THE EFFECT OF A VISUAL STIMULUS ON BEHAVIORAL STATE AND VISUAL RESPONSIVENESS IN PRETERM INFANTS

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(ABSTRACT)

Behavioral organization in infants can be characterized by the integration and coordination of component behaviors over time, mediated in part by emerging nervous system activity. This study evaluated the organization of behavioral states and the percentages of time spent in particular behavioral states by preterm infants. In addition, the effects of visual stimulation on the organization of behavioral state and on the development of the visual skills in preterm infants was assessed.

Twenty preterm infants were observed at the time of admission and discharge from the intermediate unit of a neonatal intensive care unit. Behavioral state was recorded and visual responsiveness assessed on both occasions. For one group of infants, a striped visual stimulus was placed in their incubators following the initial observation, and removed at the time of the second observation. A second group of control infants received no exposure to the visual stimulus.

Results revealed that infants who were exposed to a visual stimulus significantly decreased the number of state changes they experienced and had significantly higher visual responsiveness scores than infants who were not provided a visual stimulus. The amount of increase in the percentage of time spent in Quiet Sleep and increase in the state stability score, a measure of consistency among behavioral states, was nominally higher for infants who were exposed to the visual stimulus than for infants who were not allowed exposure to the visual stimulus.

These findings indicate that visual stimulation can influence the development of visual responsiveness in preterm infants. Furthermore, exposure to a visual stimulus appears capable of extending the amounts of time that preterm infants spent in particular behavioral states, thus reducing the number of state changes they experience. The significance of these findings is discussed in terms of preterm intervention procedures. In addition, the possible importance of self-regulation of sensory input for preterm infants and the clinical implications of low and high state stability scores are discussed.

DEDICATION

This work is dedicated to Moe who has assumed many responsibilities, given up many golfing days, and provided unfailing support throughout this process. You are unique. Thanks -

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INTRODUCTION

Infants who are born prior to completing 37 weeks of gestation are frequently unprepared for independent existence in the extrauterine environment. Although the surgical, mechanical, and chemical interventions provided within a neonatal intensive care unit (NICU) can increase the probability of survival of infants born preterm (Ichord, 1986), iatrogenic effects associated with life in the NICU may negatively affect development of the preterm infant. For example, hearing loss of high frequencies in preterm infants is associated with the length of time spent in an incubator (Douek, Bannister, Dodson, Ashcroft, & Humphries, 1976).

Features of the environment in the NICU may also affect behavioral organization of the preterm infant. The integration of behaviors such as physiological activity and motor control that are important to the physiological and behavioral functioning of the infant may be interrupted by environmental stimulation that is characteristic of the NICU (Als, 1978; Brazelton, 1978). For example, tactile-kinesthetic stimulation (such as handling) that occurs at a time when physiological functioning is unstable may interrupt the tentative balance of the physiological systems, thereby precluding their organization (Als, Lester, Tronick, & Brazelton, 1982). Importantly, behavioral organization may be reflected in a measure of behavioral state.

Behavioral state is believed to reflect the convergence of processes fundamental to nervous system function and the effects of environmental events, both internal and external, on the infant (Thoman, Denenberg, Sievel, Zeidner, & Becker, 1981; Thoman, 1986). States are characterized by constellations of behaviors such as eye and body movement, and cardiac activity that appear to be stable and repeat themselves over time (Garbanati & Parmelee, 1987). As periods of activity and quiescence among the various behaviors co-occur, distinct behavioral states emerge which become organized into patterns or sequences of states (Thoman, 1986). Although behavioral states and patterns of behavioral states have been documented in full-term infants by a number of investigators (e.g., Rose, 1983; Thoman, 1986), less is known about the behavioral states of preterm infants.

Because the development and organization of behaviors is particularly difficult for the preterm infant whose immature systems are forced to function within the environment of the NICU, several investigators have systematically manipulated features of the environment in the NICU in order to facilitate the infant's development. Interventions with preterm infants have included tactile, kinesthetic, vestibular, auditory, and visual stimulation. The results of these interventions include modifications in behavioral organization reflected in changes in behavioral state (e.g., Field, Schanberg, Scafidi, Bauer, Vega-Lahr, Garcia, Nystrom, & Kuhn, 1986) and general maturation (e.g., Powell, 1974).

Experience in the visual domain may play an important role in the development of behavioral organization. While the separate effects of such sensory experience as tactile-kinesthetic or vestibular have been described, stimulation in the visual domain has been applied only in conjunction with stimulation in other sensory domains during interventions with preterm infants (e.g., Scarr-Salapatek & Williams, 1973). The responses of preterm infants to visual stimulation alone have not been well documented. The primary purpose of the present study was to assess the effects of a controlled program of visual stimulation on the organization of behavioral states and visual responsiveness of preterm infants.

Preterm Infants

Identification of the preterm infant is based upon an estimate of the infant's gestational age. Methods for assessing gestational age include evaluating neurological, morphological, and behavioral characteristics of infants (Amiel-Tison, 1968; Dubowitz, Dubowitz, & Goldberg, 1970), and estimating the length of time since the mother's last menstrual period (e.g., High & Gorski, 1985). Infants whose gestational age is 37 weeks or less are considered to be "preterm" (Battaglia & Lubchenco, 1967).

Adaptation to the extrauterine environment is often difficult for the preterm infant. Factors which contribute to an inability to function efficiently and independently in the extrauterine environment include the general immaturity of the infant's organ systems, invasive medical interventions, and prolonged exposure to the environment of the NICU. For example, Respiratory Distress Syndrome (RDS) results from an inability of the infant's immature lungs to support an adequate exchange of oxygen and carbon dioxide (Ichord, 1986). When supplemental amounts of oxygen are provided to maintain the infant's viability, retinal injury resulting in retinopathy of prematurity (ROP) may occur. Thus, a necessary medical intervention (i.e, supplemental oxygen) may negatively affect the subsequent development of the infant. Exposure to other conditions characteristic of the NICU may similarly affect the development of the infant. The occurrence of ROP, for example, may be associated with high levels of illumination that are typical of the NICU environment (Glass, Avery, Subramanian, Keys, Sostek, & Friendly, 1985). In addition, as suggested earlier, factors associated with preterm birth may affect not only the physiological development of the preterm infant, but also the development of the infant's behavioral organization.

Behavioral Organization

The development of behavior may be characterized as the organization of component behaviors into hierarchically more complex behavioral systems (Hofer, 1981; Thoman, 1986). As component behaviors are integrated and coordinated with one another, new, hierarchically more complex levels of organization are created from which successive, more complex behaviors may emerge (see Als et al., 1982; Thoman, 1986). For example, as physiological and behavioral components, such as respiratory activity and body movement, become coordinated with one another and with other physiological and behavioral components (Garbanati & Parmelee, 1987), higher order behaviors and patterns of behavior such as periods of quiet sleep or waking activity emerge (see Hebb, 1949).

Each successive level of behavioral organization is characterized by properties that may be revealed only during evaluation at that particular level of organization (Hebb, 1949; Thoman, 1986). For example, sleeping and waking are two broad categories of behavioral state that may be subdivided into a series of behavioral states (Thoman et al., 1981). Each behavioral state is characterized by the occurrence of periods of quiescence and activity among physiological and behavioral components (Garbanati & Parmelee, 1981). Brain activity is one such physiological component. An assessment of brain activity, however, may not accurately reflect the infant's behavioral state. The level of brain activity recorded while the infant is in a quiet, alert awake state may be comparable to a level recorded during an active sleep state (see Kleitman, 1963). When the activity or quiescence of a particular parameter is combined with various levels of activity of other parameters, categorically different behavioral states may result. Thus, an accurate evaluation of behavioral state must be made at a level of organization that is higher than that of the individual parameters that become coordinated and integrated with one another to form behavioral states.

The origins of the component behaviors that merge during the development of behavioral organization may be traced to the processes of the infant's neurological systems (Thoman, 1986; Zeskind & Marshall, in press). As these systems mature, changes in behavioral organization are evident. The early behavioral organization of the preterm newborn, for example, is characterized by a struggle to stabilize and integrate physiological functions such as cardiac and respiratory activity, temperature control, digestive functioning, and elimination competence (Als, 1978; Als et al., 1982). Those functions are known to be regulated by subcortical structures (Bronson, 1982). As networks of neurons develop and interlink subcortical pathways with maturing cortical structures, reciprocal pathways or feedback loops are created among the structures. With the development of the neocortex, the behaviors that were mediated by subcortical structures (such as physiological activity) are thought to become integrated with other behaviors such as sensory, motor, and learning effects via multiple feedback loops (Bronson, 1982). Thus, as the integration or organization of components continues, the healthy infant develops reliable behaviors or patterns of behavior such as sleeping and waking that are believed to be mediated by the nervous systems within the context of the caregiving environment (Als, 1978; Thoman, 1986; Zeskind & Marshall, in press).

Of course, experiences which affect the organization of behavior may emerge from either the external or internal environment (Hofer, 1981; Thoman, 1986). For example, tactile and vestibular manipulations during a period of time when physiological functioning is unstable may infringe upon the tentative balance of the physiological systems, thus affecting their organization (Als et al., 1982). An internal event may similarly affect behavioral organization. For example, infants who are highly aroused may respond to increased visual stimulation with an even higher level of arousal which may interfere with their ability to show preferences for visual stimuli (see Gardner & Karmel, 1983). Conversely, infants who are less aroused not only show preferences for the presented visual stimulation, but prefer stimuli with higher spatial and temporal frequencies. Als and her colleagues (1982) suggest that an infant who is moderately aroused may seek sensory stimulation. Thus, the organization of behavior may be altered by an external event, such as stimulation from the infant's environmental context, or an internal event, such as level of arousal.

The ability of the infant to integrate and modulate these exogenous and endogenous sources of sensory experience may be reflected in the infant's behavioral organization. A well-organized infant may be identified by an ability to respond to or to inhibit a response to stimulation, to self-organize by incorporating and utilizing environmental input, and to control and organize periods of waking and sleeping (Als et al., 1982). Preterm infants may be less well organized than full-term newborn infants. For example, the performance of preterm infants on a standardized assessment scale, the Newborn Behavioral Assessment Scale (NBAS) (Brazelton, 1978) which reflects the infants' behavioral organization in response to changes in the environment, has been found to be less than optimal (Ferrari, Grosoli, Fontana, & Cavazzuti, 1983). Specifically, the performance of preterm infants was significantly poorer than that of full-term infants on orientation, motor performance, regulation of state, and autonomic regulation.

