Development of Behaviors in Preterm Infants: Relation to Sleeping and Waking

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Background: Although both nurse clinicians and researchers use infant behaviors to indicate the responses of preterm infant to stimulation, little is known about how the biological factors of development, sleeping and waking states, infant characteristics, and infant illness severity affect preterm infant behaviors.
Objectives: This study examined the development of eight infant behaviors over the preterm period and determined the relation of these behaviors to sleeping and waking and to infant characteristics and illness severity.
Methods: Seventy-one preterm infants were observed from 7 to 11 pm weekly from the time they were no longer critical until term or discharge. The occurrence of four sleep-wake states and eight behaviors were recorded every 10-seconds during the observations.
Results: Negative facial expressions increased over the preterm period, and sighs, startle/jerks, jitters, and the likelihood of having hiccups decreased. Infant characteristics had only minor effects: boys had more negative facial expressions, and longer mechanical ventilation was associated with more sighs and jitters. All behaviors showed state-related differences in frequency. In addition, only startle/jerks and jitters showed the same developmental patterns within each state.
Conclusions: Significant development of infant behaviors occurs over the preterm period but involves changes not only in the absolute percentage of each behavior but also in the percentages within each sleeping and waking state. Thus, preterm infant behaviors can not be used clinically for assessment without consideration of the state in which they occur.

Key words: Premature Infants, Infant Behaviors, Development

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Both nurse clinicians and researchers use specific infant behaviors to indicate preterm infant responses to stimulation. For example, changes in preterm behaviors have been used to identify acute medical complications, such as cold stress and sepsis (Holditch-Davis & Hudson, 1995), and pain (Walden et al., 2001). Researchers also used behaviors to show preterm infant responses to interventions that modified neonatal care so that it would be more developmentally appropriate (Chang, Anderson, & Lin, 2002). Infant behaviors have also been used by clinicians to indicate stress. However, there is little research validation for this. "Stress" behaviors did not differ between times when preterms were receiving routine and painful care (Grunau, Holsti, Whitfield, & Ling, 2000; Walden et al., 2001) and only occasionally differentiated the responses of preterm infants with and without chronic lung disease to handling (Medoff-Cooper, 1988).

Thus, a greater understanding of infant behaviors could strengthen the nursing care of preterm infants. According to the developmental science perspective (Cairns, Elder, & Costello, 1996), the infant and the environment form a complex system, in which every behavior of the infant is a function of the entire system (Thoman et al., 1983). Sub-systems within the infant, including maturation, physiological processes, such as sleeping and waking, and illnesses, affect the overall system and in turn are affected by it. Thus, the biological factors affecting infant behaviors as well as the environmental context of behaviors need to be examined. The purpose of this study, therefore, was to examine biological factors affecting eight preterm infant behaviors, specifically development, sleeping and waking, infant characteristics, and illness severity.

The amounts of infant behaviors are known to change over age (Cioni & Prechtl, 1990). Sighs were less common in fullterm infants than in preterm infants (Hoch, Bernhard, & Hinsch, 1998). The likelihood of having hiccups decreased and mouth movements increased with age over the third trimester in fetuses (D'Elia, Pighetti, Moccia, & Santangelo, 2001; Pillai & James, 1990). The amount of large body movements did not show developmental changes over the preterm period in infants (Giganti et al., 2001; Hayes, Plante, Kumar, & Delivoria-Papadopoulos, 1992) but did decrease in fetuses, possibly due to decreased room to move in utero late in gestation (D'Elia et al., 2001; Kisilevsky, Hains, & Low, 1999). The development of other behaviors, including startles, jitters, and negative facial expressions, has not been examined. Moreover, most studies compared incidence of behaviors in individuals of different ages; only one examined developmental changes longitudinally (D'Elia et al., 2001). Also, Only one study examined development in preterm infants (D'Elia et al., 2001; Hoch et al., 1998). Thus, little is known about developmental changes in infant behaviors over the preterm period, the time period of greatest interest to neonatal nurses.

In both preterm and fullterm infants, sleeping and waking is known to affect infant behaviors. Each behavior occurs primarily in a specific sleep-wake states. Sighs were more frequent in active sleep than quiet sleep in both fullterm and preterm infants (Hoch et al., 1998). Yawns and negative facial expressions were less common in quiet sleep than active sleep or waking states in near term fetuses and preterm infants (Giganti, Hayes, Akilesh, & Salzardo, 2002; van Woerden et al., 1988). In fullterm neonates, body movements occurred primarily in waking (Weggeman, Brown, Fulford, & Minns, 1987). Fullterm infants showed mouth movements and startles primarily in active sleep with rapid eye movements (REMs) (Korner, 1968), and startles were more common in sleeping, especially quiet sleep, than in waking states (Emory & Mapp, 1988; Huntington, Zeskind, & Weiseman, 1985; Korner, 1969). On the other hand, hiccups were not related to any particular state in near term fetuses (van Woerden, 1989). The relationship between behaviors and sleep-wake states is strong enough that a number of behaviors are used to define sleep. However, not until at least 36 weeks' post-conceptional age, do preterm infants show the same degree of correlation among these behaviors as fullterm infants (Curzi-Dascalova, Peirano, & Morel-Kahn, 1988). This suggests that both the amount of specific behaviors and the degree to which they are associated with particular sleep-wake states change with age.

