THE EFFECTS OF NONNUTRITIVE SUCKING ON STATE REGULATION IN PRETERM INFANTS

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(ABSTRACT)

Nonnutritive Sucking (NNS) has long been used to soothe crying infants. Systematic observations of this effect in newborn infants have revealed that NNS reduces arousal in general. Among preterm infants NNS has been used as an effective intervention in the newborn intensive care unit. However, there has been little systematic research on the immediate behavioral effects of NNS in this population of infants. The purpose of this study was to examine the effects of NNS on behavioral state in preterm infants. The results indicated that the amount of quiet sleep was increased following NNS, but that this increase was not greater than the amount of quiet sleep observed in two hours of undisturbed rest. These results are discussed in terms of intervention strategies which are designed to increase the amount of quiet sleep among preterm infants. It is suggested that a pacifier can increase the amount of quiet sleep when longer periods of uninterrupted sleep cannot be arranged. Additional results indicated that the rhythmic organization of state was more complex following NNS than during control conditions. A basic 40- to 60-minute rhythm in state was not affected by NNS. However, spectral analysis indicated that there were other faster frequency fluctuations in state. Following NNS there were more of these fluctuations and they accounted for more variance in state. This pattern is more similar to the pattern observed in low-risk newborns. These results are discussed in terms of inducing behavior patterns in preterm infants which are more similar to behavior seen in full term infants. Finally, a model is presented which suggests that the reduced arousal seen following NNS is an adjunct to an increase in parasympathetic activity. This increase in parasympathetic acitivity is hypothesized to be adaptive. Through this mechanism sucking is hypothesized to have a distinct behavioral effect on energy regulation in newborn infants outside of the requirements for feeding.

DEDICATION

This paper is dedicated to our son and his sibling who was not born; these two children represent the extremes of hope for the families of the infants in this study.

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INTRODUCTION

Every parent knows that one strategy for soothing a crying newborn is to let the infant suck on a pacifier. This strategy has been adopted by hospital personnel and behavioral scientists. For example, during stressful medical procedures, such as circumcision, a pacifier or finger is frequently placed in a crying infant's mouth to calm the infant. When infant subjects are going to perform a task requiring attention in the laboratory they are often given a pacifier in order to settle them in an alert state (e.g., Gardner & Karmel 1983). While the concurrent effects of sucking are often obvious, there has been little systematic investigation of which physiological or behavioral mechanisms mediate those effects. Those mechanisms might reflect the current health of an infant and at the same time represent an infant's ability to adapt to the extrauterine environment. Furthermore, little systematic research has been done on the extent to which the effects of a pacifier are evident in later behavior. In particular, these lasting effects could provide a mechanism by which NNS improves a preterm infant's adaptation to the extrauterine environment.

An understanding of these mechanisms and any lasting effects may be particularly important for preterm infants. Preterm infants have difficulty controlling their temperature, regulating their levels of arousal, and taking their feedings by mouth.

Early in their lives, preterm infants receive little experience with sucking stimuli because they are initially fed through tubes (Faranoff & Klaus, 1979). These infants begin to take their feedings from a bottle when coordination of the suck and swallow reflexes has developed. That coordination generally develops by the time an infant attains a conceptional age of 34 to 36 weeks (Gryboski, 1969). Thus, an infant born after a gestation of less than 34 weeks may be fed without the potential benefit of sucking for the first few weeks of its life. This lack of experience can be important because sucking has behavioral and physiological effects which might be beneficial to preterm infants.

One of the beneficial effects of sucking is that it might serve as a regulator of behavioral and physiological activity. In particular, sucking can reduce levels of behavioral arousal (Kessen & Leutzendorff, 1963), and help to coordinate physiological and behavioral activities (Mendelson, 1979). These effects could be mediated by an increase in parasympathetic activity (Anderson & Vidyasagar, 1979). When infants are denied access to an exogenous regulator, such as sucking, it might be difficult for them to maintain a moderate level of arousal if the endogenous sources of regulation have not yet matured. As a result, they spend a large portion of their time at excessive levels of arousal and expend energy that could be better used to facilitate growth. For preterm infants, nonnutritive sucking (NNS) might provide such an exogenous regulator which could facilitate their early development.

The purpose of the present study is to examine the effects of NNS as a regulator of biobehavioral state in preterm infants. State has been chosen as a measure of those regulatory effects because it is both a sensitive and a general indicator of levels of arousal (Anders, 1978; Wolff, 1966, 1967). Both concurrent and prolonged regulatory effects of NNS will be studied. The concurrent effects should confirm the effects of NNS already reported (e.g. the increased quiet sleep reported for full term infants by Wolff & Simmons, 1967) while description of prolonged effects would be an addition to the literature. The prolonged effects of NNS on basic biological rhythms will be studied with the statistical technique of spectral analysis. The study of rhythms should allow for a sensitive evaluation of the effects of NNS on the organization of state. Finally, preterm infants were chosen as the subjects for this study because they have a difficult task in adapting to the extrauterine environment, and the regulatory effects of NNS might facilitate their adaptation to that environment.

Preterm Infants

Preterm infants have special needs and a unique behavioral repertoire. These qualities make adaptation to the extrauterine environment difficult. Several different systems are commonly used for identifying preterm infants (see Appendix A). For this discussion, preterm infants are those infants who are born after a gestation of less than 37 weeks. Adaptation to the extrauterine environment is difficult for preterm infants because they do not have such necessary adaptive skills as obtaining food from a nipple, controlling their own temperature, or inhibiting their motor behavior (Als, Lester, Tronic, & Brazelton, 1981; Hofer, 1981). Because of these disadvantages preterm infants spend more time in the hospital being supported in an intensive medical environment that can best be characterized as stressful (Gorski et al., 1983; Gottfried, in press; Newman, 1981). This delayed adaptation and early exposure to a stressful environment further increases a preterm infant's risk for a range of later developmental problems (Holmes, Nagy-Reich, & Pasternak, 1984). For example, preterm infants are more likely to suffer Sudden Infant Death Syndrome, child abuse, and simple delays in the attainment of developmental milestones.

The primary developmental task of preterm infants during the neonatal period is to organize and coordinate their behavioral and physiological systems so that they can adapt to the extrauterine environment (Als et al., 1983). This process of adaptation is exceptionally complex because preterm infants are primarily prepared for survival and development in an enclosed and highly controlled environment. Thus, a preterm infant must acquire a set of behaviors which will facilitate its adaptation to the extrauterine environment before it is prepared for that task. Those behaviors have not yet been catalogued. For clinicians and researchers alike, this lack of information is compounded by a continuing debate about whether to treat the preterm infant as an externalized fetus or as a young newborn (Cornell & Gottfried, 1976). Devising strategies for facilitating the acquisition of those behaviors remains a sensitive and difficult issue. As a result, much of the recent interest in the behavior and development of the preterm infant has centered around discovering the behaviors which preterm infants possess, and facilitating the development of those behaviors which may in turn facilitate later development.

Increased risk in preterm infants.

Preterm infants have an increased risk for three categories of problems. First, these infants frequently experience medical complications during the first few weeks of life (Werthmann, 1981). Second, these infants commonly experience a temporary delay in attainment of developmental milestones when compared to full term cohorts (Hunt & Rhodes, 1977). And third, these infants often experience some degree of lasting intellectual or motor impairment in childhood (Caputo & Mandell, 1970).

The most severe medical risk a preterm infant faces is an increased mortality rate. Mortality during the first week of life among infants who are born with a gestational age of less than 37 weeks is approximately 13% compared with a mortality rate of 2% for all other newborns. The increased mortality rate persists throughout the first year of life. During that time the mortality rate among preterm infants is 2% compared to less than 1% among all other infants (Keller, 1981).

The other medical complications encountered by these infants often begin before birth. For example, premature onset of labor is often due to some complication in the pregnancy. Complications range from severe medical problems which jeopardize the fetus' survival to household accidents which precipitate an early labor (Werthmann, 1981). During the birth process preterm infants are also more likely to experience complications such as asphyxia and hypoxia (Werthmann, 1981). These complications have been associated with increased risk for lasting learning deficits and motor impairment (Sameroff & Chandler, 1975). During the first few weeks of life the infant is more likely to have problems with thermoregulation, respiration, circulation, feeding, and infection (Werthmann, 1981). Each of these problems can have an impact on the behavioral development of the preterm infant. Furthermore, many of these complications require special medical care such as isolating the infant in a temperature controlled environment. This care may further adversely affect the infant's development.

For many preterm infants, delays in attainment of developmental milestones early in the neonatal period are often of little consequence by the time the child reaches school age. For others, the prognosis is not as good. Of the preterm infants who survive the neonatal period more than 25% will experience moderate to severe handicaps (Goldberg & DiVitto, 1983). Research indicates that the remaining 75% are at increased risk for a variety of more subtle developmental problems. Those problems include disruptions in reading abilities and school performance (Francis-Williams & Davies, 1974), increases in behavior problems reported by parents (Field, Dempsey, & Shuman, 1979), and decreases in IQ (Hunt, 1981).

Biobehavioral effects of NNS

One experience that might facilitate the adaptation of preterm infants to the extrauterine environment is nonnutritive sucking. Nonnutritive sucking is a reflexive behavior pattern which may be elicited by placing a pacifier in an infant's mouth. In full term infants this pattern includes vigorous mouthing movements which produce a negative pressure on the nipple. These rhythmic mouthing movements are interspersed at regular intervals with movement of the esophageal muscles. The movement of the esophogeal muscles represents a pattern of swallowing.

These two reflexes are evident among all mammalian species at birth. The work of Hall and Williams (1983) suggests that the two reflexes serve very different functions for the young organism. The swallow reflex of course is necessary for the ingestion of nutrients, and sucking is the mechanism by which young mammals commonly acquire those nutrients. However, Hall and Williams propose that the sucking relfex provides two distinct functions. One function is to be ready to receive the nutrient when it is ejected from the mother's teat. The other function, more important for this discussion, is to produce a behavioral quiesence that serves to conserve energy. While both functions are involved in successfully feeding, the second function may have importance for behavioral regulation outside of the requirement for feeding. This second function represents an adaptation which is intricatley related to energy regulation in newborns, but one which is independent from the requirements for successful feeding.

Gryboski (1969) has described the development of the suck and swallow reflexes in preterm infants. Even preterm infants with a gestational age of 28 to 30 weeks make some effort at sucking when a pacifier is placed in their mouths. In these young infants mouthing movements are weaker and less rhythmic than the pattern observed in full term infants. At a conceptional age of 36 weeks the pattern of mouthing movements is similar to that observed in full term infants.

Effects of NNS on the recovery of preterm infants.

Experience with nonnutritive sucking during feedings can facilitate growth in preterm infants, however, the process mediating that facilitation has not been detailed. Three recent studies have reported that consistent experience with NNS during tube feedings increases the rate of growth among preterm infants (Bernbaum, Pereira, Watkins, & Peckham, 1983; Ignatoff & Field, 1982; Measel & Anderson, 1979). Intuitively, one might assume that practicing with a nipple facilitated the development of the coordination of the suck and swallow reflexes. In that case, these infants would drink from a bottle at a younger age than control infants as a result of that accelerated development. The increased growth observed in the treatment groups of these studies might be secondary to the improvement in feeding skills. Each of the three studies supported this hypothesis. All three demonstrated that the treatment infants were both fed their first bottle earlier, and changed from tube feedings to exclusively bottle feedings sooner than were control infants. However, NNS might also have affected growth through some mechanism other than a simple facilitation of the development of coordination of two reflexes.

The facilitation of the treatment infants' ability to feed from a bottle cannot account for all of the effects of NNS during the neonatal period. Bernbaum et al. (1983) emphasized possible effects of NNS on digestion patterns in addition to effects on readiness for bottle feedings. In addition to exhibiting more mature patterns of sucking when they were fed from a bottle for the first time, treatment infants also had faster food transit times throughout the experiment. Furthermore, while both groups consumed a similar number of calories at each feeding, the treatment infants gained weight faster than the control infants. The faster transit times and increased rate of growth were hypothesized to indicate a more efficient use of the food consumed.