Some work suggests that preterm infants may be unable to integrate various domains of behavior. Preterm infants, for example, do not respond differentially to stationary or nonstationary objects that are presented with or without sound (Lawson, Ruff, McCarton-Daum, Kurtzberg, & Vaughan, 1984). Further, changes in motor activity were found not to be conjoined with cardiac responsivity during tactile-kinesthetic stimulation (Rose, Schmidt, & Bridger, 1976) which may indicate that preterm infants may be unable to integrate sensory experience with physiological and behavioral responses. Preterm infants may also show an important asymmetry in their responsivity to sensory stimulation. Preterm infants who _are_ capable of auditory or visual attention, for example, may orient more to one direction than to another, and exhibit better motor control on one side of the body than the other (Gardner, Magnano, & Karmel, 1988). In other words, the infant's ability to attend to visual and auditory stimulation may be less well organized on one side of the body than the other.

Behavioral State

Preterm infants' lack of behavioral organization may be reflected in their behavioral states. Behavioral state refers to a collection of behaviors and physiological parameters that recur during periods of sleep and wakefulness. Wolff (1959) was the first to provide a systematic and descriptive categorization of the behavioral expressions of sleep and wakefulness in the newborn infant that had been reported anecdotally for nearly a century. Wolff's inventory of behavioral states evolved into a 6-point state scale (Wolff, 1966) that discriminates between Quiet and Active Sleep, Drowse, Alert, Active and Crying states. Specifically, Quiet Sleep is characterized by limited muscle activity, regular and relatively slow abdominal respirations, and closed eyes without movement. During Active Sleep, facial expressions and other light limb movements occur, respiration is irregular, and recurrent eye movements are evident (i.e., rapid eye movements or "REM"). Although the eyes are open during a Drowsy state, they are dull and unfocused, and the infant is relatively inactive. An Alert State is characterized by eyes that are open and bright, and by relatively little activity beyond pursuit of auditory and visual stimuli. In an Active State, diffuse motor activity involving the whole body is present. Although the eyes are open during an Active State, they are not alert. The Crying State is characterized by vigorous motor activity and crying vocalizations.

The ontogeny of behavioral states in preterm infants has been described by several investigators. Infants 24 -

27 weeks conceptional age (i.e., weeks of gestation plus weeks since birth) exhibit frequent body and facial movements, including scattered eye movements, diffuse jerks, and localized twitches (Dreyfus-Brisac, 1968). Crying occurs infrequently and for brief periods of time. Although the heart has operated previously at a fixed rate (Berg & Berg, 1987), heart rate in infants 24 - 27 weeks becomes more variable as central control mechanisms develop, reflecting an increased adaptability to varying endogenous or exogenous demands (see Stratton, 1982). Respiration is irregular, i.e., stable breath-to-breath intervals are uncommon and pauses between respirations are pronounced (Prechtl, Fargel, Weinmann, & Bakker, 1979).

During the period between 30 and 35 - 38 weeks, the full range of states from sleep to awake to alert emerges in the preterm infant. Gross and localized body movements decrease significantly from previous weeks, although localized movements occur more frequently than gross body movements (Fukumoto, Mochizuki, Takeishi, Nomura, & Segewa, 1981; Peirano, Curze-Dascalova, Korn, & Vincente, 1986; Prechtl et al., 1979). During this period, 30 - 35 weeks, sporadic opening of the eyes is rare (Prechtl et al., 1979). Prolonged periods of eye opening occur in conjunction with dampened motor movements. Longer and more frequent periods of regular respiration are evident in infants who are 35 weeks. Apneic episodes or dramatic decreases in the rate of respiration typically cease to occur after 35 weeks. An increase in variability of heart rate occurs in association with movements and respirations during this period (Watanabe, Iwase, & Hara, 1973). That is, increases or decreases in heart rate co-occur with body movements or changes in respirations. Longer periods of respiratory regularity begin to co-occur with an absence of body and eye movements (Prechtl et al., 1979). In summary, between 34 - 38 weeks, identifiable behavioral states emerge as quiescent and active phases of several parameters of state begin occurring together reliably for extended periods of time (Garbanati & Parmelee, 1987).

There is disagreement, however, concerning whether young preterm infants show detectable behavioral states. While Garbanati and Parmelee (1987) suggest that identifiable behavioral states do not occur before 34 - 38 weeks, others have found reliable measures of behavioral state in infants less than 34 weeks, and as young as 28 weeks (Rose et al., 1980). Hack and colleagues (1976, 1981), for example, have argued that preterm infants as young as 30 weeks are able to come to a Quiet Alert state during visual stimulation. The occurrence of a Quiet Alert state increased progressively from 31 - 36 weeks. While the reasons for this discrepancy are still unknown, one possible explanation is that different criteria for behavioral state have been used. While facial movements in general, and eye movements in particular, have been used to define behavioral states in some investigations (e.g., Hack, Muszynski, & Miranda, 1981), criteria that have been used to determine behavioral state in other investigations have included eye movements, motor activity, respiratory activity, and vocalizations (e.g., Becker & Thoman, 1983).

A second possible explanation for the discrepancy concerning when in development behavioral states may be observed is the frequent classification of a heterogeneous group of infants as "preterm". Differences may exist among the behavioral states of 28 week and 34 week preterm infants, but because the infants are frequently grouped by variables such as preterm vs. full-term (e.g., Rose et al., 1976), or as high vs. low risk for developmental delays (e.g., Lawson et al., 1984), those differences in behavioral states due to age may not be well documented.

The important issue may not be whether or not preterm infants show detectable behavioral states, but whether the behavioral states of preterm infants are less well organized than those of full-term infants. The performance of preterm infants, for example, on the Regulation of State dimension of the NBAS (Brazelton, 1978) is poorer and more variable than the performance of full-term newborns (Ferrari et al., 1983). Preterm infants spend greater amounts of time awake, both alert and nonalert, and in transition between sleeping and waking states, less time in Active Sleep and Drowsy States, and more time crying when they are alone than full-term infants (Booth, Leonard, & Thoman, 1980; Davis & Thoman, 1987; Rose, 1983). The difficulty that preterm infants experience in getting to sleep, in waking, and in gaining a quality of alertness may be due to a lack of coherence among the components of behavioral states that negatively affects their ability to organize their behavioral states (Barnard, 1987; Barnard & Bee, 1983). As a result, the organization of behavioral states in preterm infants has typically been described as uneven (Parmelee, 1975; Davis & Thoman, 1987) or even dysfunctional (Barnard, 1987).

Organization of Behavioral State

One way to assess the organization of behavioral state is in the frequency of state changes. Horowitz (1987) has argued that organization of behavioral state is reflected in the amount of time an infant spends in a state without brief interruptions. An extended period of time in a state is indicative of few brief interruptions or states changes, and is believed to reflect better organization or regularity of behavioral states (Booth et al., 1980; Watt & Strongman, 1984). Conversely, shorter epochs of time spent in a behavioral state indicate more frequent state changes, or "irregular" organization. Infants whose rate of state changes increased over time were found to have less optimal developmental outcomes than infants whose rate of state changes decreased or remained unchanged from one observation period to another (Thoman, Davis, Graham, Scholz, & Rowe, 1988). For example, the rate of state changes was observed to increase over time in an infant who later experienced prolonged apneic episodes and required hospitalization and resuscitation. The rate of state changes may be an important indicator of regularity or irregularity in the organization of behavioral state.

An additional manner by which the organization of behavioral state may be assessed is in the temporal domain. The temporal organization of behavioral state may be evident in either a sequential or nonsequential form. As a sequential form of behavior, young infants show a recurring, predictable pattern in how one behavioral state follows another. For example, infants who are 3-4 months of age vascillate between the states of sleep and wakefulness with a cyclic frequency of approximately 3-4 hours (Harper, Frostig, & Taube, 1983). That is, the sleep states occur for a predictable amount of time and are predictably followed by states of wakefulness which also occur for a predictable amount of time. Some evidence suggests that this sequential pattern of behavioral organization may be evident in the newborn infant (Zeskind & Marshall, in press), but further research appears necessary to clarify this issue.

In contrast to a sequential form of behavioral organization, Thoman (1986) suggests that behavioral state may be temporally organized in a nonsequential manner that developmentally precedes a sequential form of behavioral organization. According to Thoman (1986), the nonsequential organization of behavioral state is reflected in the amount of time individual infants are observed in various behavioral states. That is, temporal organization may be evident in how long an infant is observed in a given behavioral state at multiple observation periods, independent of the sequential order of the states.

One method by which the consistency or the stability in the temporal patterning of sleep-wake states over time may be assessed is with the calculation of a state stability score for each individual infant (Thoman et al., 1981). Based upon the percentage of time that an infant spends in each state during successive observation periods, an individual profile of behavioral state over time may be assembled (see Figure 1). The similarity or the stability of those percentages of time is calculated using an analysis of variance (ANOVA) procedure which yields a state stability score. Inconsistencies in the behavioral state stability profiles (see Figure 2) are reflected in state stability scores that are low (Thoman,

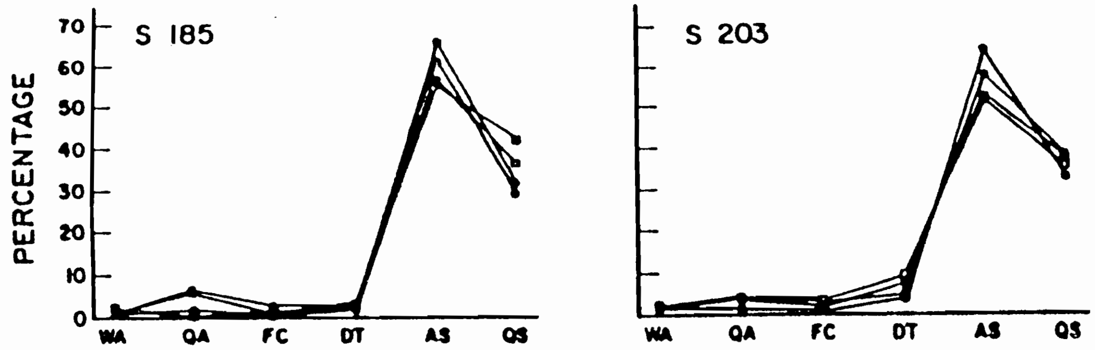


Figure 1: Individual Profiles of Behavioral State*

These individual profiles represent the amount of time that an infant (e.g., Subject #185 or Subject #203) spent in each state during successive observation periods. Along the X-axis are the behavioral states (WA: Waking Active; QA: Quiet Alert; FC: Fuss or Cry; DT: Drowse or Transition; AS: Active Sleep; QS: Quiet Sleep). Percentages of time allocated to each state while the infant was alone is shown along the Y-axis [Week 2 (●——●), Week 3 (■——■), Week 4 (○——○), Week 5 (□——□)].

