by bottle	46	54	$\chi^2 = .44$	.51	<i>r</i> = .07
Percent of infants who ate food other than by breast or bottle	98	100	$\chi^2 = 1.01$	.31	<i>r</i> = .11
Percent of infants who were teething	22	22	$\chi^2 = .00$	1.00	<i>r</i> = .00
Percent of infants who engaged in bed-sharing	73	73	$\chi^2 = .00$	1.00	<i>r</i> = .00
Number of individuals with whom the bed was shared	1.76 ± .09	1.77 ± .09	<i>F</i> = .00	.95	<i>d</i> = .00
Number of diaper changes at night	4.24 ± .11	4.17 ± .11	<i>F</i> = .24	.63	<i>d</i> = .00
Percent of infants who woke during nighttime diaper changes	90	83	$\chi^2 = .95$	.33	<i>r</i> = .11
Of the infants who woke during nighttime diaper changes, the percent who required fewer than 15 min to fall back to sleep	95	97	$\chi^2 = .27$	.61	<i>r</i> = .06

A significant Group × Administration interaction was found when considering the number of nighttime sleep disruptions due to diaper changes. Follow-up pairwise comparisons conducted by session revealed that the groups did not differ at baseline. In contrast, infants who wore disposable diapers experienced fewer sleep disruptions due to diaper changes at the final assessment relative to infants who wore cloth diapers. Significant effects associated with group, administration, and their interaction were not found when considering the number of sleep disruptions unassociated with diaper changes. However, a significant Group × Administration interaction was found when considering the total number of nighttime sleep disruptions. Follow-up pairwise comparisons revealed the same pattern of significance found when considering nighttime sleep disruptions due to diaper changes. Taken together, these data suggest that the total number of nighttime sleep disruptions is largely due to differences in the number of nighttime sleep disruptions resulting from diaper changes.

Data obtained from the home visit questionnaires also provided information on parental compliance with the study procedure. Parents reported using the appropriate diaper on their infants on each of the nights under investigation (100% compliance). Taken together, these data provide evidence that the group differences in infant sleep likely resulted from the imposed diaper manipulation, since (a) parents conformed to the groups to which their infants were assigned, and (b) significant differences were obtained only on the dependent measures that included assessment of nighttime diaper changes.

Nighttime sleep diaries. The data from the nighttime sleep diaries are shown in Table 3. We conducted one preliminary between-subjects analysis to determine whether infants in the two groups spent similar durations of time in bed at night, since infants who spent more time in bed at night would have greater opportunity for their sleep to be disrupted. The results indicated that infants who wore cloth diapers spent more time in bed at night before accounting for any nighttime sleep disruptions relative to infants who wore disposable diapers. Given this a priori group difference, we statistically controlled for the duration of time spent in bed at night in all subsequent analyses concerning the nighttime sleep diaries. This covariate was removed from the models when $p \geq .10$; correlations concerning the nighttime sleep diaries are also presented controlling for the duration of time spent in bed at night.

As was found using the home visit questionnaires, analyses indicated that the diaper manipulation produced group differences in infant sleep. Infants who wore cloth diapers at night experienced more frequent sleep disruptions overall as well as a greater number of disruptions that did and did not wake the infant from sleep relative to infants who wore disposable diapers. Infants who wore cloth diapers also experienced disruptions that were longer in duration relative to infants who wore disposable diapers when considering the total amount of time infants were disrupted as well as disruptions that did and did not wake the infant from sleep. There was no difference in the amount of time infants spent in bed

Table 2
Infant Nighttime Sleep Disruptions as Reported to Study Personnel at the Home Visits (Means and Standard Errors)

	Baseline		Postmanipulation		Manipulation effect		
	Cloth diapers (<i>n</i> = 41)	Disposable diapers (<i>n</i> = 41)	Cloth diapers (<i>n</i> = 41)	Disposable diapers (<i>n</i> = 41)	Statistic	<i>p</i> -value	<i>r</i> effect size
Total number of disruptions	5.17 ± .21	4.73 ± .21	5.05 ± .17	1.61 ± .17	<i>F</i> = 72.08	<.0001	.75
Number of diaper changes	4.12 ± .19	3.93 ± .19	3.73 ± .17	.10 ± .17	<i>F</i> = 104.53	<.0001	.69
All other disruptions	1.04 ± .22	.82 ± .22	1.32 ± .21	1.51 ± .21	<i>F</i> = 1.10	.30	.12

Note. The statistics and effect sizes are presented for the analyzed Group × Administration interaction. The baseline data represent one night of data collection before the imposition of the manipulation and the 6-week data represent the final night of data collection at the end of the manipulation.