The mechanism mediating the improved absorption of nutrients in infants given NNS experience during feeding has not been demonstrated. However, an increase in parasympathetic activity could account for improved absorption, and has been proposed to mediate other effects of NNS (Anderson et al., 1983; Anderson & Vidyasagar, 1979; Measel & Anderson, 1979). Because one of the primary functions of the parasympathetic nervous system is to facilitate digestion of food, an increase in parasympathetic activity during feedings could help preterm infants adapt to the demands of feeding in the extrauterine environment. Full term infants suck whenever they are fed while preterm infants often do not receive this experience. Thus, providing NNS for perterm infants may serve to increase parasympathetic activity and through this mechanism facilitate growth.

Behavioral effects of NNS

The other behavioral and physiological effects of nonnutritive sucking suggest that NNS has a strong effect on the arousal of an infant, and that this effect is apparent in the activity of the autonomic nervous system. The effects of NNS by full term neonates on behavioral and physiological variables include increases in heart rate (Lipsitt, Reilly, Butcher, & Greenwood, 1976), deepening of sleep patterns (Wolff & Simmons, 1967), inhibition or replacement of startles during sleep (Wolff, 1966), decreases in generalized motor activity (Kessen & Leutzendorf, 1963), decreases in behavioral activation during circumcision (Gunnar, Fisch, & Malone, in press), increases in alertness (Mendelson, 1979), and increases in the amount of time in an awake state (Neeley, 1979). Each of these findings suggests that NNS modulates the infant's arousal level. In general, that modulation is reflected in lower levels of arousal.

None of these effects have been demonstrated for preterm infants. Among these younger infants, only a change in transcutaneous oxygen tension during, and immediately following, NNS experience has been reported (Anderson, Burroughs, & Measel, 1983; Burroughs, Anderson, Patel, & Vidyasagar, 1981; Burroughs, Asonye, Anderson-Shanklin, & Vidyasagar, 1978). The mechanism producing this change in tissue oxygenation was not studied. The authors, however, hypothesized that the change in oxygen pressure was due to a decrease in the tone of smooth muscle in the lungs.

In addition to the sparse data on the immediate effects of NNS by preterm infants, there has been little research on the biobehavioral effects which may follow an episode of NNS. Burroughs et al. (1978) found that transcutaneous oxygen pressure remained elevated for eight minutes following NNS. Neeley (1979) also examined long lasting behavioral effects of NNS during the first twelve hours of extrauterine life. In her study, full term newborns were offered a pacifier every four hours between birth and their first feeding at twelve hours of age. Observations of biobehavioral state and ease of feeding were made at the first feeding. Infants who were given a pacifier prior to their first feeding were more alert at that feeding, and easier to feed than were control infants. All of these findings are consistent with the hypothesis that NNS modulates both behavioral and autonomic activity.

An autonomic model for the effects of NNS

The effects of NNS on autonomic activity could serve as a model for other behavioral and physiological effects. This model might be particularly important for understanding the effects of NNS on preterm infants. These infants do not have a mature balance in the two branches of their autonomic nervous system (Als et al., 1982). The two branches of the autonomic nervous system act in opposition to each other to maintain homeostasis of function (Hassett, 1978). In general, when an individual is excited, the sympathetic nervous system is activated and the level of autonomic activity is increased. When an individual is at rest, the parasympathetic nervous system is activated and the level of autonomic activity is decreased. One branch is always more active than the other, and thus, is dominant. Following activation of the sympathetic nervous system, the parasympathetic system will be activated and restore homeostasis. Because of this homeostatic function, the resting balance of the autonomic nervous system favors a parasympathetic dominance (Porges, 1983). Finally, cyclic shifts in the balance of the two branches during the course of a day can influence the timing of endogenous biological rhythms.

The balance of the two branches of the autonomic nervous system of preterm infants is shifted away from parasympathetic dominance. Porges (1983) reports a significant correlation between estimates of parasympathetic activity and gestational age. The correlation indicated that infants who are born earlier have a lower parasympathetic tone than infants who are born later in gestation. The pain cry of preterm infants also indicates a shift away from parasympathetic dominance. That cry is characterized by a higher fundamental frequency and short duration (Lester & Zeskind, 1978). Lester & Zeskind (1982) theorized that shifts toward higher fundamental frequencies in an infant's cry indicate an imbalance in the autonomic nervous system, particularly a shift away from parasympathetic dominance.

Findings from newborns who have cries similar to those of preterm infants suggest that preterm infants also might have difficulty achieving a homeostastic balance of the two branches of the autonomic nervous system. Infants who are harder to arouse and have a short duration pain cry also have increased variability in cardiac function when they are at rest (Zeskind & Field, 1982). This variability suggests that homeostasis of autonomic activity is achieved in these infants with some difficulty. Briefly, rather than achieving homeostasis by balancing sympathetic nervous system activity with a single compensating burst of parasympathetic activity, the system experiences a number of over-compensations before returning to homeostasis. The first response of the parasympathetic nervous system to sympathetic activity is too great. In order to compenstate for that parasympathetic burst, the sympathetic system is activated again. The cycle is then repeated until homeostasis is achieved. Thus, the picture of autonomic function that emerges for preterm infants is that achieving homeostasis of the two branches is more difficult because dominance is shifted away from the parasympathetic nervous system.

NNS might serve as a regulator of arousal, and autonomic and behavioral activity. This regulation can be modeled by effects in the autonomic nervous system. In particular, as described earlier, NNS may shift the balance in the autonomic nervous system toward a parasympathetic dominance. Increases in parasympathetic nervous system activity may correlate with changes to less active, more restive states. Thus, the effects of NNS on arousal would be reflected in biobehavioral state. Furthermore, NNS might produce prolonged effects by influencing the rhythmic interplay of the two branches of the autonomic nervous system.

Biobehavioral State

On a descriptive level, biobehavioral state refers to the pattern of behavioral and physiological parameters observed during the various stages of sleep and waking behavior. These clusters of behavioral and physiological parameters tend to recur in a cyclic pattern. The operational systems for studying biobehavioral state in infants range in complexity from discriminations among 6 to 13 different states. The systems specifically designed for use with newborns range from a 6 or 7 point scale (Brazelton, 1973; Prechtl & Beintema, 1964; Wolff, 1966) to an eleven point scale (Thoman, Korner, & Kraemer, 1976). A 13 point scale has been devised specifically for studying state in preterm infants (Als et al., 1982). This last scale is derived from the states described by Wolff (1966).

Each system devotes approximately half of the scale to describing sleep states and half to waking states. For example, Wolff (1966) described two sleep states (quiet and active), a drowsy state, and three awake states (alert, active, and crying). A brief description of each of the six states identified by Wolff follows. Deep or Quiet sleep is indicated by reduced muscle tone, closed eyes, and a regular pattern of respiration. Active sleep is indicated by some movement, a less regular pattern of respiration, and rapid eye movements which are visible beneath the closed eyelids. The drowsy state is a transition between waking and sleeping. The alert state is indicated by a "bright eyed" look, this look suggests that the infant is attending to its environment. The active state is indicated by diffuse movement. And the crying state is indicated by the production of at least one long burst of intense vocalization.

The study of biobehavioral state has been expanding rapidly in recent years (Prechtl & O'Brien, 1982). Perhaps because of this rapid expansion, a universally accepted definition for the construct of biobehavioral state has not yet been formulated. Among the difficulties with formulating such a definition is that state represents both qualitative and quantitative processes (Anders, 1978; Wolff, 1966, 1967). On the qualitative dimension, states are recognized as clusters of physiological and behavioral signs and, as such, each state represents a different kind of behavioral organization. On the quantitative dimension, states are organized along a continuum of levels of arousal.

Wolff (1966) was the first to suggest that states represent both, qualitative categorizations of patterns of infant behavior, and quantitative positions on some continuum of levels of arousal. Each position on that continuum specifically represents a different level of central nervous system (CNS) activity (Anders, 1978). States are ordered on this continuum of CNS activity such that sleep states represent less activity than awake states. The placement of states on this continuum is supported by electroencephalographic (EEG) measures of brain activity. For example, quiet sleep is marked by a lower voltage, slower wave EEG than is active sleep (Dreyfus-Brisac, 1970). Thus, within sleep categories CNS activity is reduced during the quieter state. Furthermore, the EEG of a sleeping infant is more regular and rhythmic than that of a waking infant (Parmelee, Wenner, Akiyama, Stern, & Fletcher, 1967). This difference indicates that the CNS activity of a sleeping infant is more coordinated than that of a waking infant.

Central nervous system activity could independently affect both the level of activity in the autonomic nervous system and the biobehavioral state, or all three of these systems could be interrelated. Rose (1983) suggests that states are specifically interrelated with levels of autonomic nervous system arousal. According to her observations some states are characterized by relatively higher levels of autonomic arousal than are others. Those states characteristic of such increased activity are the active sleep state, and the fussy and crying awake states. Conversely, the quiet states (e.g., deep sleep and alert) may reflect lower levels of autonomic activity. In support of this theoretical position some measures of autonomic function differ according to state. For example, heart rate is reduced during quiet sleep as compared to active sleep (DeHaan, Patrick, Chess, & Jaco, 1977; Harper, Hoppenbrouwers, Sterman, McGinty, & Hodgman, 1976). Similarly, an accelerated heart rate is seen during crying as compared to other awake states (Vaughn & Sroufe, 1979). Heart rate variability is also reduced in quiet sleep as compared to active sleep (Harper et al., 1976).

The direction of the relation between autonomic nervous system function and state regulation is not clear. Either state could determine the level of autonomic activity, or the level of autonomic activity could influence state. The only available data relate heart rate changes to the beginning of a crying state

(Vaughn & Sroufe, 1979). These data indicate that increases in heart rate precede the onset of a crying state. Thus, at least with respect to the crying state changes in autonomic function precede changes in state. When this finding is generalized to other states, changes into states with higher levels of arousal, such as crying and active sleep, would be predicted to follow increases in autonomic activity. Similarly, changes into quieter states would be predicted to follow decreases in autonomic activity.

Generally, activation of the autonomic nervous system is mediated by an increase in the sympathetic branch of the system while most often reduced activity is mediated by an increase in parasympathetic tone. Thus, changes to the more active states, such as crying and active sleep, may follow an increase in sympathetic activity. Changes to quieter states, such as quiet sleep or alert awake, may follow increases in parasympathetic activity. If NNS produces an increase in parasympathetic activity, then changes to quieter states would be expected during NNS. In general, infants have been observed to change to the states more characteristic of parasympathetic activity during NNS. For example, Gunnar, Fisch, and Malone (in press) found that a pacifying stimulus reduced crying in infants during circumcision. Gardner and Karmel (1983) found that NNS helped infant subjects to maintain an alert state. Finally, Wolff and Simmons (1967) observed that during NNS infants changed from an active to a quiet sleep.

State in preterm infants.

Preterm infants have a less mature organization of their behavior patterns than full term infants. This immaturity is obvious during observations of biobehavioral state because the behavioral and physiological characteristics of the states are less well coordinated in preterm infants (Als et al., 1982). Als et al. (1982) have described the rapid fluctuations of the component behaviors within and between states as "noisy" and less organized. In support of this generalization, Parmelee, Wenner, Akiyama, Schultz, and Stern (1967) reported that preterm infants spend more of their sleep time in a transitional state. This state does not have the same cluster of physiological and behavioral parameters as either the quiet or active sleep states observed in full term infants. This finding of more time in a disorganized sleep state was confirmed by Dreyfus-Brisac (1970). Furthermore, Dreyfus-Brisac (1970) reported that at least one atypical component of the state was observed whenever a preterm infant was in either quiet or active sleep.