*From "The time domain in individual subject research" by E.B. Thoman, 1986, in J. Valsiner (Ed.), The individual subject and scientific psychology, p. 195. New York: Plenum Press.

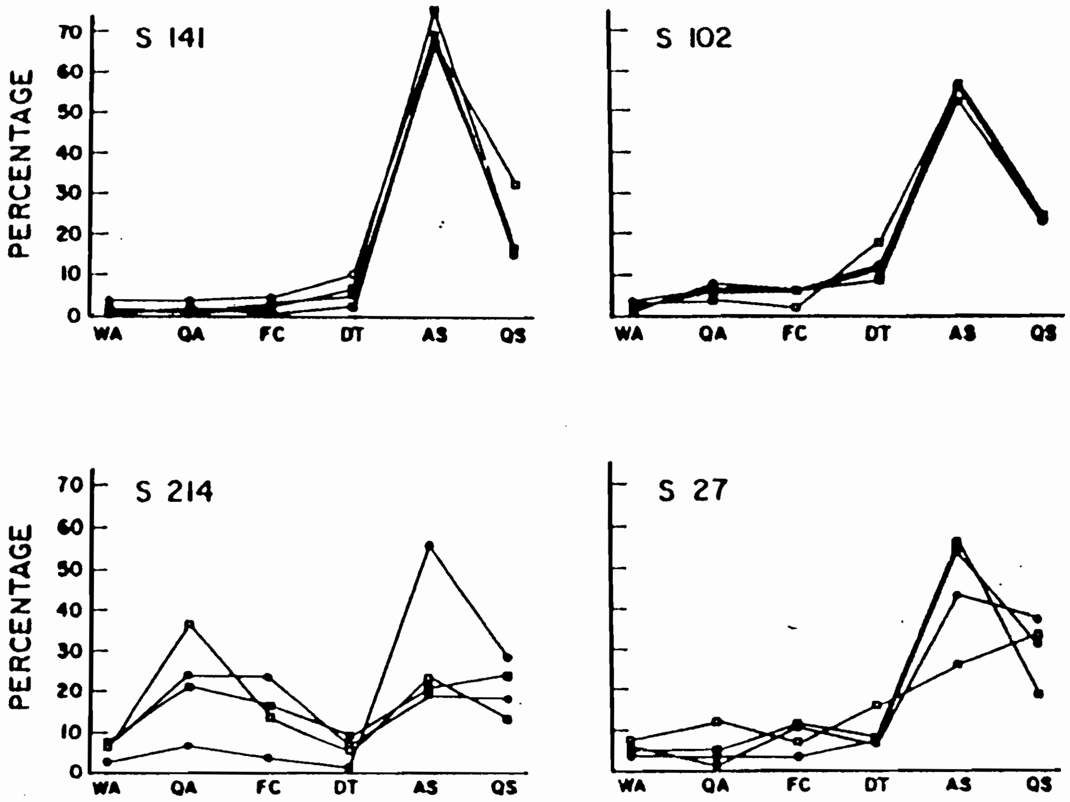


Figure 2: State Stability Scores

State profiles showing High Stability (Subjects #141 and #102) and Low Stability (Subjects #214 and #27). Corresponding state stability scores are 186.11 and 304.86 for Subjects #141 and #102, respectively, and 3.09 and 17.77 for Subjects #214 and #27, respectively. Along the X-axis are the behavioral states (WA: Waking Active; QA: Quiet Alert; FC: Fuss or Cry; DT: Drowse or Transition; AS: Active Sleep; QS: Quiet Sleep). Percentages of time allocated to each state while the infant was alone is shown along the Y-axis
[Week 2 (●——●), Week 3 (■——■), Week 4 (○——○),
Week 5 (□——□)].

*From "State organization in neonates: Developmental inconsistency indicates risk for developmental dysfunction by E.B. Thoman et al., 1981, in Neuropediatrics, 12, pp. 50-51.

1986). Profile consistencies or similarities are reflected in high state stability scores. Importantly, the distribution of time to each state may vary among infants; however, if each infant experiences its individual distribution of time consistently, the resulting state stability score will be high.

Thoman and colleagues (e.g., 1981, 1986, 1988) have used this measure of state stability to assess individual differences in the temporal organization of behavioral state. Among a group of full-term newborns viewed as "clinically normal" (Thoman et al., 1981, p. 46), some infants showed a high degree of organization in the amount of time they spent in each state over time, while others showed less organization. These individual differences were associated with developmental outcome. Infants whose state stability scores were low developed medical or behavioral dysfunctions that occurred as early as 3.5 months and as late as 2.5 years. No developmental dysfunction had been diagnosed in infants with higher state stability scores by 2.5 years. In a separate study, Thoman and her colleagues (1988) predicted that some infants who were again considered to be normal but who had low state stability scores might be at risk for Sudden Infant Death Syndrome (SIDS). Among a group of infants were three infants (SSIDS) whose siblings had died of SIDS. Two of these three infants had state stability scores that were consistent with those scores of infants who were not SSIDS, and who developed normally. The state stability score of the third SSIDS infant was comparable to that of a fourth infant who died of SIDS (see Thoman et al., 1981). This was the only SSIDS infant to subsequently experience prolonged episodes of apnea, a lowered respiratory rate, and to require resuscitation and hospitalization.

Tynan (1986) has assessed state stability in preterm infants by generating state stability scores in the manner that Thoman and colleagues (1981) have described. The state stability scores not only accurately reflected the known status of the preterm infants (e.g., a low state stability score for an infant who experienced seizures), but were also predictive of developmental disabilities (e.g., a low state stability score of a seemingly healthy infant who later developed cardiac problems). Similarly to Thoman, Tynan has concluded that this measure of consistency in the amount of time spent in an individual pattern of behavioral states, the state stability score, is a reliable indicator of underlying neurological functioning.

In light of these findings, a plausible assumption is that higher state stability scores are predictive of more optimal development, i.e., development that is not characterized by disability or dysfunction. As discussed previously, Thoman and colleagues (1981) have reported that none of the infants whose state stability scores were above a group median score showed developmental delay or dysfunction as late as 2.5 years. However, as state stability scores that are too low may be indicative of neurological dysfunction, so may be scores that are too high. An infant who spends the majority of time in one particular state may have a high state stability score that is not indicative of a healthy neurological system. For example, an infant who consistently spends very little time in awake, aroused, or sleeping states, but a large percentage of time in a transitional state, may have a high state stability score. This infant who is consistently in a state of transition may not be considered to be healthy. Additional research is necessary to clarify this issue.

Interestingly, state stability has been assessed in infants using naturalistic observation. It has not been assessed as a function of an environmental stimulus, even though the development of behavioral state is known to be affected by various forms of sensory experience. Lawson and Turkewitz (1985), for example, demonstrated a relation between environmental events and the organization of behavioral state by comparing the sensory experience of preterm infants housed in two different NICUs. One NICU was housed in a municipal hospital where the level of illumination ranged from 29.5 to 83.2 footcandles (fc) and averaged 63.2 fc. In addition, handling occurred half as frequently as in the second NICU, and some aspects of the constant speech and nonspeech sounds were reliably rhythmic. The second NICU was housed in a private hospital where the level of illumination ranged from 9.2 to 19.8 fc, averaged 20.1 fc, handling occurred more frequently than in the municipal NICU, and the speech and nonspeech sounds did not occur rhythmically.

Generally, the preterm infants in the private hospital spent more of the time observed in Active Sleep or Alert states, while preterm infants in the municipal hospital spent more time in Drowsy and Fussy states. Handling was negatively related to the amount of time spent in Quiet Sleep and positively associated with time spent in a Transitional state in both hospital units. Speech and nonspeech room sounds were negatively associated with the amount of time spent in Quiet Sleep, and positively related to time spent in a Transitional state in the municipal unit. The effects of sound on the behavioral states of preterm infants in the private hospital was not significant. Illumination was positively related to the amount of time spent in an Alert state in the private hospital. Lawson and Turkewitz (1985) concluded that the amount of time spent in each state was influenced by features of the environment.

What is not known is whether a change in the organization of an infant's behavioral states as a consequence of a specific environmental manipulation may be may be reflected in altered state stability scores. An assessment of state stability scores before and after an intervention would shed light on this important issue.

Interventions with Preterm Infants

Because sensory conditions in the NICU such as those described by Lawson and Turkewitz (1985) may have profound effects on the behavioral states of preterm infants, features of the NICU environment have been experimentally manipulated in an effort to assist the preterm infant with its organization of behavioral states (Barnard, 1987). However, the type of environmental structuring employed in an NICU depends in large part upon the manner in which the preterm infant is viewed (Ramey, Zeskind, & Hunter, 1981). Viewed as an "immature newborn infant", the preterm infant may receive the kinds of stimulation appropriate to an infant whose organ systems should function efficiently and independently of the intrauterine environment. This preterm infant would be held, picked up, rocked, talked to, and presented a range of auditory and visual stimulation that is both varied and frequent (e.g., Scarr-Salapatek & Williams, 1973). Others suggest that the preterm infant should be viewed as an "extrauterine fetus". In this case, the preterm infant would be proffered water-beds (e.g., Korner, Kraemer, Haffner, & Cosper, 1975), gentle lighting (e.g., Blackburn & Patteson, 1990), and sounds that may have been available during the prenatal period, such as the maternal heartbeat (e.g, Kramer & Pierpont, 1976) or voice (e.g., Segall, 1972). The issue of which type of stimulation is appropriate to the preterm infant remains unresolved; clearly the preterm infant is both an extrauterine fetus that has been denied the naturally occurring prenatal support system that is necessary for intrauterine maturation and is also a newborn that is, at least in some ways, unprepared for extrauterine development (Scarr-Salapatek & Williams, 1973).

Korner (1987) suggests that compensatory forms of stimulation (i.e., forms of stimulation that are prevalent in utero) such as tactile-kinesthetic, and enrichment stimulation (i.e., varied visual, tactile, auditory, and social stimuli) should utilize systems that have matured or are maturing. In this light, Gottlieb (1971) has described a progression of sensory development which provides a theoretical framework that may be useful to caregivers as they initiate planned programs of stimulation involving preterm infants. Based on the available evidence from an array of species including humans, Gottlieb demonstrated that sensory development progresses from tactile sensitivity to vestibular, olfactory, auditory, and visual responsiveness. In humans, tactile and vestibular functioning become apparent at approximately 7 and 13 - 17 weeks, respectively. Although inconsistent, auditory brainstem potential components indicate a response to sound at about 25 weeks (Krumholz, Felix, Goldstein, & McKenzie, 1985; Starr, Amlie, Martin, & Sanders, 1977). Reliable components of auditory reception are clearly apparent at 28 weeks. A primitive form of primary cortical visual evoked responses has been observed as early as 22 weeks (see Gottlieb, 1971); however, fixation of a visual stimulus has not been observed in the preterm infant until 30 weeks (Hack et al., 1981). Using these descriptions of sensory development as guidelines, Korner (1987) suggests that providing compensatory forms of stimulation such as tactile and kinesthetic to the youngest preterm infants, and providing more complex forms of auditory, visual, tactile and/or social stimuli to infants who are closer to term is conceptually reasonable based on available data.