The infant characteristics of gender and race have biological bases in the preterm period through prenatal hormones and the greater incidence of perinatal complications in minority infants (Johnson, 2000) and, thus, may affect infant behaviors. Although some researchers found no gender differences in fullterms in the amounts of large body movements, startles, and negative facial expressions (Korner, 1968; Weggemann et al., 1987), others have found that boys show more startles (Korner, 1969). African American preterm infants had more jitters than Caucasians (Pressler & Hepworth, 2002), but racial effects on other infant behaviors have not been studied.

Likewise, illness may affect infant behaviors. Even mild perinatal complications were related to more jitteriness and changes in the incidence of startles in different states in fullterm and preterm infants (Emory & Mapp, 1988; Huntington et al., 1985; Parker et al., 1990). Preterms with chronic lung disease had more sighs and jitters than other preterms (Holditch-Davis & Lee, 1993). High-risk fetuses have fewer large body movements than low-risk fetuses (Kisilevsky et al., 1999). At 41 weeks post-conceptional age, preterm infants had more large movements in active and quiet sleep and more facial movements in active sleep than fullterms (Booth, Leonard, & Thoman, 1980).

However, infant characteristics and illness severity effects on preterm infant behaviors have only rarely been studied along with development and sleep-wake states. Thus, how these factors jointly relate to preterm infant behaviors is unknown. The objectives of this study were 1) to examine the development of eight infant behaviors over the preterm period, 2) to determine how these behaviors relate to infant characteristics and illness severity, 3) to examine the development of these behaviors within different sleep-wake states, 4) to determine whether the relationships of these behaviors to infant characteristics and illness severity is different in different sleep-wake states, and 5) to determine whether the amounts of the behaviors are different in different sleep-wake states. Eight specific behaviors often observed by nurses were studied: yawn, sigh, negative facial expressions, startle/jerk, jitter, large body movements, mouth movements, and hiccups. These behaviors were related to four sleeping and waking states, to two infant characteristics (gender and race), and to illness severity indicators (birthweight, length of mechanical ventilation, and theophylline treatment). Birthweight and length of mechanical ventilation are known to be related to the neurological status and developmental outcomes of preterm infants (Bhutta, Cleves, Casey, Cradock, & Anand, 2002; McCarton, Wallace, Divon, & Vaughm, 1996); whereas theophylline is a common medication that is known to affect sleeping and waking (Thoman et al., 1985).

Methods

Participants

A convenience sample of 71 preterm infants, born at less than 35 weeks gestational age and at high risk for later developmental problems due to either a birthweight less than 1500 grams or a need for mechanical ventilation or continuous positive airway pressure, took part in this study; 56 infants were both smaller than 1500 gm and mechanically ventilated. They were patients in a neonatal intensive care unit of a regional perinatal center in the Southeast and participants in a larger study on the relationship between preterm behavior and developmental outcomes conducted in the late 1980s (Holditch-Davis & Edwards, 1998). This hospital did not use developmental care, other than for positioning and comforting infants. Infants with congenital problems associated with neurological or developmental problems (such as congenital hydrocephalus or Down Syndrome) were excluded. All other infants, including those with intraventricular hemorrhage, were eligible so that the sample would be representative of preterm infants in intensive care units.

Although neonatal nursing and medical care and the incidence of specific illnesses have changed since the time these infants were studied, the relation of biological factors, such as maturation, sleeping and waking, and illness severity, to infant behaviors should be unaffected by changes in treatment practices. To confirm that there were no changes over time in these relationships, we divided the sample into two cohorts. The only difference between the cohorts was that the 37 infants in the first cohort were recruited and studied before the 34 infants in the second cohort. There were no obvious changes between the cohorts in the nursing and medical care.

The demographic characteristics of the two cohorts are given in Table 1. The cohorts were compared using *t*-tests for continuous variables and Chi square analyses for categorical variables in Holditch-Davis and Edwards (1998). The only differences between the cohorts was that the mothers of cohort 2 infants were somewhat older than the first cohort mothers and that the infants in the second cohort were observed more often.

Variables Used for Data Analyses

Infant behaviors. Eight infant behaviors commonly observed by nurses were studied. Seven behaviors--yawn, sigh, negative facial expression, startle/jerk, jitter, large body movement, and hiccups--have been suggested to be signs of infant stress (Als et al., 1986). The eighth behavior, mouth movements, may be used by infants for self-comforting:

<u>Yawn</u>--The infant yawns.

Sigh-- A deep audible respiration of the infant.
Negative facial expression--The infant makes a cry face or a frown, in isolation or with crying.
Startle/Jerk--A sudden infant movement involving at least one whole extremity, as in a Moro reflex.
Jitter-- A rhythmic infant twitch of at least three cycles and involving part or all of the body.
Large body movement--A movement involving the extremities and the trunk.
Mouth movements—Definite movements of the infant's mouth, including sucking.
Hiccup--The infant hiccups.

Sleeping and waking states. The two sleep states were scored by direct observation of the infants, as defined in Holditch-Davis and Edwards (1998):

Active sleep--The infant's eyes are closed. Respiration is uneven and primarily costal in nature. Sporadic motor movements occur, but muscle tone is low between these movements. Rapid eye movements (REMs) occur intermittently.