The amount of time spent in the organized sleep states also differentiates pre- and full term infants. Preterm infants spend more time in active sleep and less time in quiet sleep than their full term cohorts (Dierker et al., 1982; Parmelee, Wenner, Akiyama, Schultze, & Stern, 1967). Furthermore, when a preterm infant begins to sleep the initial transition from an awake to a quiet sleep state is delayed (Rose, 1983). Thus, even when preterm infants get the same amount of total sleep as full term infants, they get a different quality of sleep. Preterm infants lack time in quiet sleep and spend much of their sleeping periods in higher states of arousal.

There are conflicting data concerning the age that preterm infants attain the degree of organization of states that full term infants exhibit from birth. Dreyfus-Brisac (1970) reported that even by the conceptional age of 38-41 weeks preterm infants' sleep states are not as well organized as the sleep states of full term infants. Specifically, preterm infants omit, or anomalously display, one or more of the behavioral and physiological parameters typically found in the cluster for a particular state. A disorganized sleep state was labeled transitional sleep by Stern, Parmelee and Harris (1973). Those authors reported that the proportion of time in a transitional state was similar among full term infants and preterm infants who had a conceptional age of 34 weeks. The amount of time in active sleep was similar among the two groups when the preterm infants were 38 weeks of age. The amount of time preterm infants were in quiet sleep did not match that of full term infants until the preterm infants were 40 weeks conceptional age. The available data suggest that the internal organization of the sleep states is mature at approximately the age that a preterm infant normally would complete its gestation.

Most of the work on the maturation of states in preterm infants has been devoted to descriptive studies. Thus, the degree to which maturational and experiential variables contribute to the development of organized states remains undetermined. The research devoted to studying factors influencing the development of states has utilized state as a behavioral response rather than as an organizational variable. Following a longitudinal study of preterm infants Aylward (1981) found no reliable correlations between postnatal age and state control at 40 weeks conceptional age. This finding suggests that conceptional age, and thus, maturational variables, rather than postnatal experience, might be the crucial determinant of the timing of development of the state control system. However, that study did not exclude the possibility that the extrauterine environment of preterm infants delayed the development of organized states. Furthermore, Aylward suggests that these findings might not be conclusive because of the small sample size.

Other findings suggest that the states preterm infants respond with can be affected by early experiences. For example, responsiveness of the state system of preterm infants is sensitive to environmental manipulations (Gabriel, Grote, & Jonas, 1981). Preterm infants under a traditional intensive care unit caregiving schedule (nursing convenience determines when procedures are administered) respond with different state modulations to stimuli than do infants under a clustered caregiving schedule. Specifically, the routine schedule, which resulted in more daily interruptions, produced infants more prone to respond to contacts with transitional states. Infants cared for under a clustered regimen responded to contacts with more organized, well defined states. In summary, the behavioral and physiological components of the states of preterm infants are less well coordinated than those of full term infants, and the rate that this coordination develops is likely affected by both maturational and experiential variables.

Rhythmic structure of state.

The immature coordination of the behavioral and physiological components of state parallels a similar immaturity in the rhythms of biobehavioral activity. Research with healthy full term newborns indicates that there are two endogenous rhythms influencing changes in state. An endogenous rhythm in sleep/wake activity with a period of four hours has been described (Meier-Koll, Hall, Hellwig, Knott, & Meier-Koll, 1978; Morath, 1974). This rhythm corresponds with the timing of feedings and has been hypothesized to represent a hunger cycle (Stratton, 1982). A cyclic alternation between quiet and active sleep with a period of 40 to 60 minutes has also been described (Emde, Swedberg, & Suzuki, 1975). This 40-minute rhythm has also been generalized to the cyclic appearance of waking states (Zeskind, Goff, Huntington, & Weiseman, 1983).

These rhythms in state cannot be readily generalized to preterm infant behavior. A comparison of the data available for newborn, preterm, and fetal behavior patterns suggests that some preterm infants might not have the two endogenous rhythms. Rhythms in fetal activity have been demonstrated after 21 weeks of gestation (Sterman & Hoppenbrowers, 1971). Those two rhythms have periods of approximately 40 and 90-minutes. The distinction between the biological rhythms of a fetus and preterm infant of similar ages might seem a semantic rather than a substantial issue. However, rhythms in fetal activity might not be endogenous to the fetus but rather supported by maternal rhythms. Thus, a preterm infant who has been separated from the maternal environment might not have these two rhythms.

There is direct evidence that a fetal circadian rhythm is mediated by the mother's central nervous system, and indirect evidence that other fetal activity rhythms are also mediated by maternal variables. Reppert and Schwartz (1983) demonstrated that the neurological changes accompanying circadian rhythms in fetal rats are directly mediated by maternal variables. When Sterman and Hoppenbrowers (1971) demonstrated the 40-minute rhythm in fetal activity they also demonstrated a 90-minute rhythm. While the latter rhythm is commonly observed in adults, it has not been observed during the newborn period and probably does not develop until later in childhood (Sterman & Hoppenbrowers, 1971). Because of this discrepency, the 90-minute rhythm observed during the fetal period is assumed to be controlled by maternal variables. Because the 40-minute rhythm has been observed in both the fetus and the newborn this rhythm is more likely to be endogenous to the infant.

While the 40-minute rhythm might represent an endogenous process, it does not represent a process that all preterm infants possess from birth. Rather, this rhythm develops during a period when some preterm infants have already been separated from the support of the maternal environment. An investigation of sleep rhythms among preterm infants demonstrated that the 40-minute rhythm was not observed at 32 weeks conceptional age, but that it was observed after 36 weeks (Stern, Parmelee, & Harris, 1973). However, the presence of a 40-minute rhythm in fetal activity prior to 32 weeks suggests that this rhythm would usually develop in the fetus before that age. Because the developmental course of the 40-minute rhythm between 32 and 36 weeks has not been described, only speculation about the effects of environmental and organismic variables on that development is appropriate.

Stratton (1982) suggested that the degree to which an infant displays common rhythms could serve as an indication of an ability to adapt to the demands of the environment. According to Stratton, an inability to adapt increases the risk of an infant for experiencing later developmental problems. These high-risk infants have a higher probability of encountering developmental problems ranging from a delay in the attainment of developmental milestones to Sudden Infant Death.

In support of Stratton's hypothesis, some common biological rhythms discriminate groups of low- and high-risk infants (e.g. Lester & Zeskind, 1982; Porges, 1983; Zeskind, 1983). Both the number of frequencies in a cry sound and the fundamental frequency of the cry sound discriminate groups of low- and high-risk infants (Zeskind, 1983; Zeskind & Lester, 1978). Similarly, the degree of coherence between respiratory and cardiac rhythms correlates with an increased incidence of significant medical problems encountered by some preterm infants (Porges, 1983). Recent spectral analyses of state data indicates that variations in rhythms of state with frequencies faster than 1.5 cycles per hour (a period or wavelength of less than 40-minutes) might also discriminate among low- and high-risk infants (Zeskind et al., 1983). In that study all low-risk infants had at least a basic 40- or 60-minute rhythm, and most also had two or more rhythms at faster frequencies. By contrast, two high-risk infants did not have the basic rhythm and relatively few high-risk infants had more than this one significant rhythm. These studies only indicate a correlation between risk status and integrity of biological rhythms. However, if Stratton's hypothesis is correct, then interventions supporting the maturation of these rhythms might be effective.

One of the short term effects of NNS is a reduction in arousal. This regulatory effect might extend to a prolonged effect on rhythmic changes in levels of arousal. Quantification of infant state provides an effective measure of changes in levels of arousal (Wolff, 1966; 1967). The effectiveness of spectral analysis as a method for describing subtle differences in endogenous state rhythms of high- and low-risk infants has been demonstrated (Zeskind et al., 1983). Thus, spectral analysis of state data collected for a period of time following NNS may provide a sensitive measure of any prolonged effects of NNS on the level of arousal.

Summary and Hypotheses

An adaptational perspective of the mechanism by which sucking may affect behavior suggests that the mechanism may also prepare the infant for digestion of a meal. This preparation would likely involve an increase in parasympathetic activity. Such an increase in parasympathetic activity during NNS has been hypothesized by others (Anderson et al., 1983). Because of the relation between state and autonomic nervous system activity, this mechanism has implications for the organization of behavior.

Clearly, state regulation is affected by NNS in the full term newborn. Neeley (1979) demonstrated that NNS by newborns increased the amount of time in an awake state. Wolff (1966) demonstrated that full term infants were more likely to achieve states characterized by increases in parasympathetic function, either a deep sleep or an alert state, following NNS. An interaction between NNS and other behavioral or physiological parameters could determine which of these two states is observed during

NNS. One hypothesis tested in this study was that NNS during feeding produces state changes toward the sleep end of the continuum while NNS at other times produce state changes toward the awake end of the continuum.

Quantifying the stability of biobehavioral state following NNS might resolve several issues. First, this measure should replicate the findings from studies of full term infants. That is, following an NNS episode infants should spend more time in states representing relatively lower levels of arousal. When they are sleeping they should spend more time in quiet sleep, and when they are awake they should spend more time in an alert state. Second, this measure should indicate if NNS has a lasting effect on a biobehavioral system which is related to autonomic activity.

The coincidence between the age at which preterm infants begin to consistently feed from a nipple and the age at which the 40-minute activity rhythm develops suggests that these two developmental milestones might not be independent. Stratton (1982) has suggested that the presence or absence of fundamental biological rhythms may serve as indicators of an infant's health and ability to adapt to the extrauterine environment. Furthermore, a recent study has found a difference in the rhythmic structure of endogenous state control of high- and low-risk infants (Zeskind et al., 1983). That study indicated the basic forty-minute rhythm was present in all but a few high-risk infants. A single short experience with NNS may not affect such a basic rhythm in healthy full term infants. However, the infants in this study will be observed at the appropriate conceptional age that the 40-minute rhythm is usually first observed. Thus, the single experience with NNS may have a particularly potent effect on the 40-minute rhythm in this population of infants.

This project will evaluate two hypotheses concerning the 40-minute rhythm. First, the presence of the 40-minute rhythm was evaluated with a spectrum analysis of a two-hour times-series of state data following a tube feeding. This analysis should demonstrate the presence of a weak forty minute cycle. Second, a two-hour time-series of state data was obtained following a tube feeding during which the infant experienced NNS. Spectrum analysis of this time-series was hypothesized to demonstrate a stronger rhythm with a period of 40-minutes. A direct comparison of the proportion of variance accounted for by these two rhythms should demonstrate that the rhythm following NNS accounts for more variance in state than does the rhythm following a tube feeding with no NNS.

The number of faster frequency rhythms may be a more sensitive measure of the effects of NNS on endogenous state regulation. In the earlier study relating endogenous state rhythms to risk status (Zeskind et al., 1983), a significant difference in the number of rhythms with frequencies greater than 1.5 cycles per hour was found between the two risk groups. Low-risk infants had more rhythms with higher frequencies than high-risk infants.

These faster rhythms were hypothesized to be more sensitive indicators of the effects of NNS on endogenous regulation of state rhythms. These faster rhythms were quantified with spectral analysis of one-hour time-series of state data following a range of NNS experiences. A wider range of significant rhythms were hypothesized to follow NNS as compared to appropriate control conditions.

METHOD

Subjects

Fifteen subjects were selected from preterm infants admitted to the Newborn Intensive Care Unit (NICU) at Roanoke Memorial Hospital. Infants who had obvious congenital or chromosomal anomolies which might interfere with sucking or who required surgery were excluded. Furthermore, infants were not studied if they were currently having problems with feeding. Informed consent was obtained from the parents of infants who met these criteria.