Table 3
Infant Nighttime Sleep Disruptions as Recorded by Caregivers in Detailed Nighttime Sleep Diaries (Means and Standard Errors)

	Cloth diapers (<i>n</i> = 41)	Disposable diapers (<i>n</i> = 41)	Group differences		
			Statistic	<i>p</i> -value	<i>d</i> effect size
Total duration of time spent in bed at night	658.21 ± 9.55	604.07 ± 9.55	<i>F</i> = 16.07	<.0001	.90
Total number of disruptions	4.99 ± .15	2.07 ± .15	<i>F</i> = 199.58	<.0001	3.10
Number of disruptions with wakes	3.68 ± .19	1.68 ± .19	<i>F</i> = 56.69	<.0001	1.71
Number of disruptions without wakes	1.30 ± .14	.41 ± .14	<i>F</i> = 20.45	<.0001	1.04
Total duration of time spent disrupted	84.94 ± 6.02	49.64 ± 6.02	<i>F</i> = 15.82	<.0001	.90
Duration of disruptions with wakes	73.04 ± 6.36	45.43 ± 6.36	<i>F</i> = 8.68	.004	.65
Duration of disruptions without wakes	11.65 ± 1.65	4.46 ± 1.65	<i>F</i> = 9.54	.003	.70
Total duration of time spent in bed at night after accounting for all nighttime disruptions	563.69 ± 8.55	564.01 ± 8.55	<i>F</i> = .00	.98	.00

Note. Duration measures are reported in minutes.

at night after accounting for the duration of all nighttime sleep disruptions.

Actigraph recordings. The actigraphy data are shown in Table 4. Analyses conducted on the primary variables of interest from the actigraphs indicated that group differences in nighttime sleep patterns were also apparent during the diaper manipulation when objective recording techniques were used. In particular, infants who wore cloth diapers spent more time awake at night both when considering the total amount of time spent awake and the average amount of time spent awake during the sleep episode. Infants who wore cloth diapers also experienced less sleep relative to infants who wore disposable diapers, as indicated by the percentage of time spent asleep.

Consistency of Findings Across Reporting Techniques

Correlations between select measures from the nighttime sleep diaries and the actigraphs were computed to determine whether consistency was apparent in parent reports and objective assessments of infant nighttime sleep habits. Consistency between parent report and actigraphy measures was apparent in the frequency measures, such that more frequent sleep disruptions overall, $r(31) = .47, p < .005$, as well as more frequent disruptions that woke the infant from sleep, $r(31) = .46, p < .005$, were related to the number of wake episodes recorded with the actigraphs. The frequency of disruptions that did not wake the infant as indicated by parents was unrelated to the number of wake episodes, $r(31) = .06, p = .71$, recorded by the actigraphs. Consistency was not

apparent in the duration measures pertaining to nighttime sleep disruptions, however (r s from $-.01$ to $.22$, p s from $.21$ to $.97$). Nevertheless, the total amount of time spent in bed at night after accounting for all other disruptions as reported by the parents was significantly related to the total duration of time spent asleep from the actigraphs: $r(32) = .47, p < .003$.

Interaction Task

We investigated relations between group assignment and characteristics of mother-infant interaction patterns by conducting analyses of covariance with group assignment as a between-subjects variable and administration (baseline and 6-week) as a within-subjects variable. The data from the mother-infant interaction task are presented in Table 5.²

Infant measures. A significant Group × Administration interaction was found on the infant factor score pertaining to engagement and positive affect. Follow-up pairwise comparisons conducted by session revealed that the groups did not differ on infant engagement and positive affect at baseline. In contrast, infants who wore disposable diapers demonstrated more engagement and positive affect relative to infants who wore cloth diapers at the 6-week assessment. Additional pairwise comparisons conducted by group indicated that this effect was due to increased engagement and positive affect across administrations for infants who wore disposable diapers during the 6-week manipulation, whereas change over time was not apparent for infants in the cloth