In support of this position, Korner and colleagues (1975) found that young preterm infants who experience the tactile-kinesthetic stimulation provided by waterbeds have fewer apneic episodes than when they are not on the waterbeds, and fewer apneic episodes than non-stimulated infants. In addition, the stimulated infants spend more time sleeping, fall asleep faster, are less restless during sleep, and have fewer unsmooth movements during sleep and wakefulness than during the time that they are not stimulated by the waterbed.

Scarr-Salapatek and Williams (1973) stimulated infants in the hospital and after discharge (i.e., older preterm infants) with a variety of different types of stimulation: tactile, kinesthetic, auditory, and visual. These infants gained more weight, and not only scored higher on the Cattell Infant Intelligence Scale at 1 year of age than those of a group of nonstimulated infants, but achieved scores that were comparable to those of children who had been full-term infants. Interestingly, full-term newborn infants provided tactile (stroking), vestibular (rocking), and auditory (simulated heartbeat) stimuli (i.e., compensatory forms of stimulation) showed less mature orientation, motor, and state regulation on the Newborn Behavioral Assessment Scale than infants in a control group who received care that was typical of the home environment (Koniak-Griffin & Ludington-Hoe, 1987). Thus, compensatory forms of stimulation provided to young preterm infants and enrichment forms of stimulation provided to older infants affected the infants positively, while a compensatory form of stimulation provided to conceptionally older infants negatively affected those stimulated infants. These findings suggest that the type of stimulation and the timing of the presentation of that stimulation may affect infants of varying ages in different ways (for a further discussion of this important point, see Turkewitz & Kenny, 1982, 1985).

Sensory Stimulation

The functional onset and the integration of the various sensory modalities may be influenced by the stimulation histories of the sensory modalities themselves, and may be affected by untimely forms of stimulation (Turkewitz & Kenny, 1982, 1985). Sensory limitations that are characteristic of early stages of development may decrease competition from emerging sensory systems, thereby facilitating sequential onset and integration of sensory functions. When the sequence is interrupted, other sensory modalities may be affected. For example, when the eyelids of rat pups were opened prematurely, homing behavior, a behavior that depends primarily upon olfactory and thermal cues, was altered (Kenny & Turkewitz, 1986). The typical decline in homing behavior that is seen at 16 - 20 days was not evident in the pups who experienced the premature visual experience. The authors suggest that the premature availability of visual cues altered an integrated response pattern in the stimulated pups. That is, unusually early visual stimulation altered a behavior that is associated with olfactory and thermal cues, sensory sensitivities that precede visual responsiveness (see Gottlieb, 1971).

In a series of recent experiments (Lickliter, 1990b), the prenatal stimulation histories of the auditory and visual modalities of bobwhite quail were made to coincide. In subsequent postnatal testing, experimental chicks did not show a naive preference for the species-specific maternal call, a reliable finding in normally reared chicks. The prenatally stimulated chicks did not demonstrate a preference for the species-specific hen based upon visual cues. Rather, the stimulated chicks required both auditory and visual cues to direct their early social preferences. This finding may indicate accelerated intersensory functioning between the auditory and visual sensory modalities in the stimulated chicks. The results of a related series of experiments (Lickliter, 1990a) indicate that chicks who experienced premature visual stimulation show a decline in auditory responsiveness within the first 24 hours following hatch that is not typical of normally reared chicks. Further, the stimulated chicks used visual cues in the absence of auditory cues to direct their preference for the species-specific hen at an earlier age than nonstimulated chicks. Thus, when the stimulation histories of the auditory and visual modalities are made to coincide, stimulated chicks may demonstrate an accelerated decline in auditory responsiveness, experience accelerated intersensory functioning, and utilize visual cues at earlier ages than nonstimulated chicks.

In these "early exposure" studies, premature stimulation of a later developing sensory system, the visual sense, influenced the functioning of earlier developing systems: olfactory and tactile in the work of Kenny and Turkewitz (1986) and auditory in the work of Lickliter (1990a,b). In contrast, enhancing an earlier developing system (e.g., audition) may serve to facilitate the development of a later developing system, such as vision (Lickliter & Stoumbos, 1991). Bobwhite quail chicks who were exposed prenatally to increased amounts of species-typical embryonic vocalizations exhibited an accelerated pattern of postnatal visual responsiveness. That is, chicks who experienced enhanced auditory stimulation directed their social preference using visual cues at an earlier age than normally reared birds. Thus, supplemental stimulation of a maturing sensory modality (i.e., audition) facilitated the functioning of a later developing system (i.e., vision).

Sensory stimulation of one sense has also been observed to influence other sensory modalities in preterm human infants. For example, infants 28 - 32 weeks who participated in a controlled program of tactile stimulation achieved more optimal scores on the Graham-

Rosenblith scales of general maturation, visual and auditory responsiveness, and motor maturation than infants who did not experience the stimulation (Neal, 1968). In a separate study, preterm infants 28 - 32 weeks who were stimulated aurally (maternal voice) also achieved more optimal scores on the Graham-Rosenblith scales of general maturation, motor and tactile-adaptive maturation, and auditory and visual functioning than nonstimulated infants (Katz, 1971). Thus, stimulation of a sensory modality that develops early (tactile) appears to influence the functioning of later developing sensory modalities (auditory and visual), and supplemental auditory stimulation during the time when the auditory sensory modality is maturing appears to influence the development of both that particular system and of later developing systems (i.e., the visual).

Some investigators have suggested that untimely sensory stimulation may negatively affect the developing organism (e.g., Gottlieb, Tomlinson, & Radell, 1989). It is certainly the case that manipulating the various sensory modalities at particular times can influence the function of earlier (e.g., Kenny & Turkewitz, 1985) or later developing systems (e.g., Lickliter & Stoumbos, 1991); however, whether the effects of premature stimulation are detrimental or even long-lasting has not been documented. For example, rat pups exposed to unusually early visual stimulation continue their homing behaviors beyond the typical 16 - 20 days. Whether this behavior is detrimental to the rat pups is unknown. Further research is required to clarify whether such sensory disruptions are indicative of an actual sensory detriment.

In any case, the fact that premature sensory stimulation can influence the function of other sensory modalities is relevant to the care and management of the preterm infant. Preterm infants are exposed at birth to an environment that has been described as "overstimulating" (Cornell & Gottfried, 1976) and is characterized by elevated levels of handling (Korones, 1976), noise (Linn, Horowitz, Buddin, Leake, & Fox, 1985), light (Glass et al., 1985), and activity (Gottfried, Wallace-Lande, Sherman-Brown, King, Coen, & Hodgman, 1981). The opportunity to experience the normally occurring progression of sensory system development is thus disrupted. Consequently, caregivers have had to work within the limitations of an overstimulating environment to manipulate features of the sensory environment in order to facilitate the development of the preterm infant.

Preterm infants have, however, responded positively to specific types of stimulation, including tactile-kinesthetic (Korner, et al., 1975), vestibular (Neal, 1968), auditory (Katz, 1971), and combinations of tactile-kinesthetic, auditory, and visual stimuli (Scarr-Salapatek, & Williams, 1973). Generally, infants who participated in the programs of stimulation gained more weight (Field et al., 1986), experienced decreased rates of activity and better state regulation (Barnard & Bee, 1983), achieved more optimal scores on assessments of general development (Powell, 1974) and intelligence (Zeskind & Iacino, 1984), experienced fewer apneic episodes (Korner et al., 1975) and shortened periods of hospitalization (Zeskind & Iacino, 1984), and achieved more optimal auditory and visual functioning (Katz, 1971) than nonstimulated infants. Although the mechanisms that would explain these results are unknown, possible explanations include:

1) an alteration in the basal metabolic functioning per se, or an increase in metabolic efficiency as a function of increased activity (Field et al., 1986);

2) an increase in the amount of growth hormones that are released, and the responsivity of enzymes to those hormones (Schanberg, Evoniuk, & Kuhn, 1984);

3) the activation of particular systems during specific stages of neural development (Korner, 1987);

4) the facilitation of myelination (Holmes, Reich, Pasternak, 1984);

5) the facilitation of dendritic branching and cell formation (Hubel & Weisel, 1970);

6) chemical (nutrient) stimulation of autonomic, i.e., sympathetic and parasympathetic, neural integration (Hofer, 1984);

7) the establishment or activation of brain tissue in general by sensory input (Hebb, 1949); and

8) the effects of social interaction on the regulation and organization of autonomic and central nervous system functioning (Zeskind & Iacino, 1984).

Interventions that have employed specific forms of sensory stimulation have certainly affected the behavioral states of preterm infants. Infants who participated in a controlled program of tactile-kinesthetic stimulation, for example, experienced an increase in the amount of time that they spent in a quiet sleep state (Barnard, 1973). Quiet Sleep is the state during which infants experience the greatest amount of physiological stability, and is indicative of nervous system maturation (Garbanati & Parmelee, 1987). During this state, the infant sustains regular respiration, regular heart rate, and an absence of movement. For preterm infants whose primary task is the coordination and integration of physiological systems (Als et al., 1982) an increased amount of time in Quiet Sleep can be viewed as a desirable goal of planned interventions (Barnard, 1987; Barnard & Bee, 1983).

Similarly to infants in the Barnard (1973) study, infants exposed to a tape-recorded sound of the human heartbeat also experienced reduced physiological activity (Schmidt, Rose, & Bridger, 1980). Preterm infants exposed to the auditory stimulation were observed less often in an active sleep state than nonstimulated infants. Active Sleep is not unitary in terms of any of the parameters (e.g., respiration is irregular, and eye, facial, or body movements may or may not occur), and has been described as the least organized and the most variable of all states (Prechtl & Lenard, 1967). Less time in an active sleep state may facilitate the integration and coordination of the various physiological parameters that is critical for the preterm infant.