Conceptional age was determined by adding the gestational age to the number of weeks between birth and the day of the first observation (postnatal age). The infant's gestational age at birth was obtained from the pediatrician's Dubowitz Exam (Dubowitz, Dubowitz, & Goldberg, 1970). This exam is a standard pediatric procedure used to estimate the length of a newborn's gestation in weeks. The exam is based on observations of the morphological and neurological characteristics of an infant. The conceptional age of the infants studied ranged from 32 to 37 weeks and averaged 34.1±1.3 weeks.

The means and standard deviations for the medical characteristics of the sample of infants studied are presented in Table 1. Of the fifteen infants eleven were female and two were black. Gestational age (GA), postnatal age, birthweight, Ponderal Index (PI=birthweight [measured in grams] *

100)/birthlength^3 [measured in centimeters]; Miller & Hassanien, 1971), Apgar scores at one and five minutes, Postnatal Factors Score (PNF) (Littman & Parmelee, 1978), postnatal age at testing, weight at testing, weight at discharge, and length of hospitalization were based on information obtained from the hospital medical records. In addition to quantifying the medical characteristics of the sample a number of these variables (GA, birthweight, PI, Apgar scores, and PNF) have been used previously as indicators of an infant's risk status.

The Apgar score is a clinical evaluation of a newborn's physiological functioning made by the attending pediatrician at one and five minutes after birth. The score is the sum of five items valued between zero and two with two being the optimal score for each item. The individual items are ratings of the infant's color, respiratory effort, heart rate, muscle tone, and response to intranasal stimuli. Thus, a maximum Apgar score is ten and a minimum score is zero, a score of 7 or more is considered normal (Apgar & Beck, 1972). The PNF is a standardized score based on a count of the number of medical complications the infant has encountered since birth (see Appendix B). A high PNF score indicates that an infant has encountered few medical complications.

Table 1.

Medical characteristics of the fifteen subjects.

Measure	Mean	Standard Deviation
Gestational Age (weeks)	30.8	2.7
Birthweight (grams)	1279.9	259.9
Apgar 1	4.6	2.2
Apgar 2	6.6	2.0
Ponderal Index	2.05	.15
Postnatal Factors Score (PNF)	69.3	9.3
Postnatal Age (days)	23.4	17.7
Weight at 1st Observation (grams)	1431.6	148.8
Length of Hospitalization (days)	46.5	18.8
Weight at Discharge (grams)	2017.3	129.6

Procedures

Each infant was observed during four different experimental sequences. Each sequence consisted of four consecutive 30-minute periods. The four sequences necessary for fulfilling the experimental design are presented in Table 2. The first of those periods began at the same time that a nasogastric (NG) feeding was started. For half of the sequences, the infant was given a pacifier on which to suck, during the first period. The feedings from the other two sequences were administered without a pacifier. These two manipulations provided an opportunity to compare the effects of a pacifier during a feeding. For all four sequences, the second and fourth 30-minute periods consisted of naturalistic observations of the infant. The third 30-minute period served as a control for the feeding condition. During half of the third period observations the infant was again given a pacifier. Comparisons of the effects of these manipulations with those observed during the feeding periods allowed for an evaluation of the effects of the pacifier independently of the effects of feeding. These manipulations yield a 2(pacifier or not) X 2(feeding or later) X 2(during or after a manipulation) repeated measures design. In addition, because one of the concerns of this project was to evaluate possible lingering effects of NNS, order of stimulus presentation was also controlled. This last control procedure, whether the stimulus

Table 2.

Experimental design

	30-Minute Observation Period			
Sequence	1	2	3	4
A	Pacifier Feeding	No Pacifier Not Feeding	Pacifier Not Feeding	No Pacifier Not Feeding
B	Pacifier Feeding	No Pacifier Not Feeding	No Pacifier Not Feeding	No Pacifier Not Feeding
C	No Pacifier Feeding	No Pacifier Not Feeding	Pacifier Not Feeding	No Pacifier Not Feeding
D	No Pacifier Feeding	No Pacifier Not Feeding	No Pacifier Not Feeding	No Pacifier Not Feeding

presentation in the third period was the same as or different from the stimulus presentation during the feeding observation, was labeled order. Thus, the above design was expanded from three factors to four factors. The order of the four experimental sequences for each infant was randomly determined. Infants were observed in all four sequences within a span of eight days.

Pacifiers were constructed from standard preterm-sized nipples manufactured by Ross Laboratories. A small dry gauze pad was stuffed into the open end of the nipple which was then taped closed. The time that the infant sucked on the pacifier was quantified by counting the number of thirty second periods that the infant held the pacifier in its mouth. Infants sucked on the pacifiers for an average of 24.3±5.4 minutes during the feeding periods and for an average of 21.5±4.7 minutes during the later periods. A fifteen minute exposure to the pacifier was arbitrarily chosen as a lower limit for the NNS experience. Thus, when an infant sucked on a pacifier for less than half of the duration of a 30-minute manipulation period that entire two hour sequence was repeated.

Biobehavioral measures. During each sequence the infant's state was recorded once every thirty seconds. Biobehavioral state was scored according to the scale used in the Assessment of Preterm Infant Behavior (APIB) (Als et al., 1982). Table 3

Table 3.

Observable signs of biobehavioral states*

1A: Deep Sleep - Eyes are closed, breathing is momentarily regular, facial expression is relaxed, and there is no spontaneous activity oscillating fairly rapidly with isolated startles or the jerky movements and other behaviors charateristic of State 2.

1B: Deep Sleep - Eyes are closed, breathing is predominantly regular, facial expression is relaxed, and there is no spontaneous activity except isolated startles.

2A: Light Sleep - Eyes are closed, rapid eye movements may be visible beneath closed lids, respirations are irregular, facial twitching and grimacing is common, and the impression of a "noisy" state is given.

2B: Light Sleep - Eyes are closed, rapid eye movements may be visible beneath closed lids, some dampened motor activity may also be present, respirations are somewhat irregular, and facial movements are confined to isolated sighs or smiles.

Table 3. Continued

3A: Drowsy - Eyes may be open, closed or fluttering; if open, eyes have a glassy look; activity level is variable, some mild startles may be observed, and there is much diffuse movement with fussing, grimacing and possibly some vocalizations.

3B: Drowsy - Same as 3A, but with fewer facial movements and no vocalization.

4AL: Awake - Eyes are half open or open but with a glazed look giving the impression of looking through rather than at an object, and motor activity is minimal.

4AH: Awake - Eyes are wide open, giving the impression of panic, fear, or of being "hooked" by a stimulus, and motor activity is minimal.

4B: Alert - Eyes are open with a bright, shiny, focused look, and motor activity is minimal.

5A: Active - Eyes may or may not be open, but the infant is clearly awake and aroused as indicated by muscle tonus; there is some grimacing and other signs of discomfort, and fussing is diffuse.

5B: Active - Eyes may or may not be open, but infant is clearly awake and aroused with considerable well defined motor activity; infant is fussing but not crying.

Table 3. Continued

6A: Crying - Intense crying as indicated by intense facial movements but with strained and weak sound.

6B: Crying - Rhythmic intense crying which is robust and strong in sound.

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*from Als, Lester, Tronick, & Brazelton 1982.

presents operational definitions of each of the states. There were six basic states; 1=Quiet Sleep, 2=Active Sleep, 3=Drowsy, 4=Alert, 5=Wakeful Activity, 6=Crying. Each of those states was divided into two or more categories. One category for each state corresponds precisely with the definition of the state as it is used in the Newborn Behavioral Assessment Scale (NBAS) (Brazelton, 1973) for fullterm newborns and is designated as "B". The other category is designated as "A", and can be described generally as a more "noisy" or preterm like state. The exception to this pattern is the alert state which is divided into three categories. In that state the "B" designation corresponds with the NBAS alert state, and "H" and "L" designations indicate the infant's focus of attention.

Trained research assistants, who were unaware of the hypotheses of the study, considered ten second epochs in evaluating the current state of the infant. Reliability of the research assistants was assessed by comparing their observations of an infant with those of the experimenter on one of every four to eight sequences. The inter-observer reliability averaged 86.3%±8.1% with a range of 75.0% to 97.5%.

The following summary measures of state were derived separately for each of the 30-minute periods: 1) the number of observations that the infant was judged to be in a drowsy or awake state, 2) the number of observations which were designated as B-states, 3) the highest state attained, and 4) the modal state. The last two measures have been previously demonstrated to discriminate between groups of high- and low-risk full term newborns (Goff & Zeskind, 1983; Goff & Zeskind, 1984).

Each of the 60-minute time-series for state was submitted to spectral analysis. The number of significant peaks, the frequency of the lowest significant peak, and the range of frequencies of the significant peaks were obtained from the spectral density functions for each 60-minute state data time-series.

The two-hour state data time-series from the sequences which contained no manipulations during the third period (sequences B and D in Table 2) were also submitted to spectral analysis. These two sequences were chosen for this analysis because they represent undisturbed two-hour observation periods which differed only with respect to availability of the pacifier at the beginning of the sequence. This two-hour period allowed for the observation of three complete cycles of the hypothesized forty-minute rhythm and allowed for a statistically robust measure of that rhythm. From these analyses, the presence of the forty minute rhythm following a feeding which included NNS and a feeding which did not include NNS was evaluated. Furthermore, the amount of variance accounted for by that rhythm was quantified from the spectral density functions.

Statistical Analyses

Spectral Analyses. The time-series data were prepared for spectral analysis according to the procedures recommended by Gottman (1981). The 60-minute times-series were non-stationary. The stationarity of these time-series was improved by using a least-squares multiple regression to fit a third-order polynomial equation of the raw data. The spectral density functions were then calculated based on the residuals obtained from that analysis. The two-hour state data time-series were prepared in an identical manner.

Spectral density functions were calculated from autocorrelations with a Tukey-Hanning lag window (Gottman, 1981). The bandwidth for that window was determined from preliminary analyses. For the 60 minute time-series a lag of 40 was used, yielding a bandwidth of .10 and estimated degrees of freedom of 8.01. Analogously, for the 2-hour time-series a lag of 80 was used in the Tukey-Hanning window, yielding a bandwidth of .10 and estimated degrees of freedom of 8.01.

A Kolmogorov-Smirnov statistic was used to compare each of the spectral density functions to a random process (Jenkins & Watts, 1968). This test is based on the assumption that if there are no significant rhythmic patterns in the time-series then every frequency will have the same spectral density value. Thus, a significant Kolmogorov-Smirnov statistic indicates that there is at least one significant peak in the spectral density function. When that test was significant at the .05 level the spectral density function was examined for the presence of significant peaks. An increase in the spectral density was judged to be a peak if the spectral density exceeded the .05 confidence interval for the white noise level (Gottman, 1981).

Analyses for treatment effects. The statistical measures of state were analyzed for differences among the sixteen cells of the design with two separate overall analyses. The first of those was a 2 X 2 X 2 X 2 within-groups Multivariate Analysis of Variance (MANOVA). The independent variables in this analysis were 2 pacifier manipulations (pacifier or no pacifier), 2 feeding conditions (during feeding or later in the observation sequence), 2 times (during or after manipulation periods), and 2 orders (same manipulation in periods 1 and 3, or different manipulations in those two periods). The dependent variables in this analysis were 1) modal state, 2) highest state, 3) number of minutes observed in B states, and 4) number of minutes observed in awake states.

The data obtained from the spectral density functions of the 60-minute time-series were analyzed for differences in the testing conditions with a second within-groups MANOVA. The design of this second analysis was similar to the first except that the during/after factor was not included. As a result, the design for the second analysis was 2(pacifier or not) X 2(feeding or later) X 2(orders). The dependent variables in this second analysis were 1) the number of significant peaks, 2) the frequency of the lowest significant peak, and 3) the range of frequencies of the significant peaks.

In general, whenever a significant MANOVA was obtained appropriate univariate statistics were calculated to explicate the source of the significant overall statistic. The multivariate effects were evaluated based on F-approximations.

The amount of statistical variance in state accounted for by the slowest frequency significant peak in the 2-hour time-series from a pacifier and a control condition were compared with a paired t-test.