Quiet sleep--The infant's eyes are closed, and respiration is relatively regular and abdominal in nature. A tonic level of motor tone is maintained, and motor activity is limited to occasional startles, sighs, or other brief discharges.

Periods when the infant showed mixed signs of active and quiet sleep were scored as quiet sleep if they were transitional either into or out of quiet sleep. Otherwise they were scored as active sleep. Active sleep was sub-divided into periods of active sleep with REMs and active sleep without REMs because the literature on fullterm infants suggests that neurological activity and infant behaviors may be different during phasic periods (active sleep with REMs) (Kohyama, 1996; Korner, 1968). The periods that infants were not in active or quiet sleep because they were awake or in transition between sleeping and waking were scored as non-sleeping.

Measures. For this report, the eight infant behaviors were measured as percentages of the total observation and of the four sleeping and waking states. These percentages were calculating by dividing the number of 10-second periods in which a behavior occurred by the number of 10-second periods in the total observation or each sleep-wake state.

Infant Characteristics. Information on seven infant characteristics and illness severity variables (post-conceptional age, cohort, birthweight, race, gender, days of mechanical ventilation, and theophylline treatment) was obtained form the medical record. Post-conceptional age at each observation was the number of weeks since birth added to gestational age at birth, which was calculated from the obstetric estimated date of confinement, determined either by the date of the mother's last menstrual period or by an ultrasound examination. If this gestational age did not agree within 2 weeks with the results of a gestational age examination (Ballard, Novak, & Driver, 1979) conducted by nursery staff on admission to intensive care, the age calculated using just the physical criteria on the assessment was used. Whether or not the infant was receiving theophylline was determined at each observation because theophylline is known to affect sleeping and waking (Thoman et al., 1985). Theophylline has a 30-hour half-life in the preterm period (Aranda & Turmen, 1979), so infants were scored as receiving theophylline if they had received a therapeutic dose (more than 2 mg per kg) of the drug in the 24 hours before the observation. Cohort 1 was scored as 0, and cohort 2 as 1. Race was scored as either white or minority. (There were 22 African American and 1 Native American infants in cohort 1 and 14 African American and 2 Native American infants in cohort 2.) Days of mechanical ventilation was a highly skewed variable (mean 10.3, standard deviation 13.0, median 5). Thus, infants with 1 day or less of mechanical ventilation were scored as receiving 1 day, and the natural log of each subject's score was used in analyses.

Procedures

Procedures for this study have been previously reported (Holditch-Davis & Edwards, 1998, Holditch-Davis & Lee, 1993). Briefly, the study was approved by the institutional committee for protection of human subjects. Infants were enrolled as soon as their medical conditions were no longer critical if an additional hospital stay of at least 1 week was anticipated and informed consent was obtained from the parents. They left the study on discharge or on reaching 40 weeks post-conceptional age. Thus, the ages at which subjects were in the study varied, but 27 weeks was the earliest study age for any infant, and 39 weeks was the oldest.

Infant behaviors and sleeping and waking states were observed once a week from about 7 to 11 pm. Because the purpose of the study was to examine the development of infant behaviors in the hospital environment, nursing and medical care and parental visiting continued during the observation period as though the observer were not there. During the observations, the occurrences of behaviors and sleeping and waking states were recorded every 10 seconds. The end of each 10-second period was signaled audibly through an earphone from a small electronic timer on a Tandy 100 portable computer used as an event recorder. At this signal, the observer recorded all behaviors that occurred during the period and the sleep-wake state lasting the greatest portion of the 10-second period. Multiple occurrences of the same behavior in the same epoch were not recorded, but these behaviors rarely occurred more than once every 10 seconds. Each observation was conducted by one of two observers, who observed the entire 4-hours without taking breaks but was able to sit down or move around the incubator to maintain a clear view of the infant even when visitors or nurses were at the bedside. Correlations between observers, calculated by having the observers score 45 minutes of observations together, were .99 for active and quiet sleep, .79 for the presence of REMs, and ranged from .79 (sigh) to 1.00 (hiccups) for the infant behaviors.

Data Analysis

The primary analysis for this study was the general linear mixed model, or mixed model, in the form of a random coefficients model (Fairclough & Helms, 1986; Holditch-Davis, Edwards, & Helms, 1998). The general linear mixed model (mixed model) is a flexible statistical procedure that is widely used for analyzing continuous longitudinal data and easily accommodates missing values and mistimed data. This approach models a curve across time, where time is included in the model as a continuous explanatory variable. It accounts for the correlation present across the repeated measures within each subject, as well as treating as random effects the subject-specific deviations from the overall curve for both the intercept and the slope. In this manner, a regression curve is computed for each subject, in addition to the overall mean curve. Parameterization of the mixed model includes population (fixed) effects while simultaneously calculating individual (random) effects. The fixed effects can be interpreted the same way as the effects in a multiple regression.

A generalized estimating equation (GEE) approach was used for hiccups due to its skewed distribution. The hiccups variable was converted into a dichotomous variable: either present or not present during an observation. Analyses examined the likelihood of having hiccups at each age. GEE is like the mixed model in its ability to accommodate missing values and mistimed observations (Zeger, Liang, & Albert, 1988). However, parameterization of the GEE only includes population (fixed) effects. Here, it was utilized to model time as a continuous explanatory variable, and the repeated measures within a subject were treated as being correlated.