Table 4
Infant Nighttime Sleep Disruptions During the Nighttime Sleep Period as Recorded by Actigraphs (Means and Standard Errors)

	Cloth diapers (<i>n</i> = 19)	Disposable diapers (<i>n</i> = 19)	Group differences		
			Statistic	<i>p</i> -value	<i>d</i> effect size
Number of wake episodes	4.95 ± .44	3.79 ± .44	<i>F</i> = 3.46	.07	.63
Total duration of time spent awake	99.04 ± 8.83	61.53 ± 8.83	<i>F</i> = 9.02	.005	1.01
Total duration of time spent asleep	495.92 ± 13.27	527.51 ± 13.27	<i>F</i> = 2.83	.10	.56
Mean duration of wake episodes	20.33 ± 1.63	14.85 ± 1.63	<i>F</i> = 5.66	.02	.80
Mean duration of sleep episodes	99.54 ± 23.80	157.87 ± 23.80	<i>F</i> = 3.00	.09	.58
Percentage of time spent asleep	83.71 ± 1.43	89.48 ± 1.43	<i>F</i> = 8.10	.007	.95
Total duration of sleep period	594.96 ± 11.92	589.04 ± 11.92	<i>F</i> = .12	.73	.00

Note. Duration measures are reported in minutes.

Table 5
Group Differences in Participant Behavior at the First and Second Administrations of the Mother-Infant Interaction Task

	Baseline		Postmanipulation		Manipulation effect		
	Cloth diapers (<i>n</i> = 29)	Disposable diapers (<i>n</i> = 29)	Cloth diapers (<i>n</i> = 29)	Disposable diapers (<i>n</i> = 29)	Statistic	<i>p</i> -value	<i>r</i> effect size
Infant measures							
Engagement and positive affect	2.51 ± .11	2.38 ± .11	2.49 ± .08	2.74 ± .08	<i>F</i> = 4.99	.03	.29
Activity level	2.31 ± .12	2.14 ± .12	2.31 ± .11	2.21 ± .11	<i>F</i> = .22	.77	.06
Maternal measures							
Engagement and sensitivity	2.43 ± .09	2.35 ± .09	2.28 ± .10	2.58 ± .10	<i>F</i> = 5.71	.02	.30
Detachment and flat affect	1.26 ± .11	1.41 ± .11	1.37 ± .14	1.62 ± .14	<i>F</i> = .22	.65	.06
Negative regard for child	1.10 ± .07	1.14 ± .07	1.10 ± .07	1.17 ± .07	<i>F</i> = .07	.80	.04

Note. The statistics and effect sizes are presented for the analyzed Group × Administration interaction.

diaper control group. Group differences were not found on the factor score pertaining to infant activity level.

Maternal measures. A significant Group × Administration interaction was found on the maternal factor score pertaining to engagement and sensitivity. Follow-up pairwise comparisons conducted by session revealed that the groups did not differ on maternal engagement and sensitivity at baseline. In contrast, mothers of infants who wore disposable diapers demonstrated more engagement and sensitivity relative to mothers of infants who wore cloth diapers at the 6-week assessment. Additional pairwise comparisons conducted by group indicated that this effect was due to increased engagement and sensitivity across administrations for mothers of infants who wore disposable diapers during the 6-week manipulation, whereas change over time was not apparent for mothers of infants who wore cloth diapers. Group differences were not found on the factor scores pertaining to maternal indifference or maternal negative regard.

Discussion

The present research was conducted to examine the influence of an experimental manipulation of disposable diaper use on (a) infant sleep habits, and (b) characteristics of mother-infant interactions in typically developing 6-month-old Chinese infants without any documented sleep problems. Results indicated that the diaper manipulation promoted consolidated nighttime sleep and facilitated more positive mother-infant interactions. In particular, data from the nighttime sleep diaries indicated that relative to infants who wore cloth diapers, infants who wore disposable diapers during the 6-week manipulation experienced less frequent sleep disruptions overall as well as fewer disruptions that did and did not wake the infant from sleep. In addition, the data from the actigraphs indicated that infants who wore disposable diapers slept for a greater proportion of the night relative to infants who wore cloth diapers. Consistency was also apparent in the parent-report and actigraphy measures of the frequency of nighttime sleep disruptions, although parents were less informative as to the duration of nighttime sleep disruptions.