In addition to these analyses which were proposed earlier, a number of other analyses were conducted to examine the effects of NNS on Quiet Sleep and to further explore the effects of NNS on the organization of state. These later measures included the amount of variance in state accounted for by the lowest frequency peak, and the amount of variance accounted for by all of the significant peaks in the spectral density functions from the one-hour time-series. Two additional measures were taken from the spectral density functions of the 2-hour time-series. These measures were the number of significant peaks and percent variance accounted for by all of the significant peaks in the spectral density functions for the 2-hour time-series.

RESULTS

Summary Measures of State

The results of the multivariate analyses of the four summary measures of state, 1) number of minutes awake, 2) number of minutes in B-states, 3) highest state, and 4) modal state, are presented in Table 4. The interaction of feeding condition with during/after manipulations yielded a reliable multivariate effect ($F(4,11)=10.79$, $p<.001$). Reliable univariate interactions were also found for three of the dependent measures: highest state($F(1,14)=20.66$ $p<.001$), minutes awake ($F(4,14)=51.98$, $p<.001$), and modal state ($F(1,14)=5.92$, $p<.05$). Figure 1 presents the means and standard deviations for the highest state data. The observations made during feeding periods yielded a drowsy state as the average highest state. The average for each of the other three observation periods was active sleep. The data for number of minutes awake are presented in Figure 2 while the data for modal state are presented in Figure 3. The pattern of these differences are identical to that observed for highest state. The infants spent more time awake (7.5 minutes) during the feeding period then they did during the other three periods (approximately one minute). Likewise, the average modal state for the during feeding period was 2, this average dropped to less than 2 for the other three periods. None of the other interactions yielded significant differences.

Table 4.

The reliable effects of the interaction between feeding conditions with during/after manipulation on the summary measures of state.

Multivariate effect $F(4,11)=10.79$, $p<.001$

Dependent Variables	$F(1,14)$	p
Highest State	20.66	<.001
Minutes Awake	51.98	<.001
Modal State	5.92	<.05
Minutes in B-States	.03	n.s.

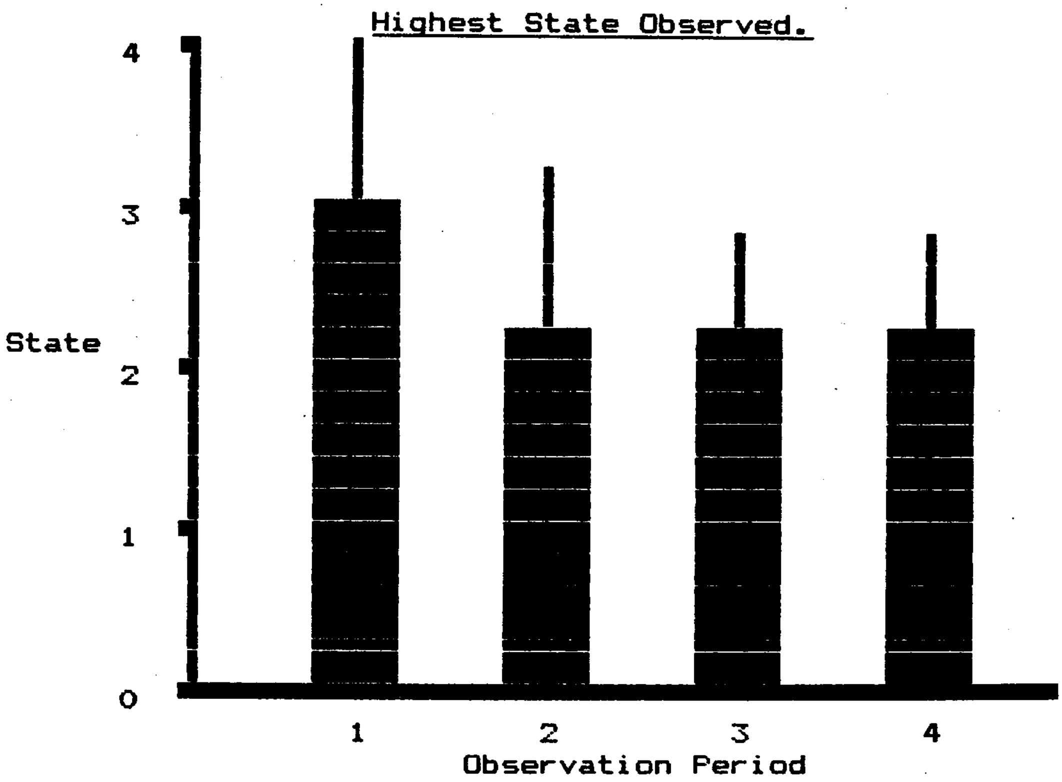

Figure 1. Means and Standard Deviations for the highest state observed in each of the 30-minute periods presented according to the feeding/later by during/after interaction. Period 1 was the during feeding condition. Period 2 was the 30 minutes after the feeding condition. Period 3 was the 30 minutes during the feeding control condition. Period 4 was the 30 minutes after the feeding control condition.

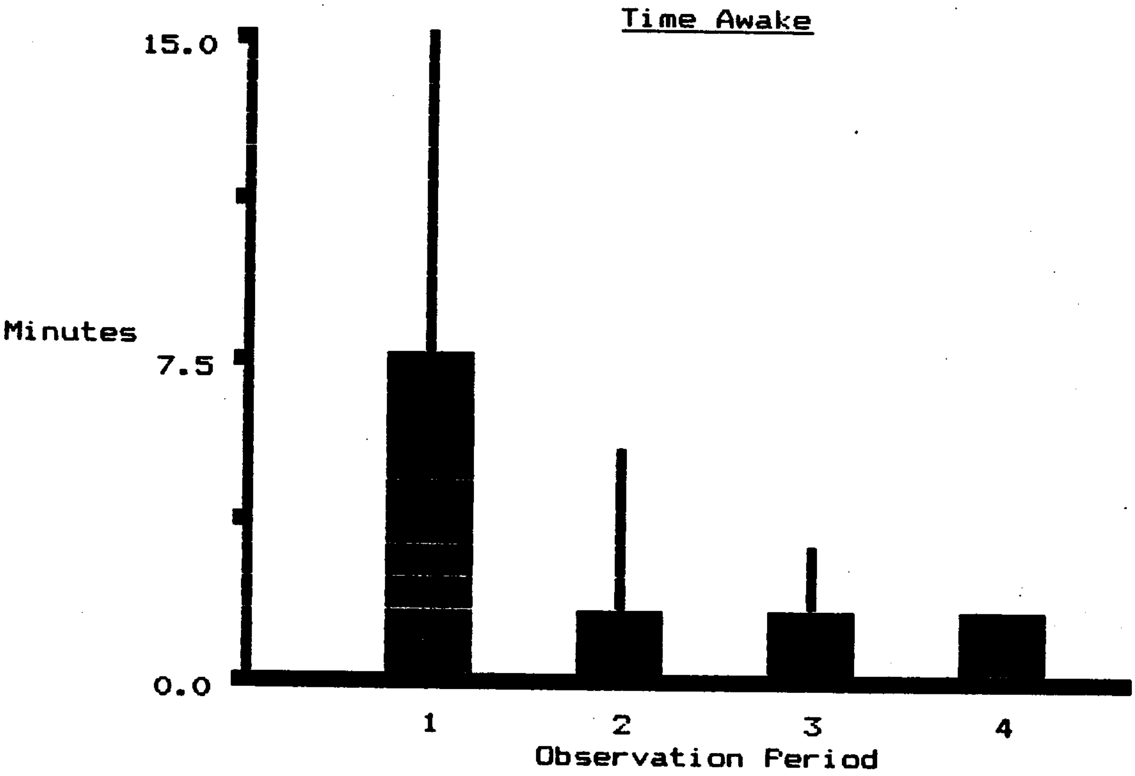

Figure 2. Means and Standard Deviations for the number of minutes awake in each of the 30 minute periods presented according to the feeding/later by during/after interaction. Period 1 was the during feeding condition. Period 2 was the 30 minutes after the feeding condition. Period 3 was the 30 minutes during the feeding control condition. Period 4 was the 30 minutes after the feeding control condition.

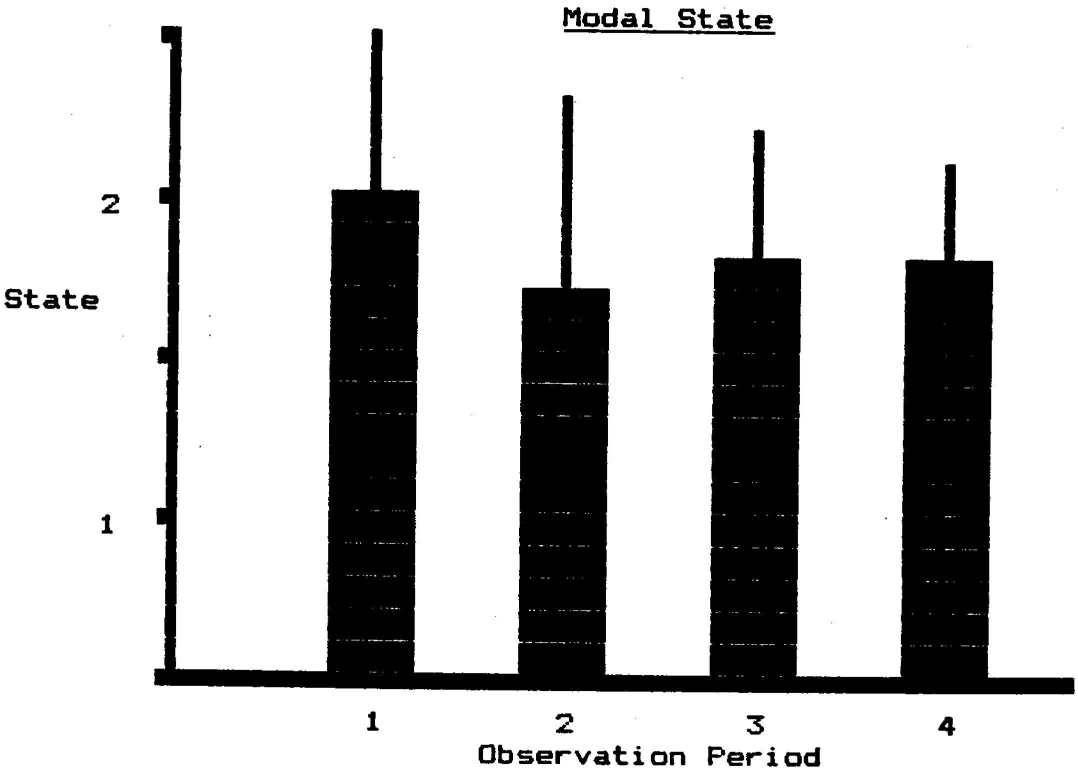

Figure 3. Means and Standard Deviations for the modal state in each of the 30 minute periods presented according to the feeding/later by during/after interaction. Period 1 was the during feeding condition. Period 2 was the 30 minutes after the feeding condition. Period 3 was the 30 minutes during the feeding control condition. Period 4 was the 30 minutes after the feeding control condition.

Within this multivariate analysis the only significant main-effects were the components of the interaction discussed above. The reliable effects for Feeding conditon are presented in Table 5. Feeding yielded a reliable multivariate effect ($\underline{F}(4,11)=12.08$, $\underline{p}<.001$). Two of the dependent variables yielded significant univariate effects, number of minutes awake ($\underline{F}(1,14)=29.42$, $\underline{p}<.01$), and highest state ($\underline{F}(1,14)=13.00$, $\underline{p}<.005$). Of course these effects can only be interpreted in terms of the significant interaction already presented. A third dependent measure, number of minutes observed in B-states, had a marginal univariate effect ($\underline{F}(1,14)=4.28$, $\underline{p}<.06$). This difference indicated that infants spent more of their feeding observations (24.4 ± 4.2 minutes) in B-states than later observations (23.5±5.0 minutes). In summary, the reliable effects for the summary measures of state indicated that the highest state, modal state, and number of minutes awake were a function of the interaction between the feeding condition and during/after manipulations conditions, While, the number of minutes in B-states was, in part, a function of the feeding condition. None of these measures were affected by the pacifier manipulations.