To address objectives 1-4, infant behaviors as percentages of the total observation and of each sleep-wake state were regressed over post-conceptional age using either the mixed general linear model (for all behaviors except hiccups) or the GEE (for hiccups). Birthweight, race, gender, days of mechanical ventilation, theophylline treatment, and cohort were used as covariates in the fixed effects component of the model. Only intercept and post-conceptional age effects were included as random (individual subject) effects. Cohort was also used as a covariate. Prior to analysis, post-conceptional age was "centered" so that 34 weeks, roughly the mean value for post-conceptional age, equaled 0. An elimination (or model reduction) procedure was followed whereby each variable, except intercept and the linear effect of post-conceptional age, had to reach $p < 0.05$ in a preliminary mixed model. The variables remaining after this screening procedure were used in a final mixed model. This procedure simplified the model and led to inferences that some effects were either zero or not large enough to be detected. Valid covariance matrices were not obtained for the models with both random intercepts and slopes for two behaviors in non-sleeping (sigh and startle/jerk) so only random intercepts (but not random slopes) were included in the model.

To address objective 5 and determine whether infant behaviors differed between sleep-wake states, the difference in the percentage of each behavior in each pair of sleep-wake states was calculated. A mixed model was used to calculate the developmental pattern of the difference scores for all behaviors except hiccups. A significant intercept indicated the percentage of the behavior differed between the two states. A significant post-conceptional age effect indicated that the difference between the states changed over age. For hiccups, a record was formed for each pair of states at each age for each subject. A GEE model was then specified with the binomial distribution and logit link for main effects of age and state, as well as their interaction; an exchangeable correlation matrix was further specified. This provided a logistic regression line for each of the states, while accounting for the dependency due to the correlated effects within each subject. The main effect of state then corresponded to the difference in the intercepts of the lines, and the interaction provided the difference in the slopes.

Results

The infants in cohort 1 had 132 weekly observations, and 157 weekly observations were obtained for cohort 2. The number of observations for each infant ranged from 1 to 11, with 5 infants having only 1 observation. Infants averaged 39 minutes out the 4-hour observation with caregivers, including gavage feedings were left hanging after the nurse left the bedside and interruptions in caregiving lasting less than 2 minutes. Parents visited during only 36 observations.

Development of Infant Behaviors over the Entire Observation

Table 2 shows the analyses of the development of behaviors as percentages of the entire observation. Five behaviors showed development over the preterm period: the percentage of negative facial expressions increased, and sighs, startle/jerks, jitters, and the likelihood of having hiccups decreased. The developmental patterns of these five variables are shown in Figures 1 and 2.

The covariates had minor effects. Boys had more negative facial expressions. Length of mechanical ventilation was related to sighs and jitters, such that longer mechanical ventilation was associated with more sighs and jitters. Cohort 1 had more yawns, negative facial expressions, and large movements and greater likelihood of hiccups but fewer sighs. Birthweight, race, and theophylline treatment did not significantly affect the amount of any infant behavior.

Development of the Sleeping and Waking States

The percentage of three of the four sleeping and waking states changed significantly over age (see Table 3). Non-sleeping and quiet sleep increased, and active sleep without REM decreased over the preterm period. Active sleep with REM did not show significant developmental changes.

Development of Infant Behaviors within Sleeping and Waking States

Table 4 shows the analyses of the development of infant behaviors as percentages of the four sleeping and waking states. Every behavior showed significant development in at least one state, but only negative facial expressions, startle/jerks, and jitters showed significant development in all four states. Yawns decreased over age in non-sleeping and active sleep with REMs. Sighs decreased in all sleep states. Startle/jerks and jitters decreased in all states. Negative facial expression decreased in non-sleeping, active sleep with REM, and quiet sleep but increased in active sleep without REMs. Large body movements decreased in active sleep with REMs and quiet sleep but increased in active sleep without REM. Mouth movements increased in active sleep without REMs. The likelihood of hiccups decreased in both active sleep states.

Covariates had inconsistent effects. Only the few covariates with the same effects on a given behavior in more than one sleeping and waking state are likely to represent real effects, rather than chance findings. Cohort 1 had fewer sighs and more negative facial expressions in all sleep states and fewer jitters in active sleep without REMs and non-sleeping. Mechanical ventilation was related to more jitters in all states. Girls had fewer startle/jerks in active sleep without REMs and quiet sleep and fewer large movements in non-sleeping and quiet sleep. Minority infants had more jitters in non-sleeping and active sleep without REMs.

Relationship of the Sleeping and Waking States to the Percentages of Infant Behaviors

To determine whether state affected the percentages of variables, general linear mixed models (or GEEs) were conducted on the differences between each pair of states for each behavior (see Table 5). Yawns, negative facial expressions, and large movements were most frequent in non-sleeping, more frequent in the active sleep states than quiet sleep, and more frequent in active sleep without REM than in active sleep with REM. Mouth movements showed a similar pattern except that the active sleep states and non-sleeping did not differ. Jitters also showed a similar pattern, but the percentage of jitters did not differ between the two active sleep states. Startle/jerks occurred most frequently in active sleep without REMs, more frequently in both active sleep states than in quiet sleep, and least frequently in non-sleeping. Sighs occurred most frequently in quiet sleep, more frequently in active sleep states than in non-sleeping, and more frequently in active sleep without REMs than active sleep with REMs. The probability of having hiccups was lower in quiet sleep than in either active sleep state or non-sleeping.