The diaper manipulation also affected characteristics of mother-infant interactions as indicated by significant Group × Administration interactions with medium effect sizes (Cohen, 1988). Infants who wore disposable diapers during the 6-week manipulation received higher ratings on a composite score of engagement and positive affect at the second administration of the mother-infant

interaction relative to the infants who wore cloth diapers; the ratings were made by coders who were unaware of the group assignment of the dyads. This effect resulted from infants in the disposable diaper group receiving higher ratings on the composite over time relative to infants in the cloth diaper group, whose scores did not change across administrations. Effects of the diaper manipulation were also observed on maternal behavior. In particular, the mothers of infants who wore disposable diapers received higher ratings on a composite of engagement and sensitivity at the second administration of the interaction task relative to mothers of infants who wore cloth diapers. This finding also resulted from change over time for mothers of infants who wore disposable diapers relative to the ratings for mothers of infants who wore cloth diapers, which remained relatively stable across administrations. These results indicate successful experimental manipulation of infant sleep habits and characteristics of mother-infant interactions in typically developing 6-month-old Chinese infants through the use of disposable diapers in combination with parent information sessions over a 6-week period.

Our findings are remarkably similar to those obtained by Minde, Faucon, and Falkner (1994), even though our data were not collected from infants with sleep problems. The similarity of our findings suggests evidence of generalizability across cultures, although the possibility of cross-cultural differences should be further explored in infants from different countries using the same experimental procedures. Both our study and that published by Minde and colleagues (1994) report that the manipulation facilitated infant sleep and promoted positive gains in mother-infant interactions. Whereas we report on change in infant and mother behavior in this study, Minde and colleagues (1994) identified differences in infant behavior alone. They suggest that their intervention may not have influenced maternal behavior during the interaction task because the mothers were not the ones who participated in the intervention. Had the mothers participated, the authors suggest that their behavior may have been altered either through (a) increases in parent mood due to changes in infant sleep habits, or (b) generalizing principles learned during the counseling sessions to daytime interactions with the infant. Nevertheless, other studies indicate that infant sleep habits are associated with maternal behavior during parent-infant interactions (Paret, 1983; Priddis, 2009; Schwichtenberg & Poehlmann, 2009).

We speculate that the interaction findings obtained in the present report likely result from increases in parent mood due to

changes in infant sleep habits relative to the generalization of principles learned while participating in the diaper manipulation. Because the informational sessions were specific to the properties and practical application of disposable diaper use and parents were not instructed which diapers to use on their infants during the day, it is more probable that increases in maternal positive affect and reductions in fatigue were associated with changes in maternal behavior during the parent-infant interaction. Based on the transactional theory developed by Sameroff (Sameroff, 1989; Sameroff & Emde, 1989) and extended by Sadeh and colleagues (Sadeh & Anders, 1993; Sadeh et al., 2010), an alternative explanation may be that consolidated infant sleep facilitated increased infant engagement and positive affect, which then promoted maternal engagement and sensitivity. Of course, these possibilities are not mutually exclusive. Future research should examine these issues directly by focusing on changes in parent sleep habits and health indices (both mental and physical) as infants participate in sleep manipulation studies. Indeed, research has indicated that mothers of infants with sleep problems report worse mental health (Bayer, Hiscock, Hampton, & Wake, 2007; Goldberg et al., 2013) and physical (Bayer et al., 2007), and that sleep interventions may ameliorate these problems (Hiscock et al., 2007; Hiscock, Bayer, Hampton, Ukoumunne, & Wake, 2008; Hiscock & Wake, 2002; Mindell et al., 2011). Independent assessment of maternal sleep quality through the use of actigraphs or through questionnaires such as the Pittsburgh Sleep Quality Index (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989) would allow for the determination of whether maternal sleep quality is affected by infant sleep manipulations and whether these changes mediate relations between infant sleep habits and maternal behaviors in the parent-infant interaction task. Previous research has suggested that maternal sleep quality mediates the relation between infant sleep habits and parent mental health (Bayer et al., 2007) and that maternal sleep quality is associated with parent perceptions of infant behavior, such as infant sadness (Tikotzky, Chambers, Gaylor, & Manber, 2010).