Some changes in behavioral states, such as an increased amount of time in Quiet Sleep and a reduced amount of time in Active Sleep, are considered to be more mature forms of behavior, i.e., behaviors that are characteristic of full-term infants (Schmidt et al., 1980). Interestingly, preterm infants have been observed to not only experience changes in their behavioral states as a function of an intervention, but to experience an organization of behavioral states that is considered to be more mature (i.e., more like the organization of behavioral states of full-term infants). For example, the decrease in the amount of time spent in Active Sleep mentioned previously not only indicated a change, but also became comparable to the amount of time that full-term infants spend in Quiet Sleep (Schmidt et al., 1980).

A change in the behavioral organization of stimulated preterm infants may also be evident in standardized assessments of overall development. For example, preterm infants who experienced tactile-kinesthetic and/or auditory stimulation achieved more optimal scores than nonstimulated infants on Range of Behavioral States in the NBAS (Barnard & Bee, 1983). That is, the stimulated infants experienced a range of behavioral states from sleeping to alert to crying that is similar to the range of states of a full-term newborn. Similarly, Field and colleagues (1986) found that infants who experienced tactile-kinesthetic stimulation showed a more mature range of state behavior on the NBAS than nonstimulated infants. Thus, stimulating specific sensory modalities in preterm infants may affect not only the organization of their behavioral states, but may affect their behavioral organization in general.

It is important to stress that the characterization of changes in the behaviors of preterm infants that indicate more "mature" behaviors requires acceptance of the assumption that the behaviors of full-term infants are desirable for preterm infants. That is, the behaviors of full-term infants have become the standard by which optimal development in the preterm infant is typically judged. Even in instruments that are sensitive to behavioral characteristics that are specific to preterm infants, such as the Assessment of Preterm Infants' Behavior (APIB) scale developed by Als and colleagues (1982), the reference for more optimal performance is the behavior of full-term infants. For example, the goal of the orientation and interaction package in APIB is "[to] bring the infant to an optimally alert state..." (p. 101). However, unresponsiveness in the preterm infant may serve as a form of protection from an overstimulating environment (Tronick, Scanlon, & Scanlon, 1987). Bringing the infant to an "optimally alert state" may not only violate the infant's adaptive mechanisms, but may indicate a level of interaction that may be atypical and maladaptive for the preterm infant. An important consideration here is that the behaviors of preterm infants, although they may appear to be less mature by some standards, may be indicative of behavioral adaptations that are necessry to the preterm infant, but unlike the behaviors that are expected of full-term infants (see Davis & Thoman, 1987). That is, behaviors that are specific to preterm infants may be important at particular stages of maturity only in the preterm infant, and may not be comparable to the behaviors of full-term infants (see Oppenheim, 1981). Continued study of the development of preterm infants and their responses to features of their environments is required to better understand the development of preterm infants, and to generate appropriate instruments that may accurately assess the infants' development.

As discussed earlier, sensory experience in the visual domain may play an important role in the development of the preterm infant. Because preterm infants at 31 weeks of age spend just 10% of a 6-hour daytime observation period awake and nonfussing (High & Gorski, 1985), the amount of sensory input in the visual domain that the infants experience may be minimal. There is, however, a number of reasons why a controlled program of visual experience may be important.

First, recall that infants who are highly aroused were unable to attend to a presented visual stimulus (Gardner & Karmel, 1983), and that preterm infants who are moderately aroused may seek environmental stimulation (Als et al., 1982). As such, the status of the infant and quality of stimulation, both which affect behavioral organization, may be controlled in a structured program of visual stimulation. Placement of a visual stimulus within the visual field of the infant may allow the infant to self-regulate the amount of sensory input, thereby facilitating the organization of behavior.

Second, the available evidence from the comparative and the human literature suggests that manipulation of various sensory modalities at particular times may influence the function of earlier (e.g., Kenny & Turkewitz, 1985) or later developing systems (e.g., Katz, 1971; Lickliter & Stoumbos, 1991; Neal, 1968), or systems that are undergoing maturation (e.g., Katz, 1971; Lickliter, 1990a,b). At the present time, little is known regarding the effects of visual sensory experience on the organization of behavior or on sensory function in the preterm infant. As indicated previously, most studies which have controlled some form of visual experience have done so in combination with other forms of stimulation. Scarr-Salapatek and Williams (1973), for example, provided auditory, visual, tactile, and kinesthetic stimulation to preterm infants during hospitalization and at home. Stimulated infants had more optimal scores on the NBAS at 4 weeks, gained more weight, and had more optimal scores on the Cattell Infant Intelligence Scale at 1 year than infants in a control group. However, the authors did not report the effects of the visual experience on sensory responsiveness or the behavioral development of preterm infants.

Third, a controlled program of visual exposure may also be important as an efficient and noninvasive form of sensory experience. Sensory input in the visual domain is readily accessible, and does not require either additional personnel (as in tactile-kinesthetic stimulation, e.g., Field et al., 1986), equipment (as in programs of auditory stimulation, e.g., Katz, 1971), or maintenance. In short, providing preterm infants with a visual stimulus may prove to be an efficient means by which to facilitate aspects of their development.

In this light, major manufacturers of infant toys and accessories have provided caregivers in some NICUs with white vinyl squares adorned with various high contrast patterns. Because the caregivers are encouraged to make these patterns available to the infants, the patterns are apparently assumed to facilitate or, at least, to not be detrimental to infant development. However, the effects of long-term exposure to a high contrast visual stimulus remain unknown.

Visual Development

Investigators of infant vision initially employed measures of visual functioning such as psychophysiological responses (see Pratt, 1954). Pioneering work by Fantz (1956, 1963) provided a technique to study visual activity directly. Using a testing chamber, infants' preferences for particular patterns were documented. More detailed analysis of infant visual activity has been conducted using a corneal reflection technique that allowed investigators to monitor eye movement as the infant attended or "scanned" features of a visual pattern (Salapatek & Kessen, 1966). Using this technique, newborn infants have been found to terminate a broad scan when an edge is found, and to scan a vertical edge more narrowly than a horizontal edge (Haith, 1980).

One possible explanation for this difference in scanning vertical or horizontal edges concerns the ability of the ocular muscles to negotiate eye movements. Because of the immaturity of these muscles in the newborn, scanning a vertical edge may be less difficult than scanning a horizontal edge. When presented stimuli that were more complex than vertical or horizontal bars, e.g., contours surrounding internal elements, newborn infants continued to fixate the external regions of high contrast such as the border of the stimuli while fixations in two-month old infants clustered around the internal rather than the external features (Haith, Bergman, & Moore, 1977). Thus, the features of visual stimuli that are scanned and fixated by infants are known to change over time.

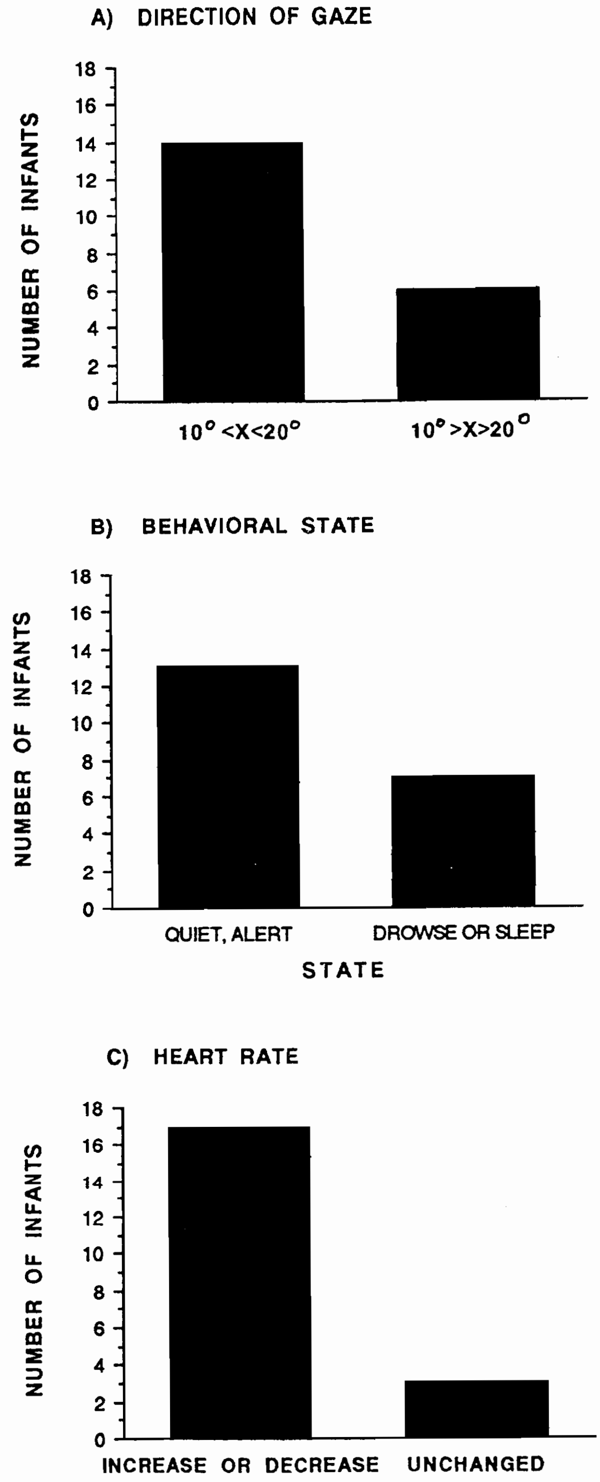
Similar to investigations with newborn and young infants, the visual abilities of preterm infants have been investigated using a variety of visual stimuli. Typically, the infants have been placed in a testing chamber and presented pairs of visual stimuli which differ in a number of features, including acuity, complexity, linearity, and density (e.g., Fantz & Fagan, 1975; Miranda, 1970). The infants were observed to discriminate between stimuli, and, in some instances, to indicate a preference for one of the stimuli by visually attending to a particular stimulus.

As previously mentioned, visual fixation has been observed in preterm infants as young as 30 weeks of age (Hack et al., 1981). Discriminative visual functioning, characterized by fixation, preference, and tracking, has been observed in preterm infants at 31 - 32 weeks (Dubowitz, Dubowitz, Morante, & Verghote, 1980). Infants this age prefer striped stimuli over either unpatterned or complex stimuli, and are able to differentiate 1/8", 1/4", and 1/2" black stripes against a white background (Miranda, 1976). When a gray square is paired with 1/8", 1/4", or 1/2" striped stimuli, infants 32 weeks look longer at the pattern with 1/2" stripes. Infants 33 - 36 weeks look longer at a stimulus with 1/4" stripes than at stimuli with either 1/8" or 1/2" stripes that are paired with a gray square (Miranda, 1976).