A few state-related differences changed over age. The differences between non-sleeping and the sleep states for yawns became smaller with age. The difference in sighs between non-sleeping and quiet sleep and active sleep without REMS and between active sleep with and without REMs also became smaller with age. The differences in the percent of negative facial expressions between quiet sleep and active sleep without REM and between active sleep with and without REMs increased over age. For startle/jerk, the difference between quiet sleep and the two active sleep states became smaller with age. The difference between jitters in quiet sleep and active sleep with REM decreased over age, and although the two active sleep states did not differ significantly for jitters, the difference between them was larger at older ages. The differences in the percent of large movements between quiet sleep and active sleep without REMs and between the two active sleep states increased over age. The differences in the percent of mouth movements between quiet sleep and non-sleeping decreased over age, and the differences between the two active sleep states increased over age. Although the probability of having hiccups did not differ between non-sleeping and the active sleep states, the difference was greater between active sleep with REMs and non-sleeping at younger ages and between active sleep without REMs and non-sleeping at older ages.

Discussion

Clearly, development of infant behaviors occurs over the preterm period. The percentage of one behavior increased (negative facial expressions), and four decreased (sighs, startle/jerks, jitters, and the likelihood of having hiccups) over time. The development of behaviors was related to sleeping and waking. All behaviors showed state-related differences in frequency, and every behavior showed development in at least one sleep-wake state. However, only startle/jerks and jitters showed the same developmental patterns in all four states. Two behaviors showed opposite development in different states: negative facial expression decreased in four states and increased in the other, and large body movements decreased in two state but increased in a third.

Consistent with the findings of other studies, we found that infant behaviors exhibited developmental changes. Like other studies, we found that sighs and the likelihood of having hiccups decreased over age (Hoch et al., 1998; Pillai & James, 1990) and that large body movements did not show developmental changes (Giganti et al., 2001; Hayes et al., 1993). However, unlike D'Elia et al. (2001), we did not find any developmental changes in mouth movements. We also found developmental changes in startle/jerks, jitters, and negative facial expressions even though other studies have not examined the development of these behaviors. Our study examined development longitudinally over the preterm period so our findings are more likely than those of previous studies to be applicable to preterm infants in neonatal intensive care units.

Moreover, like other studies, we found that the frequency of infant behaviors differed in different sleeping and waking states. Similar to previous studies, we found that yawns, negative facial expressions, and large body movements were less common in quiet sleep than active sleep or waking states (Giganti et al., 2002; Weggeman et al., 1987; van Woerden et al., 1988) and that. mouth movements were most frequent in the active sleep states (Korner, 1968). Our finding that startle/jerks were most common in active sleep without REMs is similar to that of Huntington et al. (1985) but differed from studies finding more startles in quiet sleep (Emory & Mapp, 1988; Korner 1969). We found that sighs were more common in quiet sleep than active sleep, whereas other researchers found the opposite (Hoch et al., 1998), possibly because the other studies were limited to healthy infants without residual lung disease. We also found that the likelihood of having hiccups was lower in quiet sleep than either active sleep state or non-sleeping despite findings that hiccups in fetuses were not related to any particular state (van Woerden et al., 1989).

Since the amounts of the sleep-wake states changed over the preterm period and the amounts of behaviors differed among states, the development of sleeping and waking probably has a major impact on the development of most infant behaviors. Developmental patterns of behaviors reflect changes in both the absolute amounts of the behaviors and the amounts of the sleep-wake states in which they occurred. For example, an overall increase in negative facial expressions occurred despite a developmental decrease in three of four states because the state in which it was most common, non-sleeping, was increasing more rapidly over age than the rate at which negative facial expression was decreasing within this state. Thus, infant behaviors are not only a response to environmental stimulation but also reflect the sleeping and waking states in which they occur.

Compared to sleeping and waking, infant characteristics and illness severity had only minor effects on behaviors. Race, birthweight, and theophylline treatment had no effect on any behavior over the total observation although a previous study found that African American preterms had more jitters than whites (Pressler & Hepworth, 2002). Likewise, the only gender effects in this study were that boys had more negative expressions over the total observation, more startle/jerks in active sleep without REMs and quiet sleep, and more large movements in non-sleeping and quiet sleep. Some previous studies have found gender effects on behaviors (Korner, 1969), but others have not found any gender effects (Korner, 1968; Weggemann et al., 1987). Like other studies (Parker et al., 1990), we found that longer mechanical ventilation was related to more sighs and jitters. Unlike many studies, we did not find any effects of illness severity on body movements, facial movements, or startles (Booth et al., 1980; Emory & Mapp, 1988; Kisilevsky et al., 1999).