In addition to including measures of maternal sleep and health, future research should also attempt to directly relate infant nighttime sleep data to characteristics of mother-infant interactions at the second session. Although we collected parent-report data on infant sleep for all of the infants enrolled in the study and had actigraph recordings on a subset of the infant participants, these measures were not obtained at the same time of the mother-infant interactions. The recording of infant sleep was completed during the fourth or fifth weeks of the diaper manipulation, whereas the mother-infant interactions occurred before the initiation and during the final week of the diaper manipulation. This difference in the timing of measurements would have made the interpretation of correlations between infant sleep and mother-infant interactions tenuous. Nevertheless, the observed group differences in infant and maternal behavior at the second administration of the interaction suggest that changes in sleep behavior likely contributed to the obtained pattern of results.

Finally, future research should also attempt to identify the mechanism allowing for the changes in infant sleep habits. Because we did not differentiate between parent- and infant-initiated nighttime arousals, we could not determine whether wearing disposable diapers directly affected infant sleep, whether the parent information session led to reductions in the number of times

parents disrupted the sleep of their infants at night, or some combination of the two. Nevertheless, we suggest that the imposed manipulation likely influenced the behavior of both the infants and their parents. Parents may have reduced the number of times they disrupted the sleep of their infants at night due to the influence of the parent information sessions. Yet because parents were not made aware that wearing disposable diapers could reduce the amount of time infant sleep was disrupted at night, it is reasonable to attribute the group difference on this variable to the effect of the manipulation on the infants themselves. Future research could attempt to disentangle these effects within the imposed experimental paradigm by including an additional cloth diaper group whose parents are provided with information concerning the importance of reducing the number of times parents disrupt infant sleep at night. Additional work using a paradigm similar to the one described herein should also include provision of information sessions and free cloth diapers to parents of infants enrolled in the cloth diaper control group, since the provision of these additional experiences to parents of infants in the disposable diaper group could contribute to differential feelings of parental involvement in the study. Future research should attempt to facilitate consolidated nighttime sleep in other ways. For example, the implementation of a bedtime routine before infants went to sleep facilitated consolidated nighttime sleep (including the frequency and length of night wakings) and resulted in more positive maternal mood relative to control (Mindell, Telofski, Wiegand, & Kurtz, 2009).

Indeed, there are numerous additional directions for experimental work examining the causal influence of sleep manipulations on functional outcomes of both infants and their parents. This study is the first, to our knowledge, to include an experimental manipulation of diaper use and examination of infant nighttime sleep and parent-infant outcomes in infants without any known sleep problems. Other experimental manipulations have been conducted to examine whether infant napping behavior is causally related to cognitive functioning in infants (Gómez, Bootzin, & Nadel, 2006; Hupbach, Gomez, Bootzin, & Nadel, 2009; Werchan & Gómez, 2014); longitudinal research has helped inform this question as well (Bernier, Carlson, Bordeleau, & Carrier, 2010). However, there has been a paucity of experimental work examining causal relations between infant nighttime sleep and functional outcomes to date. In their review on associations between sleep and functional outcomes in infancy, Ednick et al. (2009) concluded that “. . . although the literature generally suggests an association between sleep and daytime functioning in infants, we currently do not have sufficient data to conclude that a causal relationship exists” (p. 1455). Our data suggest that nighttime sleep manipulations can be conducted with infants without sleep problems and that measurable gains can be observed in terms of consolidated nighttime sleep and characteristics of mother-infant interactions. Although we were afforded the opportunity to examine the impact of disposable diaper use and parent education about the properties of disposable diapers and their application in a sample of Chinese 6-month-old infants who did not commonly wear disposable diapers, we do not suggest that this manipulation is the only means of achieving the benefits reported in the present study. On the contrary, we are hopeful that researchers will examine other means by which to promote positive change in infant sleep for the purposes of examining causal relations between sleep and functional outcomes in infants and their parents. Such research endeavors will

not only more clearly identify the significance of infant nighttime sleep for infant and parent functioning in infants who do not have sleep problems but will also provide a metric against which to evaluate sleep-behavior relations in those who do.

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