Table 5.

The reliable effects of the feeding conditions on the summary measures of state.

Multivariate effect *F*(4,11)=12.08, *p*<.001

Dependent Variables	*F*(1,14)	*p*
Highest State	13.00	<.005
Minutes Awake	29.42	<.001
Modal State	1.12	n.s.
Minutes in B-States	4.28	<.06

Analysis of Quiet Sleep Data

The number of minutes from each 30 minute period spent in quiet sleep, and the number of minutes spent in quiet sleep B were tallied and included in a 2(pacifier) X 2(feeding) X 2(during/after) X 2(order) MANOVA similar to the analysis for the summary measures of state. The reliable multivariate effect for the pacifier by order interaction is summarized in Table 6. There was a significant interaction between order and pacifier conditions at the multivariate level ($F(2,13)=4.41$, $p<.05$). Both the number of minutes in quiet sleep ($F(1,14)=9.46$, $p<.01$) and the number of minutes in quiet sleep B ($F(1,14)=8.25$, $p<.02$) yielded reliable univariate effects. As can be seen in Figure 4 infants spent approximately 11 minutes in quiet sleep if they were given a pacifier (first and second bars of Figure 5) or if they were left undisturbed for two consecutive hours (third bar in Figure 4). However, when the infants were not given a pacifier and similar manipulations did not follow each other they spent approximately 6 minutes in quiet sleep (fourth bar in Figure 4). An identical pattern was observed for quiet sleep B (see Figure 5). The results for quiet sleep indicated that infants spent more time in quiet sleep and quiet sleep B if they were given a pacifier or if they were allowed to sleep undisturbed for two hours.

Table 6.

The reliable effects on quiet sleep of the interaction of pacifier manipulations with the order of manipulations.

Multivariate effect $F(2,13)=4.41$, $p<.05$

Dependent Variables	$F(1,14)$	p
Quiet Sleep	9.46	<.01
Quiet Sleep B	8.25	<.02

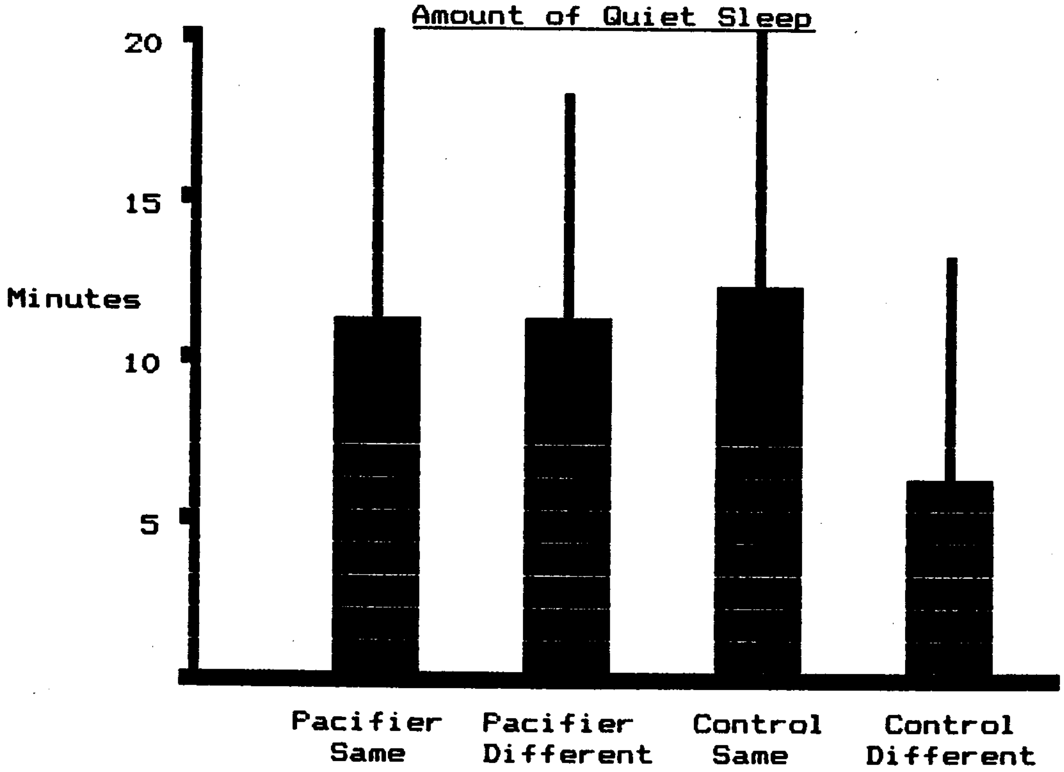

Figure 4. Means and Standard Deviations for the amount of quiet sleep observed presented as a function of the pacifier by order interaction.

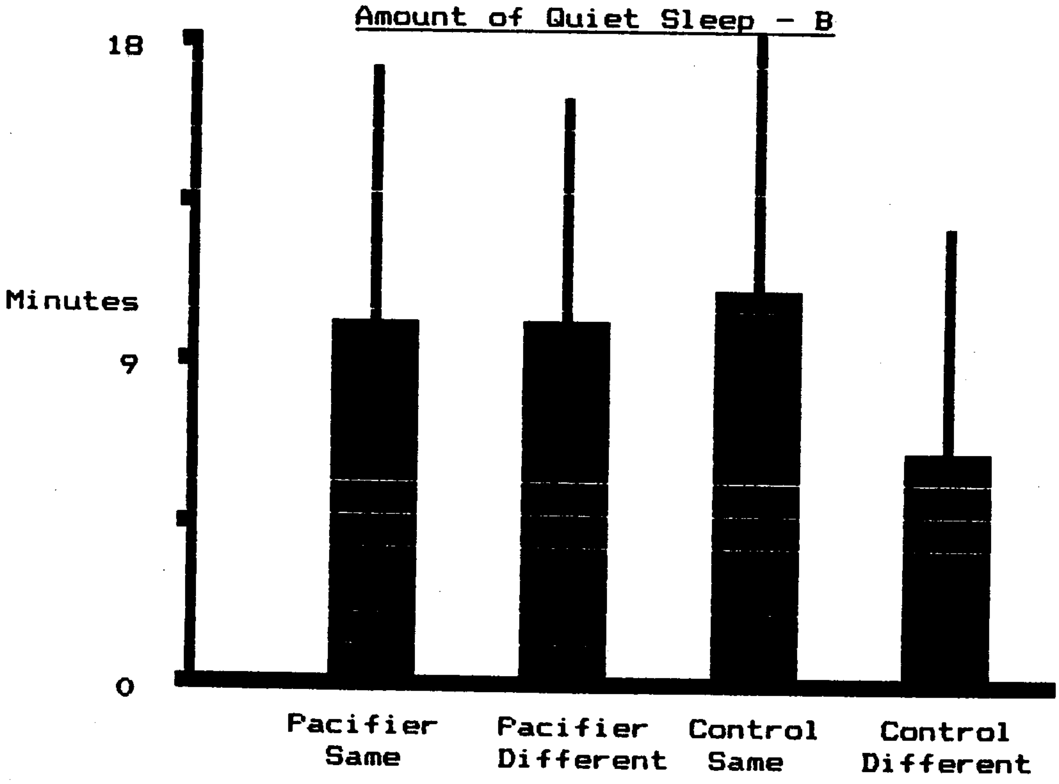

Figure 5. Means and Standard Deviations for the amount of quiet sleep B observed presented as a function of the pacifier by order interaction.

Analyses of 1-Hour Time-Series Data

An example of a spectral density function derived from a one-hour time-series of state data is presented in Figure 6. The data for this function were collected during a one-hour time-series which started with the subject sucking on a pacifier and being fed. This function differed significantly from a random process (*K.S.*=.24, $p<.01$). The upper bound for the 95% confidence interval around white noise is represented by the line at .082. Points that projected above this line were judged to represent significant peaks in the spectral density function. This spectral density function had 2 significant peaks at frequencies of 4.0 and 18.0 cycles per hour. The other spectral density functions had a range of 0 to 3 significant peaks, with a mean of 1.1±.7. The frequencies of the slowest frequency peak ranged from 2.0 to 19.0 cph, with a mean of 4.9±4.1 cph.

Of the 120 spectral density functions calculated for the one-hour time-series 92 differed significantly from a random process. The percent of spectral density functions which were significant are presented in Table 7 as a function of the pacifier by feeding interaction. A Cochran's Q (Siegel, 1956) indicated that the number of significant spectral density functions was a function of the interaction between the pacifier and feeding conditions ($Q(3, N=15)=8.85$, $p<.05$). The likely source of this significant effect is in the pacifier dimension. When an infant sucked on a pacifier, the spectral density

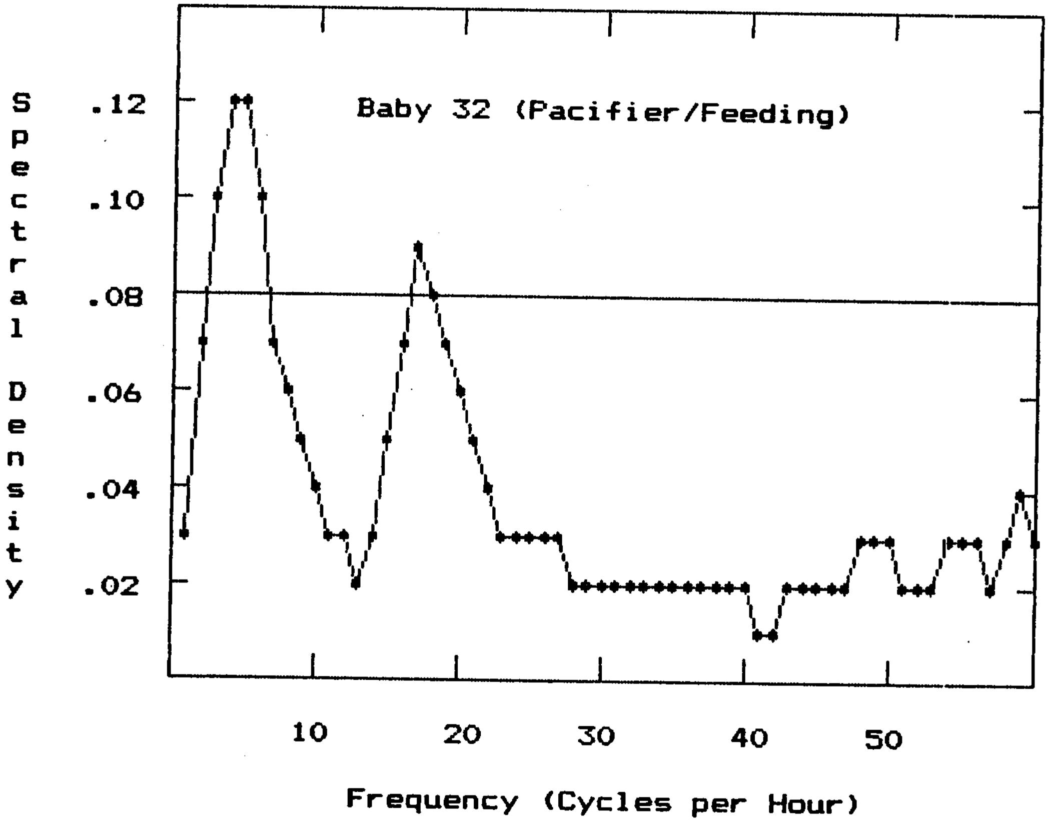

Figure 6. Spectral density function for a one-hour time-series for baby 32 which started with pacifier and feeding manipulations. The two peaks which projected above the spectral density value of .082 at 4.0 and 18.0 cycles per hour were judged to represent significant rhythmic processes.

function for the one-hour state data time-series was more likely to differ significantly from a random process.