In fact, the covariate with the greatest effect on infant behaviors was cohort: infants from cohort 1 had more yawns, negative facial expressions, large movements, and likelihood of having hiccups but fewer sighs than cohort 2 infants. These cohort differences were not due to slight differences in the illness severity of the two cohorts since the illness differences were not significant and three covariates reflecting illness severity were included in every analysis. However, they may have reflected changes in the medical and nursing care of preterms, in the prenatal care of their mothers, and in the population of infants in the nursery between December 1985 to June 1988 when the first cohort was studied and July 1988 to September 1990 when the second cohort was studied. Contrary to expectations, historical changes probably affected the relation of infant behaviors to development, but these effects were small, ranging from 0.36% for yawns to 4% for large movements. Thus, the general relationships described in this study probably hold over time even though the absolute amounts of behaviors varied somewhat.

Altogether, our findings indicate that the factors affecting the frequency and development of infant behaviors in the preterm period are complex. Since sleeping and waking affected both frequency and development, future studies of behaviors need to include state. Research is also needed to determine the nature of the relationships between behaviors and sleeping and waking. Behaviors may be indicators of particular states, responses to other state-related changes such as apnea, or reflections of underlying neural activation (Hoch et al., 1998; Huntington et al., 1985; van Woerden et al., 1988). In other cases, behaviors may be signs of arousals or imminent state changes (Giganti et al., 2002); or the behaviors, such as hiccups, might actually cause state changes.

More research is also needed on the underlying causes and consequences of behaviors in preterms. Preterm infants have limited behavioral repertoires so the same behavior may have different meanings in different situations. We found that all eight infant behaviors occurred in all four sleep-wake states. Yet infants usually arouse and change state in response to stress or pain (Zahr & Balian, 1995). Behaviors are not always responses to external stimulation, but rather sometimes they may be the result of endogenous processes that contribute to the development of the nervous system (e.g., Korner, 1969) or only reflect changes in the underlying sleep-wake state. Therefore, to make clinically useful interpretations of infant behaviors, more empirical data is needed about how the co-occurrence of infant behaviors and sleeping and waking is affected by different stimuli, including nursing care and painful procedures, and how these co-occurrences are affected by differing levels of illness severity or differing post-conceptional ages.

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Table 1.

Demographic Characteristics of the Two Cohorts of Preterm Infants.

	Cohort 1 N = 37	Cohort 2 N = 34
	Mean (SD)	Mean (SD)
Gestational Age in Weeks	28.6 (2.5)	27.9 (2.0)
Birth Weight in Grams	1121 (347)	1109 (311)
Size: % Average for Gestational Age	86.5%	88.7%
Sex: % Male	48.6%	55.9%
Race: % White	37.8%	52.9%
Maternal Age in Years *	23.8 (4.2)	26.5 (4.9)
Mothers: % Married	51.4%	67.6%
Number: % Multiple Births	29.7%	29.4%
Delivery Route: % Vaginal	48.6%	44.1%
Apgar Score: 1 Minute	5.6 (2.3)	5.8 (2.0)
5 Minute	7.6 (1.6)	7.6 (1.2)
Neonatal Complications:		
% Mech. Ventilation < 24 hr.	70.3%	70.6%
% Chronic Lung Disease	24.3%	35.3%

table continued

Table 1 continued.

	Cohort 1 N = 37		Cohort 2 N = 34	
	Mean	(SD)	Mean	(SD)
IVH: % Grades 1 or 2	18.9%			38.3%
% Grades 3 or 4	18.9%		11.7%	
% Major Surgery	18.9%			38.2%
Age at 1st Observation in Days	23.9	(20.0)	25.3	(17.3)
Number of Observations *	3.6	(2.1)	4.6	(2.3)

* Cohorts differ, $p < .05$.

Table 2
The Results of the Fixed Effects from Mixed Model and GEE Analyses for the Eight

Infant Behaviors over the Entire Observation.

Behavior	Predictor[a]	Parameter	SE
Yawn	Intercept	1.24***	0.14
	P-C Age	-0.03	0.01
	Cohort	-0.36***	0.09
Sigh	Intercept	1.77**	0.54
	P-C Age	-0.26***	0.05
	Cohort	0.97**	0.32
	Mech. Ventilation	0.04**	0.01
Negative Facial Expression	Intercept	8.88***	1.12
	P-C Age	0.59***	0.10
	Cohort	-2.13**	0.64
	Gender	1.30*	0.63
Startle/Jerk	Intercept	1.94***	0.09
	P-C Age	-0.26***	0.03
Jitter	Intercept	5.91***	0.53
	P-C Age	-0.80***	0.13
	Mech. Ventilation	0.15***	0.03

table continued
Table 2 continued

Behavior	Predictor[a]	Parameter	SE
Large Movements	Intercept	29.78***	1.39
	P-C Age	0.12	0.16
	Cohort	-4.15***	0.86
Mouth Movements	Intercept	22.99***	0.69
	P-C Age	0.08	0.17
Hiccups	Intercept	0.86***	0.23
	P-C Age	-0.17***	0.05
	Cohort	-0.54*	0.27

Note: P-C Age = post-conceptional age; Mech. Ventilation = mechanical ventilation.

[a] The intercept parameter equals the expected value for the group at 34 weeks minus the effects of any covariates, and the post-conceptional age parameter equals the slope.

*p < .05. **p < .01. *** p < .001.