Outside of a visual testing chamber, preterm infants 29 - 38 weeks of age have also been observed to respond to a visual stimulus of 1/4" black stripes placed in their incubators (Marshall-Baker, 1986). Following a feeding, infants were observed during 3 successive 2-minute time periods: Baseline (Time 1), Exposure Period 1 (Time 2), and Exposure Period 2 (Time 3). The visual stimulus was introduced into the incubator at the beginning of Time 2, and remained in the incubator through Time 3. The stimulus was presented in 2 modes: stationary and nonstationary. During the nonstationary mode, the striped stimulus rotated at a speed of 1 cycle/2 seconds. Order of the stimulus mode was counterbalanced.

Although not statistically significant, more infants (n=14) looked in the direction of the visual stimulus than in any other direction (n=6) during Time 2 ($X^2(1) = 3.25$, $p<.07$), and a greater number of infants experienced a quiet, alert state (n=13) than a drowsy or sleep state (n=7; $X^2(1) = 1.85$, $p<.17$) (see Figure 3). A significant number of infants showed nonspecific changes in heart rate during Time 2, either an increase or a decrease, rather than no change from Baseline (Time 1) ($X^2(1) = 9.85$, $p<.002$). In contrast to these responses, during Time 3, a significant number of infants looked in the direction of the visual stimulus than looked in any other direction ($X^2(1) = 6.42$, $p<.01$), more infants experienced a quiet, alert state than a drowsy or sleep state ($X^2(1) = 9.85$, $p<.002$), and more infants showed heart rate decelerations from Time 1 than showed accelerations or remained unchanged ($X^2(2) = 6.70$, $p<.03$; see Figure 4). Further, the infants looked longer at the stimulus during Time 3 than during Time 2 ($t(19) = 2.01$, $p<.03$).

These data indicate that preterm infants can respond to a visual stimulus that is placed inside their incubators. Although the infants studied did not demonstrate increased attention to the visual stimulus as a function of pattern mode (stationary or nonstationary), they did demonstrate increased attention as a function of time. General orienting responses characterized by a longer length of time looking at the stimulus, an angle of


A) DIRECTION OF GAZE

B) BEHAVIORAL STATE

C) HEART RATE

Figure 3. Exposure Period 1. Number of infants who looked toward or away from the stimulus (A), came to a quiet awake state or became drowsy and fell asleep (B), and whose heart rates were altered or remained unchanged (C) from baseline during the first exposure period.

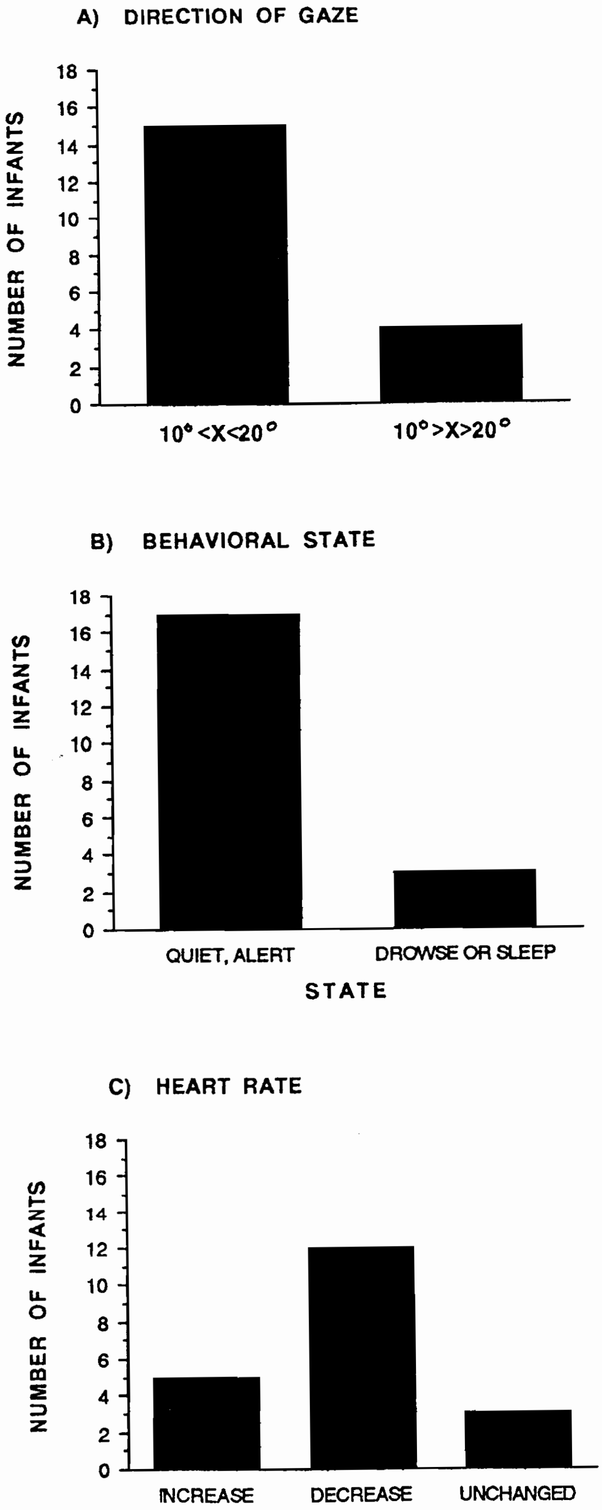


Figure 4. Exposure Period 2. Number of infants who looked toward or away from the stimulus (A), came to a quiet awake state or became drowsy and fell asleep (B), and whose heart rates increased, decreased, or remained unchanged (C) from baseline during the second exposure period.

gaze directed toward the stimulus, a quiet, alert behavioral state, and a deceleration in heart rate, were observed in more infants during Time 3 than during Time 2. These results suggest that preterm infants may require longer periods of sensory experience in order to respond.

Some investigators (e.g., Friedman, Jacobs, & Werthmann, 1984; Parmelee & Sigman, 1976; Spungen, Kurtzberg, & Vaughan, 1985) have argued that sustained visual attention is an indicator of nervous system immaturity, and that the infant is unable to "break away" (Friedman et al., 1984, p. 65) from a visual stimulus. Whether preterm infants are unable to redirect their attention and whether this supposed "captivity of attention" is either detrimental or beneficial to infant development is unknown. Further research will be required to clarify this issue.

Summary

Behavioral organization is characterized by the integration and coordination of component behaviors or units over time (Hofer, 1981; Thoman, 1986), and is believed to be mediated by fundamental processes of the nervous systems during the on-going flow of internal and external events (Thoman, 1986; Zeskind & Marshall, in press). Behavioral organization may be reflected in the infants' behavioral states, which may either exclude stimuli and inhibit responding, or admit stimuli and accord the opportunity to respond, thus facilitating or precluding the integration of behaviors (Brazelton, 1978; Thoman, 1986).

Behavioral state is characterized by the co-occurrence of periods of quiescence and activity among a variety of parameters such as heart rate and eye and body movements (Garbanati & Parmelee, 1987; Prechtl & O'Brien, 1982). One manner in which to assess the organization of behavioral state is in the regularity or irregularity of its occurrence (Booth et al., 1980; Horowitz, 1987; Watt & Strongman, 1984). Because behavioral states may also become organized into patterns of behaviors within a temporal domain, a second manner in which organization of behavioral states may be assessed is the calculation of a state stability score that evaluates the consistency of the allocation of time in behavioral states over time (Thoman et al., 1981).

An important underlying assumption of the present work is that the organization of behaviors and of behavioral state is dependent upon the on-going interchange between the infant and the environment (see Thoman, 1986). When specific features of the environment have been manipulated (e.g., in controlled programs of tactile, kinesthetic, vestibular, auditory, and visual manipulation) preterm infants have responded positively (e.g., Barnard & Bee, 1983; Scarr-Salapatek & Williams, 1973). Although a controlled program of visual experience has not previously been conducted, preterm infants can discriminate and have indicated a preference for particular visual stimuli (Miranda, 1976), and have oriented to a visual stimulus placed in their incubators (Marshall-Baker, 1986). Thus, a primary purpose of this study was to examine the effects of visual experience on the organization of behavioral state in preterm infants.

Because controlled programs of stimulation have not evaluated the effect of the manipulation on the stimulated sensory modality (e.g., Scarr-Salapatek & Williams, 1973), an additional purpose of this study was to evaluate the effect of visual experience on visual responsiveness.

Hypotheses

Behavioral State

1) The state stability score developed by Thoman and colleagues (1981) was implemented using full-term newborns to reflect developmental status at one point in time, independently of controlled environmental stimulation. In contrast, state stability scores calculated before and after an experiential manipulation can provide information concerning the development of the stability of behavioral state as a

function of an intervention. A hypothesis of the present study was that a visual stimulus would provide structure to the infants' visual environments, and was expected to facilitate the organization of their behavioral states. Specifically, the state stability scores of those infants (in the Intervention Group) were expected to be

a) comparable at the time of the initial observation to the state stability scores of infants not provided a visual stimulus (i.e., infants in the Control Group).

b) In addition, the state stability scores of infants in the Experimental Group should be higher at the time of the second observation than the scores of infants in the Control Group.

2) Changes in the organization of behavioral states have been observed as a function of specific interventions. For example, Barnard (1973) found that preterm infants altered the amount of time that they spent in their behavioral states after a period of controlled tactile-kinesthetic stimulation. Changes in the behavioral states of infants in the Intervention Group are thus expected to be similar to the types of changes that have occurred in the behavioral states of other stimulated infants. Specifically,

a) infants in the Intervention Group were expected to spend more time in Quiet Sleep (Barnard, 1973) at the time of the second observation than infants in the Control Group. An increased amount of time in Quiet Sleep, a state that is characterized by physiological stability, has been linked to greater nervous system maturation (Garbanati & Parmelee, 1987).

b) At the time of the second observation, the infants in the Intervention Group were expected to spend less time in an active sleep state than infants in the Control Group (Schmidt et al., 1980). Active Sleep is a state that has been described as the least organized, and is associated with nervous sytem immaturity (Garbanati & Parmelee, 1987).

3) An increased length of time spent in a state without brief interruptions is believed to reflect better organization of behavioral states (Horowitz, 1987). Because the organization of behavioral states has been positively affected in preterm infants as a function of an intervention (e.g., Barnard, 1983), infants in the Intervention Group were expected to experience greater organization in their behavioral states than infants in the Control Group. Specifically, infants in the Intervention Group were expected to experience fewer interruptions (i.e., state changes) at the time

of the second observation period than infants in the Control Group.

Visual Responsiveness

4) Preterm infants who were exposed to an auditory stimulus have achieved more optimal scores on a standardized assessment of auditory functioning (e.g., Katz, 1971). Thus, stimulation of a maturing sense may have affected the functioning of the stimulated sensory modality. In this light, a hypothesis of this study was that infants provided a visual stimulus would exhibit more optimal performances on tasks of visual ability such as focusing and tracking at the time of the second observation than infants who were not provided a visual display. In other words, sensory input in the visual domain would result in more developed visual skills for infants in the Intervention Group.