Inspection of the data summarized in Table 7 indicated that one of the 15 infants presented a distinctly different pattern of spectral density functions from the other 14. Of the 14 infants, all had three of the four spectral density functions achieve conventional levels of significance when the infant sucked on a pacifier. Only four infants had even one non-significant spectral density function when in a pacifier condition. Conversly, Baby 30, did not have a significant spectral density function in any of the four pacifier opportunities. The only other quantified difference between this infant and the other subjects was that she had an exceptionally high PNF. The PNF is a measure of the number of medical complications encountered by an infant. A high score indicates that the infant has had few complications. The only medical complications encountered by this infant were that she did not control her temperature, and she did not feed by mouth in the first 48 hours. Because this subject was such an extreme outlier the analysis was conducted again. When she was excluded from this analysis the value of the statistic increased dramatically ($\underline{Q}(3, \underline{N}=14)=13.29$, $\underline{p}<.005$). The change in the proportions of significant spectral denstiy

Table 7.

Percent of significant spectral density functions from the pacifier and feeding conditions.

Feeding Condition	Pacifier Condition	
	Pacifier	Control
Feeding	93.3%	66.7%
	100.0%*	64.3%*
Later	80.0%	66.7%
	84.7%*	64.3%*

*Baby 30 excluded

functions when baby 30 was not included in this analysis are also indicated in Table 7. Because of the fundamental difference between this infant and the rest of the infants in the sample, analyses which involved measures taken from the spectral density functions were performed twice, once including this outlier and once excluding her.

When the number of significant peaks, the range of frequencies of the significant peaks, and the frequency of the slowest frequency significant peak from each spectral density function were analyzed in a 2(pacifier) X 2(feeding) X 2(order) MANOVA and baby 30 was included there were no significant effects. The reliable effects of this analysis when baby 30 was excluded are summarized in Table 8. Under this condition the pacifier manipulation yielded the only reliable multivariate effect ($\underline{F}(3,11)=11.12$, $\underline{p}<.01$). Of the three dependent variables, only the number of significant peaks yielded a reliable univariate effect ($\underline{F}(1,13)=7.05$, $\underline{p}<.02$). The spectral density functions from observations which started with the infant sucking on a pacifier had more significant peaks ($1.2\pm.6$) than did the other observations ($.9\pm.8$). Of the three measures derived from the spectral density functions, only the number of peaks was increased by the pacifier manipulation. None of the measures was affected by any of the other manipulations.

Two additional measures were taken from the spectral density

Table 8.

The reliable effects of the pacifier manipulations on the spectral density measures.

Multivariate effect *F*(3,11)=11.12, *p*<.01

Dependent Variables	*F*(1,13)	*p*
Number of Peaks	7.05	<.02
Range of Frequencies	1.94	n.s.
Slowest Frequency	.65	n.s.

functions for the 1-hour time-series. Those measures were the amount of variance accounted for at the slowest frequency peak regardless of whether that peak was significant, and the amount of variance accounted for by all of the significant peaks. Those measures were included in a 2(pacifier) by 2(feeding) by 2(order) MANOVA. The same pattern was seen here as was seen in the results presented earlier for the number of peaks, the lowest frequency peak, and the range of significant peaks. When baby 30 was included in the analysis there were no significant effects. However, when baby 30 was excluded from this analysis there was a reliable main effect for the pacifier condition ($\underline{F}(2,12)=7.97$, $\underline{p}<.01$). A summary of the reliable effects of the pacifier manipulation is presented in Table 9. There were significant univariate effects for both the percent of variance accounted for by the slowest rhythm on the pacifier factor ($\underline{F}(1,13)=9.11$, $\underline{p}<.01$) and for the percent of variance accounted for by all of the significant peaks ($\underline{F}(1,13)=17.08$, $\underline{p}<.001$). More variance was accounted for at the slowest frequency peak in the pacifier condition (43.0%±19.0%) than in the control condition (30.2%±18.0%). Likewise, more variance was accounted for by all of the significant peaks in the pacifier condition (45.5%±24.3%) than in the control condition (36.1%±29.6%). These results indicated that significantly more variance was accounted for by the modeled rhythms when the infants sucked on pacifiers than when they did not.

Table 9.

The reliable effects of the pacifier manipulation on percent variance accounted for by peaks in the spectral density functions.

Multivariate effect $F(2,12)=7.97$, $p<.01$

Dependent Variables	$F(1,14)$	p
Slowest Frequency Peak	9.11	<.01
All Significant Peaks	17.08	<.001

Analyses of the 2-Hour Time-series Data

The spectral density functions from the two-hour time-series allowed for an estimation of the presence of the 1.0 to 1.5 cycles per hour rhythm which has been described in full term infants. All of the 30 spectral density functions calculated for the 2-hour time-series were significantly different from a random process. The frequencies of the lowest frequency significant peak ranged from 1.0 to 5.0 cycles per hour, with a mean of 1.7±1.0 cph. In the pacifier condition 11 infants had a significant peak in the range of 1.0 to 1.5 cycles per hour, while in the control condition 13 infants had significant peaks in that range. Only one infant did not have a peak within that range in either of the two conditions. Although the means for the proportion of variance accounted for by the lowest frequency significant peak differed in the hypothesized direction, the difference was not statistically significant ($t(14)=1.19$, $p>.05$) (without baby 30, $t(13)=1.00$, $p>.05$). Thus, the basic rhythm did not account for more of the variance in state when the infant sucked on a pacifier than when the infant did not suck on a pacifier.

Finally, two additional measures from the spectral density functions for the 2-hour time-series were evaluated. Those measures were the number of significant peaks in the spectral density functions, and the percent of variance accounted for by all of the significant peaks. The effects of the pacifier manipulations on these two measures was evaluated with paired t-tests. There were more significant peaks in the pacifier time-series (2.1+1.3) than in the control time-series (1.5±.7), however, this difference was not reliable ($t(14)=1.46$, $p>.05$) (without baby 30, $t(13)=1.99$, $p<.07$). The percent of variance accounted for by all of the peaks did represent a reliable difference between the two conditions ($t(14)=2.49$, $p<.05$) (without baby 30, $t(13)=2.83$, $p<.02$). More variance was accounted for in the pacifier condition (55.0%±14.4%) than in the control condition (41.1%±15.0%). These results indicate that more variance was accounted for by all of the significant rhythmic processes when the infants were given pacifiers on which to suck than when they were not. However, the number of rhythms and the percent of variance accounted for by the slowest rhythm were not affected by the pacifier manipulations.

DISCUSSION

The results of this study indicate that nonnutritive sucking affects the organization of state in preterm infants. The most prominent effects of NNS on state were seen as a change in the rhythmic organization of state. There were more significant peaks in the spectral density functions following NNS. The rhythms represented by those peaks also accounted for more of the variance in state. These measures indicated that the rhythmic organization of state in preterm infants following NNS was more like the organization of state in low-risk full term infants. There was also a subtle effect of NNS on the amount of quiet sleep. The amount of quiet sleep was increased by NNS but not beyond the level observed in an undisturbed two-hour observation sequence. The NNS manipulation had no effect on summary measures of state such as time awake, highest state, modal state, and time spent in B-states. However, these summary measures of state activity were effective indicators of responses to physiological or environmental factors other than NNS.

Organization of State

The results derived from the spectral density functions confirm the overall hypothesis that NNS affects the organization of state in preterm infants. More of the spectral density functions from the one-hour time-series were significant when the infants sucked on a pacifier than when they did not. Furthermore, more of the statistical variance in state was accounted for by the significant peaks in the spectral density functions of the 2-hour time-series when the subjects sucked on a pacifier. These effects indicate that the NNS experience had an organizing effect on state in these infants. However, one infant in this study showed a unique response to the nonnutritive sucking experience. When this infant was excluded from the analyses a broader effect of nonnutritive sucking on the organization of state was demonstrated.

Spectral density functions were more likely to represent significant rhythmic organization in state if the functions were derived from observations which included NNS. Ten of the fifteen infants in this study had significant rhythmic organization of their state activity in response to the pacifier on all four of the pacifier manipulations. Of the remaining infants, four had significant rhythmic organization of their state activity in response to the pacifier on three of the four occasions. The remaining infant had no significant rhythmic organization of her state activity in response to the pacifier on all four of the occasions. By comparison, an average of only two out of three observations which did not include NNS yielded significant spectral density functions. Thus, at the most basic level of analysis, infants responded to the pacifier with more rhythmic organization of their state activity.

One infant consistently responded to the pacifier with less rhythmic organization in her state while the other infants responded to the pacifier with more organization. Explaining the unique response of one infant is a difficult task. The only other quantified characteristic which differentiated this infant from the other subjects was her unusually high PNF score. The high score suggests that this infant was extraordinarily healthy. Yet, the data for this infant indicate that she responded to the NNS experience with less organization of her behavior. Als et al. (1981) have proposed that the major developmental task of preterm infants of this age is to coordinate behavioral and physiological systems. The reduced organization seen in this infant may indicate an inability to coordinate her responses to the pacifier. Furthermore, Wolff (1967) describes the nonnutritive sucking of an infant who was suffering from a brain dysfunction. The rhythm of that infant's sucking was disrupted by the dysfunction. Some analogous process might have affected this infant and her response to the pacifier. Thus, despite her high rating on the other indicator of risk, it might be that this infant was in fact at exceptionally high-risk. The remainder of the discussion of the effects of NNS on the organization of behavioral state is based on the assumption that this infant is a special case, and the results obtained when she was excluded from the analyses are discussed.

The hypothesis that these infants would show a basic 40- to 60-minute rhythm was confirmed. The lowest frequency peaks for the two-hour time-series were consistently in the range of 1 to 5 cycles per hour with most of the slowest rhythms being in the 1.0 to 1.5 cph range. These data indicate that most of the preterm infants in this study had a 40- to 60-minute rhythm in their state activity. This description of a state rhythm between 1.0 and 1.5 cycles per hour is consistent with earlier reports of a basic rest activity rhythm (Emde et al., 1975), and of a similar description of organization of state in full term infants (Zeskind et al., in preparation). The present data then demonstrate that preterm infants of approximately 34 weeks conceptional age do have the same basic 40- to 60-minute rhythm that has been observed in full term infants.

The hypothesis that more of the variance in state would be accounted for by this basic rhythm when the infants sucked on a pacifier was not confirmed. The basic rhythms accounted for equal proportions of the variance in the two experimental conditions. These two findings indicate that preterm infants who are approximately 34 weeks conceptional age have the basic 40- to 60-minute rhythm, and that rhythm might not be very sensitive to to exogenous regulation. This relative lack of sensitivity suggests that the 40- to 60-minute rhythm is regulated primarily by an endogenous source.

Although the basic rhythm was relatively constant across the two experimental conditions, there were differences in the state spectra as a function of the pacifier conditions. There was a marginal increase in the number of significant peaks when the infants sucked on a pacifier and there was more variance in state accounted for by those rhythms. These findings indicate that following NNS the rhythmic structure of state is more complex; there are more detectable rhythms, and those rhythms account for more of the variability in state. Zeskind et al. (in preparation) also describe a difference in the rhythmic organization of state. In that description high-risk infants had fewer significant peaks in their state spectra than did low-risk infants. The current results indicate that the rhythmic organization of state in preterm infants following NNS is more like that of low-risk full term infants.