Table 3

The Results of the Fixed Effects from Mixed Model Analyses for the Four Infant Sleeping and Waking States.

State	Predictor[a]	Parameter	SE
Non-Sleeping	Intercept	13.15***	0.65
	P-C Age	1.22***	0.20
	Cohort	-3.74**	1.32
Active Sleep with REM	Intercept	27.74***	1.71
	P-C Age	-0.27	0.15
	Cohort	3.44**	1.08
	Race	-2.25*	1.09
Active Sleep without REM	Intercept	34.43***	2.09
	P-C Age	-1.66***	0.18
Quiet Sleep	Intercept	19.71***	0.58
	P-C Age	0.87***	0.21

Note: P-C Age = post-conceptional age.

[a] The intercept parameter equals the expected value for the group at 34 weeks minus the effects of any covariates, and the post-conceptional age parameter equals the slope.

*p < .05. **p < .01. *** p < .001.

Table 4

The Results of the Fixed Effects from Mixed Model and GEE Analyses for the Eight Infant Behaviors Within the Four Sleeping and Waking States.

		Non-Sleeping	AS with REM	AS w/o REM	Quiet Sleep
Behavior	Predictor[a]	Parameter (SE)	Parameter (SE)	Parameter (SE)	Parameter (SE)
Yawn	Intercept	3.17*** (0.22)	0.54*** (0.09)	0.96*** (0.17)	0.02*** (0.01)
	P-C Age	-0.18** (0.06)	-0.02* (0.01)	-0.03 (0.02)	-0.00 (0.00)
	Cohort	1.15*** (0.30)	-0.15** (0.06)		
Sigh	Intercept	0.36*** (0.05)	1.78** (0.56)	1.62* (0.67)	2.07 (1.25)
	P-C Age	-0.02 (0.02)	-0.15** (0.04)	-0.22*** (0.06)	-0.50*** (0.11)
	Cohort		1.29*** (0.35)	1.36*** (0.39)	1.98*** (0.74)
	Mech. Vent.				0.09*** (0.03)
	Theoph.			0.75* (0.33)	

table continued

Table 4 continued

		Non-Sleeping	AS with REM	AS w/o REM	Quiet Sleep
Behavior	Predictor	Parameter (SE)	Parameter (SE)	Parameter (SE)	Parameter (SE)
Neg. Expr.	Intercept	22.78*** (6.29)	2.72*** (0.33)	7.92*** (0.77)	0.37*** (0.06)
	P-C Age	-0.99*** (1.94)	-0.09** (0.03)	0.20** (0.07)	-0.04*** (0.01)
	Cohort		-0.50* (0.21)	-2.01*** (0.48)	-0.09*** (0.03)
	Gender	19.26** (6.19)			
Startle/Jerk	Intercept	1.51*** (0.18)	2.01*** (0.12)	2.13*** (0.16)	1.34*** (0.18)
	P-C Age	-0.21*** (0.04)	-0.24*** (0.03)	-0.32*** (0.04)	-0.12*** (0.03)
	Cohort	-0.62* (0.24)			
	Gender			0.45* (0.20)	0.52* (0.23)
	Theoph.		0.35* (0.15)		

table continued

Table 4 continued

Behavior	Predictor	Non-Sleeping Parameter (SE)	AS with REM Parameter (SE)	AS w/o REM Parameter (SE)	Quiet Sleep Parameter (SE)
Jitter	Intercept	4.63* (2.06)	6.98*** (0.58)	3.49* (1.50)	2.22*** (0.36)
	P-C Age	-0.85** (0.29)	-1.08*** (0.14)	-0.66*** (0.15)	-0.35*** (0.09)
	Cohort	6.02*** (1.59)		2.91*** (0.85)	
	Race	-3.56* (1.60)		-2.23* (0.91)	
	Mech. Vent.	2.40*** (0.67)	0.15*** (0.03)	0.17*** (0.04)	0.08*** (0.02)
	Theoph.	2.99* (1.49)			
Large Move.	Intercept	63.18*** (6.81)	13.68*** (0.49)	32.12*** (0.82)	4.14*** (0.39)
	P-C Age	-3.45 (1.84)	-0.47*** (0.12)	0.52** (0.19)	-0.29*** (0.07)
	Gender	11.45* (4.62)			1.49*** (0.51)
	Race	10.06* (4.93)		-2.97* (1.23)	
	Theoph.	-15.41* (6.32)			
	Mech. Vent.	0.41* (0.20)			

table continued

Table 4 continued

Behavior	Predictor	Non-Sleeping Parameter (SE)	AS with REM Parameter (SE)	AS w/o REM Parameter (SE)	Quiet Sleep Parameter (SE)
Mouth Move.	Intercept	35.97*** (4.99)	26.43*** (0.76)	29.47*** (0.91)	9.85*** (0.89)
	P-C Age	-2.17 (1.59)	-0.07 (0.19)	0.82*** (0.22)	0.18 (0.19)
Hiccups	Intercept	-0.02 (0.19)	-0.18 (0.15)	-0.21 (0.13)	-2.91*** (0.26)
	P-C Age	-0.04 (0.04)	-0.22*** (0.05)	-0.22*** (0.05)	-0.13 (0.09)
	Cohort	-0.86*** (0.25)			

Note: AS with REM = active sleep with REMs; AS w/o REM = active sleep without REMs; Neg. Expr. = negative facial expressions; Large Move.= large body movements; Mouth Move. = mouth movements; P-C Age = post-conceptional age; Birthwt.= birthweight, Theoph. = theophylline; and Mech. Vent. = mechanical ventilation.