METHOD

Subjects

This study assessed 32 preterm infants, who were housed on the intermediate side of the NICU in Roanoke Memorial Hospital in Roanoke, Virginia. The data derived from 12 of these infants were not included in the final analyses of this study. For one infant, parental consent was withdrawn during the initial observation. A second infant was discharged from the hospital before all the data were collected. The data from 4 infants were lost to the experimenter (theft). The remaining 6 infants did not complete the investigation for medical reasons: 3 were diagnosed with abnormal EEGs, 1 died from necrotizing enterocolitis, 1 had heart surgery, and 1 was excluded because of a complicated medical history. Data from the remaining 20 infants were included in the final analyses and are reported here.

The twenty infants ranged in age from 29 - 34 weeks ($\bar{X} = 31.05 \pm 1.85$) conceptional age (gestational age plus the number of weeks since birth) at the time of the initial observation. Gestational age was determined by the members of the NICU staff during routine pediatric care using maternal history, ultrasound, and the Dubowitz exam (Dubowitz, Dubowitz, & Goldberg, 1970). Infants who exhibited obvious behavioral or physiological problems as determined by the hospital staff were not considered for participation in this study. Parents of infants who met these criteria were contacted by the experimenter, informed of the study, and asked if their infant might participate. Infants whose parents signed a letter of informed consent were included in the study. Of the twenty infants, 10 were male and 10 were female. Six of the infants were black, 13 were white, and 1 infant had a black mother and a white father.

Visual Stimulus

The visual stimulus consisted of a 4" translucent white acrylic disc with 3 black stripes of 1/2" wide Chartpak® tape spaced 1/2" apart (Miranda, 1976) (see Appendix A). Because preterm infants have not be found to respond differently to either vertical or horizontal stripes (Shepherd, Fagan, & Kleiner, 1985), the stimulus was positioned with stripes perpendicular to the floor, and was attached to the interior of the incubator with double-sided foam tape.

Procedure

The subjects were randomly assigned to either an Experimental (n=10) or Control group (n=10). The two groups of infants did not differ significantly on measures of gestational age ($t(18) = -.35$, $p<.72$), conceptional age at the time of the initial observation ($t(18) = -.95$,

$p<.35$), Apgar scores at 5 minutes ($X^2(3) = 3.11$, $p<.37$), or length of time before transfer from the intensive to the intermediate side of the NICU ($t(18) = -.98$, $p<.34$). Further, the two groups of infants did not differ significantly at the time of the initial observation period in any of the dependent variables (see Table 1 for a summary of sample characteristics).

Each infant was observed on 2 days: when the infant was transferred from the intensive to the intermediate side of the NICU (Time 1), and again during the week that the infant was discharged from the hospital (Time 2). On each of these days, the infants were observed twice (Thoman, Korner, & Kraemer, 1976). Each observation period was 2 hours long (see Tynan, 1986), and followed a feeding. Thus, each infant was observed twice for 2 hours following successive feedings on 2 separate occasions, a procedure that generated 4 hours of observation on each day, for a total of 8 hours of observation on each infant.

During each observation period, behavioral state was recorded every 30-seconds using Thoman's 8-point state scale (e.g., Davis & Thoman, 1987; see Appendix B). During the last 10 seconds of each 30 second epoch, the state of the infant was assessed, and that state was recorded (Goff, 1985).

At the end of the second observation period of Time 1, a visual stimulus was placed on the side of the infant

Table 1. Summary Characteristics of the Sample

	Group 1	Group 2
Gestational age (weeks) mean and standard deviation	30.9 ± 1.91	31.2 ± 1.87
Age at initial observation mean and standard deviation	31.7 ± 1.25	32.4 ± 1.96
Days to intermediate status mean and standard deviation	2.2 ± 1.87	3.3 ± 2.98
Apgar scores at 5 minutes mode	8,9	9

Dependent Variables	
State stability scores	t(18) = -.78, p>.05
Percentage of time in Quiet Sleep	t(18) = -1.12, p>.05
Percentage of time in Active Sleep	t(18) = 0.59, p>.05
Rate of state change	t(18) = 1.93, p>.05
Visual responsiveness	U(n1=10, n2=10) = 50.50, p>.05

incubator for infants in the Experimental Group (Group 1). The stimuli remained in the incubators until discharge.

Preceding the first 2-hour observation period on each day, the visual responsiveness of the infant was assessed using a portion of the Attention/Interaction Package of the Assessment of Preterm Infant Behavior scale (APIB; Als, Lester, Tronick, & Brazelton, 1982). An examiner using APIB assesses and scores five systems, physiological, motor, state, attentional-interactive, and regulatory, in each of six packages: sleep/distal, uncover/supine, low tactile, tactile/vestibular, high tactile/vestibular, and attention/interaction. Package VI, attention/interaction, is used to assess the infant's attentional and social interaction capacities with animate and inanimate stimuli using auditory and visual stimuli in combinations and alone. For purposes of this study, attention to an inanimate object (silent bell) was assessed (see Appendix C). The procedure consisted of presenting a silent bell to the infant at midline, and then slowly moving the bell through the infant's visual field in horizontal and vertical directions.

The examiner, although not blind to the hypotheses of the study, remained blind to the group assignment of each infant. Specifically, at the time of the first observation the group assignment was not known to the examiner. At the time of the second observation each infant had previously been removed from its incubator and placed in an open crib, preventing the examiner from identifying Control or Intervention Infants.

Infants in the no-treatment Control Group (Group 2) experienced routine care in the NICU. Like the infants in the Experimental Group, infants in the Control Group were observed twice on 2 days, and evaluated using the same portion of Package VI of the APIB scale previously described.

Reliability

Three trained research assistants who were unaware of the hypotheses of the study assisted with data collection. Interobserver reliability of the research assistants was based upon the proportion of observations that agreed with those of the examiner divided by the total number of observations (e.g., Goff, 1985). Reliability for the behavioral state measure on three separate occasions was 87%, 84%, and 91%, respectively. Reliability for the measure of visual responsiveness was 80% on two separate occasions.

Statistical Analyses

Behavioral State

State Stability Score

Two state stability scores (one each from Time 1 and

Time 2) were calculated for individual infants using the percentages of time spent in each of the eight behavioral states (e.g., Thoman et al., 1988). These percentages were used in an analysis of variance (ANOVA) procedure that generated an "F" score for each infant per obsevation day. Because the percentages of time spent in each state summed to 100% for each observation period, there was no Between Observations variation. The "F" statistic was calculated using the two remaining sources of variance: Between States and the interaction of States X Observations. Individual state stability scores were generated by dividing the Between States mean square by the States X Observations mean square (see Thoman et al., 1981; 1988), indicated how similar the infant's state profiles were for the two 2-hour observations on a particular observation day. A high state stability score represented a high consistency between the state profiles, and a low state stability score indicated low consistency between profiles.

Individual profiles of state stability were generated using the percentages of time spent in behavioral states at each observation (see Appendix D for a visual representation of the state stability scores).

Although Thoman and colleagues (e.g., 1988) have only used state stability scores descriptively to rank infants on consistency, a test for normality of the data indicated that inferential statistical procedures were appropriate. Consequently, a 2 (Intervention versus Control Group) X 2 (Time 1 versus Time 2) repeated measures analysis of variance (ANOVA) was conducted using the mean state stability scores (Hypothesis #1a and #1b).

Because a group mean may not reflect individual changes such as increases or decreases in state stability scores at Time 2 from Time 1, a difference score was calculated for each subject by subtracting the state stability score at Time 1 from the state stability score at Time 2. For example, a difference of 289.59 was revealed for one infant whose state stability score at Time 1 (59.41) was subtracted from the state stability score at Time 2 (349.00), i.e., 349.00 - 59.41 = 289.59. In this example, the infant's state stability score was 289.59 units higher at Time 2 than at Time 1.

These data were analyzed using two nonparametric procedures that consider the median as the measure of central tendency rather than the mean. An arithmetic average (a mean) may fluctuate as a function of extreme scores, and no longer accurately describe the distribution (see Kerlinger, 1973). A median score reflected the middle or the 50th percentile in an ordered distribution, and may have been closer numerically to the other scores in the distribution.

Two procedures used to compare the median difference scores of the infants in the Control Group at Time 1 and Time 2 were the Median Test and Mann-Whitney U-Test (Hinkle, Wiersma, & Jurs, 1979). The Median Test assessed whether one median score, e.g., the median of the infants at Time 2, was higher than the median at Time 1. The second test based upon the median scores was the Mann-Whitney U-Test, which was sensitive to the measure of central tendency and also to the distribution of scores. This test indicated not only that the medians differed, but also tested the magnitude of that difference. For example, a significant finding in this test indicated not only that the median state stability score was different for one group than the other, but also that the scores were higher for one group than the other (Hinkle et al., 1979).

Percentage of Time in Quiet Sleep

The percentage of time spent in Quiet Sleep at Time 1 and Time 2 was calculated using the following formula:

$$\frac{\text{number of epochs in Quiet Sleep}}{\text{total number of observations}}$$

A 2 (Intervention versus Control Group) X 2 (Time 1 and Time 2) repeated measures ANOVA was conducted to determine the differences in the percentages of time spent in a quiet sleep state at Times 1 and 2 for infants in the Experimental and Control Groups (Hypothesis #2a).

In order to assess changes by the individual infants in the percentages of time spent in Quiet Sleep that have occurred from Time 1 to Time 2, a difference score was calculated for each infant. This score was computed by subtracting the percentage of time spent in Quiet Sleep at Time 2 from the percentage of time spent in that same state at Time 1.

Two nonparametric procedures described previously were used to assess the amount of change (difference scores) in the percentages of time that the infants spent in Active Sleep at Time 2 from Time 1: the Median Test and the Mann-Whitney U-Test (Hinkle et al., 1979). These tests indicated whether the median amount of change differed between the groups, and whether the amount of that difference was larger for one group of infants than the other.

Percentage of Time in Active Sleep

Similarly to the statistical procedures previously described, the percentages of time spent in an active sleep state were compared on all subjects using a 2 (Intervention versus Control Group) X 2 (Time 1 versus T Time 2) repeated measures ANOVA (Hypothesis #2b). Difference scores were calculated and compared using the Median and Mann-Whitney U-Tests (Hinkle et al., 1979).