One hypothesis suggested by the comparison of these two findings is that the reason preterm infants typically do not behave like low-risk infants is that they are routinely denied the exogenous regulators which are available to healthy full term infants. Thus, the high-risk status of preterm infants might not be due to the fact of their early birth but rather due to a failure of the caregiving environment to provide appropriate exogenous regulators. This hypothesis is supported by the report of Holmes et al. (1982). That report indicates that the major predictors of risk in preterm infants are the number of medical complications and the length of hospitalization. Providing the same sorts of stimulation which are available to healthy full term infants might allow perterm infants to behave more like low-risk infants. Of course, there is a limit to what kinds of similar stimuli can be provided because preterm infants are more fragile than full term infants (Als et al., 1983).

Similar effects were observed in the one-hour time-series of state data. The number of significant peaks, and the proportion of variance accounted for by those rhythms were both significantly increased in the pacifier conditions. Thus, the effects of NNS on the organization of state was evident in both the shorter and longer time-series. Again these data indicate that the organization of state is more like that of low-risk full term infants. In addition to these two findings, the variance accounted for by the slowest rhythm in the one-hour time-series was also increased in the pacifier conditions. The frequencies of these rhythms ranged from 4.0 to 18.0 cycles per hour. While these rhythms were not significant for all of the infants in all of the situations, they still accounted for some variance in state. This finding indicates again that faster rhythms account for more of the variability in state when the infants sucked on a pacifier.

Briefly, the 40- to 60-minute rhythm may represent a relatively stabile endogenous process while the faster rhythms represent a more dynamic process which is responsive to exogenous regulation. These faster rhythms might represent the mechanism which Stratton (1982) hypothesizes facilitates an infant's adaptation to the demands of the extrauterine environment. This broader range of rhythmic activity is hypothesized to allow for a broader range of responsiveness. If Stratton's hypothesis is correct then preterm infants who receive regular experience with NNS should be more able to adapt to the rigors of the NICU, because they have a broader range of responsiveness.

Quiet Sleep

The effects of the NNS experience on the amount of time in quiet sleep and quiet sleep B were subtle. NNS increased the amount of both quiet sleep and quiet sleep B, but not beyond that obtained during an uninterrupted two hour observation. By comparison, the subjects did not spend as much time in quiet sleep or quiet sleep B when they were observed in a different order of manipulation, and the two 30-minute observation periods did not include NNS. Thus, giving a preterm infant a pacifier on which to suck did provide for more quiet sleep. However, the preterm infants in this study experienced a similar amount of quiet sleep if they were provided 2-hours undisturbed sleep time or if they were given a pacifier.

The findings of an increase in quiet sleep in response to NNS support the earlier reports of the effects of NNS on sleep states. Wolff and Simmons (1967) observed that quiet sleep was increased in full term infants during NNS. The current results provide data which allow that earlier observation to be generalized to preterm infants. However, this effect is qualified for preterm infants because they got the same amount of quiet sleep if they were simply allowed to sleep undisturbed for two hours. This last point suggests that NNS would not affect the total amount of quiet sleep that a preterm infant experienced unless there were frequent interruptions of its sleep. Typically the sleep of a preterm infant is interrupted an average of once every 30 minutes (Gottfried, in press). Under these conditions a pacifier would likely increase the total amount of quiet sleep an infant receives.

Another interesting aspect of the current data is that the percentage of quiet sleep is quite high. The average of approximately 11 minutes of quiet sleep seen in the first three bars of figure 5 represents 36% of the total observation period. By comparison, an earlier report of percent of quiet sleep for preterm infants was 23%, and 31% for full term infants (Parmelee, Wenner, Akiyama, Schultz & Stern, 1967). The 20% of quiet sleep observed during the periods in which a pacifier was not given to the infant and a different order of manipulations was used approximates the earlier reports for quiet sleep in preterm infants. The other conditions approximate the earlier report for percent of quiet sleep in full term infants. These findings suggest that if a preterm infant is observed under conditions which more closely approximate the typical treatment for a newborn that the observed behavior pattern will be more similar to that observed in newborns.

The effect on quiet sleep is important because intervention programs for preterm infants are frequently designed to increase the amount of time in quiet sleep (e.g. Thoman & Graham, 1985). The current results suggest that NNS may provide an effective strategy for increasing the amount of quiet sleep in preterm infants to near that of full term infants. A similarly effective strategy is to provide extended periods of uninterrupted sleep. As a final note, the NNS experience in this study also increased the amount of time in quiet sleep B which is more like the quiet sleep of full term infants. Thus, providing preterm infants with an NNS experience or allowing extended periods of uninterrupted sleep allows them to obtain a quality of sleep which is more like that of full term infants.

Extended periods of quiet sleep are hypothesized to provide for a conservation of energy (Thoman & Graham, 1985). Thus, if a preterm infant can spend more time in quiet sleep the infant can make more effective use of any nutrients. NNS experience provides a mechanism for achieving this need. Hall and Williams (1983) have proposed that sucking provides distinct functions in the newborn rat. A similar scheme is proposed here for the human infant. Sucking is proposed to provide three distinct functions for the human infant. The first function is the intake of nutrients. The second function is the preparation of the digestive tract for the nutrients once they have been consumed. In support of this function, Bernbaum et al. (1983) have demonstrated that sucking can aid the digestive processes in preterm infants. The third function is the production of a behavioral quiesence so that the nutrients can be used most effectively. At this age the most effective use of nutrients might be the conversion of these nutrients into compounds which can be used to support development in the central nervous system (Holmes et al., 1984). These last two functions are probably mediated by the same physiological mechanism, an increase in the level of parasympathetic functioning. The parasympathetic nervous system is activated by sucking to prepare the digestive tract for the digestive processes, and as an adjunct the level of arousal is reduced. This reduction in the level of arousal is most clearly evident in the increase in the amount of quiet sleep following NNS.

Summary Measures of State

While the summary measures of state, that is, highest state, minutes awake, and modal state, were not sensitive to the effects of NNS, these measures did change over the course of the two hour observations. The significant interaction between the feeding conditions and the during/after manipulations factor showed that these preterm infants were in a higher state of arousal during a feeding than at other times later in the observation sequences. In one respect, this finding quantifies the observation that even preterm infants enter sleep states after being fed. Beyond the obvious, these findings demonstrate that preterm infants will reduce their levels of arousal in response to a feeding even if they are not given an opportunity to suck during that feeding.

One possible explanation for this pattern is that the behavioral quiesence seen after a bottle feeding in an infant may be a function of a physiological response to digestion rather than the sucking experience. Another possible explanation is that the homeostatic state of preterm infants is a sleep state and a feeding simply produces an artificial disruption of that resting state. Thus, the caregiver wakes the preterm infant up, provides any necessary care, and then starts a feeding. The preterm infant responds to this interruption by returning to a sleep state as quickly as possible.

The findings with respect to the amount of time spent in B-states can help to clarify this issue. In defining the state scale used in this study Als et al. (1981) described the B-states as representing more organized patterns of each of the states. Thus, a B-state represents a lower level of arousal within the overall state. For example, an infant in active sleep B would be in a less aroused state than if it were in active sleep A. If the caregiving schedule was responsible for an increase in levels of arousal at the time of feeding then either no change, or a decrease in the time in B-states during the disruption would be expected. The opposite pattern was observed. Infants were observed in B-states for more time during feedings than during other times. Thus, it is more likely that the observed pattern in waking states reflects a behavioral response to the physiological changes accompanying the feeding.

A clustered caregiving schedule has been shown to increase the amount of quiet sleep in preterm infants and to moderate the responses of these infants to environmental stimuli (Gabriel et al., 1981). While those authors do not report how clustering was achieved, the most appropriate time to cluster caregiving procedures in the NICU is at feedings because these are regularly scheduled events (Faranoff & Klaus, 1979). Thus, one of the reasons that clustering is an effective means of affecting the maturation of state in preterm infants might be that these infants can better respond to the clustered caregiving schedule because the physiological changes accompanying feeding induce a change in state toward lower levels of arousal. However, a comparison of these effects with the effects seen in quiet sleep suggests that the response to the physiology of digestion is qualitatively different from the response to sucking.

Summary and Conclusions

In summary, the findings of this study indicate that NNS provides for regulation of state in preterm infants that is more like the regulation seen in low-risk infants. Furthermore, NNS improves the quality of sleep in preterm infants. Specifically, this improvement is demonstrated by an increased amount of quiet sleep. The effects of NNS on quiet sleep suggest that there might be separate physiological and behavioral functions of sucking in human infants. However, these behavioral functions are hypothesized to be mediated by the same physiological mechanism, an increase in parasympathetic activity.

Finally, these findings suggest that NNS as an intervention in the NICU may be beneficial to preterm infants in a realm other than digestion. NNS provides an exogenous regulator for the organization of infant state. This regulatory effect produces an organization of state which is more like that of low-risk newborns. NNS also provides a means for improving the quality of sleep when frequent interruptions are necessitated by the caregiving schedule. The current results suggest a need for a thorough study of the possible maturational effects when NNS is provided as an intervention for preterm infants in the NICU.

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Appendix A

Identification of preterm infants.

Regardless of whether the interest in preterm infants is based on research or clinical questions the first task is identification of preterm infants. An intuitive perspective suggests that there should be no problem in identifying these infants. Preterm infants should include all the babies who are born more than four or five weeks before they have completed a normal length gestation (Battaglia & Lubchencko, 1967). Yet there are at least three commonly used methods for identifying preterm infants.

Historically, all infants who are born with a birthweight bellow some statistical norm (typically 2500 gms) were identified as preterm (Caputo & Mandell, 1970). while this definition has significant disadvantages, its use persists in the modern literature (e.g., Keller, 1981). A major experimental confound can occur when this definition is used to place infants in groups. Within this system, infants who may have experienced very different intrauterine environments are often placed in a single group (Dubowitz et al, 1970). Some of those infants are small because they experienced an incomplete gestation, others are small because they experienced some sort of disruption of growth in the uterus but a complete gestation and still others are small because of their genetic makeup (Caputo & Mandell, 1970). Because the infants from such differing backgrounds likely also have different medical, biological, and behavioral characteristics, the classification of these different infants into a single group introduces additional variance to any research design.

The two other systems commonly used for classifying preterm infants avoid the criticism raised for classification according to birthweight. These two systems are used to directly estimate the length of the gestation of an infant. The older system simply counts the number of weeks since the mother's last menses and uses that figure as the estimate of the infant's gestational age. Babies with a gestation of 37 weeks or less are then classified as preterm (Battaglia & Lubchenco, 1967). Use of this system can produce erroneous estimates of gestational age when the last menses was one or more months before conception occured, or when a period of menses like flow followed conception, or when the mother does not accurately remember the date of her last menses. This last problem is particularly common among mothers who have had no prenatal care because they are asked six to nine months after their last menses to recall its date.

The third system improves on the traditional method of estimating a gestational age for the newborn from dates. This improvement is attained by classifying the infant on the basis of its own neurological, morphological and behavioral characteristics (Dubowitz, Dubowitz, & Goldberg 1970). Using this system the gestational age of an infant can be estimated to within two weeks of the actual gestational age. While a Dubowitz Exam is subject to errors of clinical judgement, it does provide for a categorization of newborns which is based on the characteristics of individual infants. Of the three, this system can be used to produce the most homogeneous groupings. Categorization of infants within this system is based on individual characteristics, thus, infants who have a low-birthweight but a full gestation can be excluded from preterm groups. For this project infants who are born with a gestational age of less than 37 weeks as estimated by a Dubowitz Exam will be considered preterm.

Appendix B

Postnatal Factors Scale

1. Respiratory Distress	No______	Yes_____
2. Positive or Suspected infection	No______	Yes_____
3. Ventilatory Assistance	No______	Yes_____
4. Noninfectious Illness or Anomaly	No______	Yes_____
5. Metabolic Disturbance	No______	Yes_____
6. Convulsion	No______	Yes_____
7. Hyperbilirubemia	No______	Yes_____
8. Temperature Disturbance	No______	Yes_____
9. Feeding Within 48 Hours	Yes_____	No______
10. Surgery	No______	Yes_____

Total_______

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