[a] The intercept parameter equals the expected value for the group at 34 weeks minus the effects of any covariates, and the post-conceptional age parameter equals the slope.

*p < .05. **p < .01. *** p < .001.

Table 5

The Intercept and Post-Conceptional Age Fixed Effects from Mixed Model and GEE Analyses for the Differences between the Percents of the Eight Infant Behaviors between each Pair of Sleeping and Waking States.

		QS - ASREM	QS – NoRAS	QS – NS	ASREM - NoRAS	ASREM – NS	NoRAS – NS
Behavior	Predictor[a]	Parameter (SE)	Parameter (SE)	Parameter (SE)	Parameter (SE)	Parameter (SE)	Parameter (SE)
Yawn	Intercept	-0.30*** (0.03)	-0.65*** (0.04)	-2.53*** (0.15)	-0.35*** (0.04)	-2.24*** (0.15)	-1.88*** (0.14)
	P-C Age	0.02 (0.01)	0.03 (0.02)	0.18** (0.06)	0.01 (0.01)	0.16** (0.06)	0.15** (0.06)
Sigh	Intercept	2.41*** (0.24)	2.13*** (0.21)	5.71*** (0.28)	-0.35** (0.11)	3.36*** (0.14)	3.73*** (0.16)
	P-C Age	-0.17 (0.11)	-0.02 (0.09)	-0.33* (0.16)	0.13** (0.04)	-0.12 (0.06)	-0.26** (0.09)
Neg. Expr.	Intercept	-1.93*** (0.13)	-5.65*** (0.35)	-36.91*** (5.58)	-3.74*** (0.29)	-35.20*** (5.58)	-32.31*** (5.59)
	P-C Age	-0.03 (0.03)	-0.24* (0.07)	0.34 (2.20)	-0.27** (0.06)	0.28 (2.20)	0.52 (2.20)
Startle/Jerk	Intercept	-0.57*** (0.10)	-0.82*** (0.10)	0.50** (0.16)	-0.23* (0.10)	1.04*** (0.12)	1.21*** (0.14)
	P-C Age	0.14** (0.04)	0.19*** (0.03)	0.10 (0.07)	0.05 (0.03)	-0.04 (0.05)	-0.09 (0.06)

table continued

Table 5 continued.

		QS - ASREM	QS - NoRAS	QS – NS	ASREM - NoRAS	ASREM – NS	NoRAS – NS
Behavior	Predictor	Parameter (SE)	Parameter (SE)	Parameter (SE)	Parameter (SE)	Parameter (SE)	Parameter (SE)
Jitter	Intercept	-5.79*** (0.27)	-5.89*** (0.30)	-9.33*** (0.65)	-0.08 (0.25)	-3.57*** (0.59)	-3.48*** (0.53)
	P-C Age	0.59*** (0.11)	0.21 (0.13)	0.34 (0.28)	-0.39*** (0.12)	-0.24 (0.25)	0.14 (0.21)
Large Move.	Intercept	-8.78*** (0.82)	-25.94*** (0.61)	-61.22*** (5.43)	-17.16*** (0.61)	-54.98*** (5.44)	-38.31*** (5.47)

	P-C Age	0.22 (0.13)	-0.72** (0.19)	1.96 (2.12)	-1.00*** (0.17)	1.86 (2.12)	2.71 (2.13)
Mouth Move.	Intercept	-16.28*** (1.02)	-19.00*** (0.84)	-26.69*** (0.91)	-2.93*** (0.58)	-9.87 (5.60)	-7.10 (5.61)
	P-C Age	0.47 (0.27)	-0.37 (0.34)	2.68*** (2.14)	-0.89** (0.19)	2.81 (2.15)	3.75 (2.15)
Hiccups	Intercept	-2.73*** (0.30)	-2.72*** (0.28)	-2.42*** (0.28)	0.02 (0.07)	0.29 (0.16)	0.28 (0.15)
	P-C Age	0.10 (0.10)	0.10 (0.09)	0.08 (0.09)	0.00 (0.00)	-0.18*** (0.05)	0.18** (0.06)

Note: QS= quiet sleep; ASREM = active sleep with REMs; NoRAS = active sleep without REMs; NS = Non-sleeping; Neg. Expr. = negative facial expressions; large move.= large body movements; mouth move. = mouth movements; P-C Age = post-conceptional age.

[a] The intercept parameter equals the difference in the percent of the behavior between the two states, and the post-conceptional age parameter shows whether this difference changes with age
*p < .05. **p < .01. *** p < .001.

Figure Captions

Figure 1: The predicted regression of sighs, negative facial expressions, startle/jerks, and jitters, over post-conceptional age with cohort, gender, and mechanical ventilation held constant at zero (i.e., cohort = cohort 1, gender = female, and mechanical ventilation = 1 day).

Figure 2: The predicted probability of having hiccups over post-conceptional age.