Rate of State Change

To assess the rate of state change, Thoman and colleagues (1988) summed the number of changes that had occurred per hour during the longest sleep period for a total number of state changes at each weekly observation. This procedure was modified in the present study in order that the number of changes relative to the length of the sleep period be considered. The total length of time of each of the longest sleep periods per hour was summed and divided by the total number of state changes that occurred during those epochs of sleep:

$$\frac{\text{longest sleep epoch per hr 1 + hr 2 + hr 3 + hr 4}}{\text{number of state changes per hr 1 + hr 2 + hr 3 + hr 4}}$$

This procedure yields the average number of state changes that occurred during the longest sleep epochs for Time 1 and Time 2. Because the data were recorded in 30-second intervals, the average number of state changes represented the average number of intervals. To understand this frequency of change in minutes, the number of changes was divided by 2 (two 30-second intervals per minute). A state change that occurred on average every 8 epochs, for example, indicated that a state change had occurred every 4 minutes.

These data were analyzed with a 2 (Intervention versus Control Group) X 2 (Time 1 versus Time 2) repeated measures ANOVA to determine differences in the rate of state change between the two groups of infants (Hypothesis

#3).

As described previously, difference scores in the rate of state changes at Time 2 from Time 1 were calculated and assessed using the Median Test and the Mann-Whitney U-Test (Hinkle et al., 1979).

Visual Responsiveness

The data collected for visual responsiveness were not normally distributed. Thus, possible differences in visual responsiveness between the groups were assessed using a Median Test and Mann-Whitney U-Test. This statistical procedure indicated whether the visual responsiveness scores for infants in the intervention group differed (e.g., were larger) than those of infants in the control group (Hypothesis #4).

To assess changes in visual responsiveness at Time 2 from Time 1, difference scores were calculated for each infant and assessed as before, using the Median Test and the Mann-Whitney U-Test (Hinkle et al., 1979).

RESULTS

Summary Measures of Behavioral State

The parametric analyses of the measures of behavioral state did not indicate statistically significant differences between the two groups of infants in the measures of state stability, percentages of time in Quiet Sleep or Active Sleep, or in rate of state changes. The lack of significant results are likely explained by the large and unequal amounts of variability among the scores. Had significant results been revealed in the parametric procedures (even though the assumption of homogeneity of variance had been violated), nonparametric procedures would not have been necessary. However, because of the negative effects revealed employing the parametric procedures (see Appendix E), the data were also analyzed using nonparametric procedures.

State Stability Score

As mentioned previously, preterm subjects were selected according to prespecified criteria. Specifically, infants who exhibited obvious behavioral or physiological problems as determined by the hospital staff were not considered for participation in this study. The inclusion of two subjects, one in each of the groups, was reevaluated when their state stability scores were found to be unusually high (565.26 and 776.16; see Table 2). Both of these scores were greater than 2 standard deviations above the mean.

One of these infants had been diagnosed with phenylketonuria (PKU). This disease is caused by an accumulation of phenylalanine, an amino acid, and is associated with decreased myelination if undetected (Harper & Ja Yoon, 1987). PKU may be diagnosed in the neonate, and may be controlled by diet. In this case, the infant's diet had been altered within a week of birth, and the levels of phenylalanine remained within normal limits both during the 13 days before the infant was observed for the first time and until the time of discharge. As a consequence, this infant was not considered to violate the selection criteria, and was included in this study.

The second infant whose state stability score was unusually high was found to have had a Grade 1 intraventricular hemorrhage (IVH). Although some have argued that any "brain bleed" is detrimental (Karmel & Gardner, 1988), others have argued that significant damage to the neural tissue does not occur except in an IVH of Grade 3 or 4 (see Kopp & Krakow, 1982). As a consequence, infants with an IVH of Grade 1 or 2 have not been considered to be either abnormal or unhealthy. Thus, the infant with the low grade IVH was also considered to meet the selection criteria of this study.

Table 2. State Stability Scores at Time 1 and Time 2

Group 1	Subject#	Time 1	Time 2
	19	565.26	15.71
	30	330.74	60.77
	32	155.39	29.22
	22	59.41	349.00
	15	33.34	61.47
	07	12.99	66.05
	17	8.05	28.76
	11	4.54	47.89
	29	3.38	197.23
	01	1.33	4.48
Group 2			
	04	280.15	34.80
	16	164.94	5.24
	10	58.37	32.98
	31	19.48	2.30
	12	19.12	14.06
	20	13.98	1.10
	08	11.59	33.58
	02	10.14	495.46
	18	9.25	776.16
	21	5.98	52.98

There is no documented relationship between either PKU or a low grade IVH and state stability scores. However, because the medical histories of these two infants were atypical when compared to the other infants who were included in the study, and because their unusually state stability scores were unusually high (more than 2 standard deviations above the mean), these two infants were excluded from the reported statistical analyses.

The results of the Median Test and the Mann-Whitney U-Test on the difference scores of 18 infants did not indicate a significant difference in the amount of change (either increases or decreases) in state stability scores of the two groups of infants at Time 2 from Time 1 ($X^2(1) = 2.00$, $.05<p<.10$; $U(n1=10, n2=10) = 29$, $p>.05$), respectively. However, the results of the Median Test indicated that the amount of change in the state stability score was nominally higher than the group median for the infants in the Intervention Group than for the infants in the Control Group. It is interesting to note that in the 2 X 2 contingency table generated by the Median Test, 66% of the infants in the Intervention Group had increases in their state stability scores at Time 2 that were above the median amount of change (see Figure 5). That is, 66% of the infants in the Intervention Group increased their state stability scores by amounts that were larger than

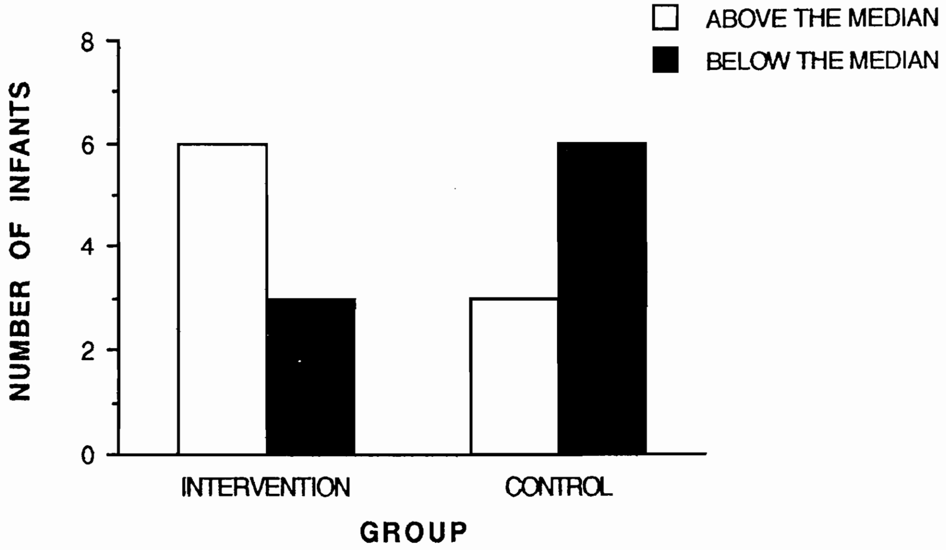


Figure 5. State Stability Scores: Amount of Change. Number of infants whose changes in state stability scores were above and below the median amount of change at Time 2.

the median amount of change. Only 33% of the infants in the Control Group had increases in their state stabilty scores that were above the median amount of change. These nonparametric procedures reveal a nominal increase in the amount of change in the state stability scores of the infants in the Intervention Group at Time 2.

Percentage of Time in Quiet Sleep

The results of the Median Test using the percentages of time in Quiet Sleep for 18 infants indicated that the median amount of change in the percentage of time spent in Quiet Sleep was nominally higher for infants in the Intervention Group than for infants in the Control Group ($X^2(1) = 2.00$, $.05<p<.10$). Specifically, 66% of the infants in the Intervention Group showed an increase in the amount of time that they spent in Quiet Sleep at Time 2 (see Figure 6). In the Control Group, 33% of the infants had an increase in the amount of time that they spent in a quiet sleep state that exceeded the median amount of change. Interestingly, these results indicate a movement of the data in the predicted direction. However, it is not statistically significant.

The Mann-Whitney U-Test on the difference scores in the percentage of time spent in Quiet Sleep at Time 2 did not reveal a significant difference between the two groups of infants ($U(n1=10, n2=10) = 29$, $p>.05$). That is, neither

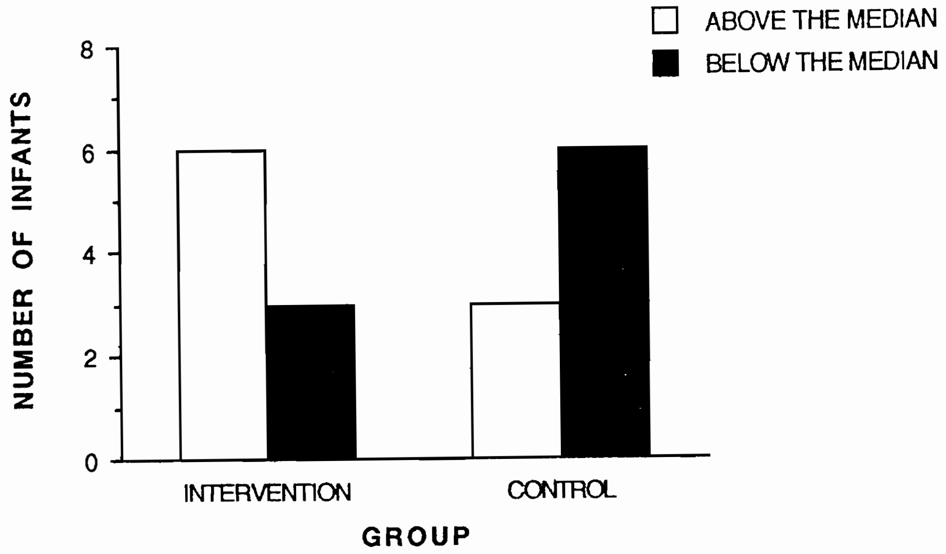


Figure 6. Quiet Sleep: Amount of Change. Number of infants whose changes in the percentage of time in Quiet Sleep were above and below the median amount of change at Time 2.

group of infants significantly altered the amount of time that they spent in Quiet Sleep at Time 2 from Time 1.

Percentage of Time in Active Sleep

Neither the results of the Median Test nor the Mann-Whitney U-Test indicated that either group of 9 infants altered the amount of time that they spent in Active Sleep significantly, ($X^2(1) = .22$, $p>.05$) and ($U(n1=10, n2=10) = 39$, $p>.05$), respectively. The 2 X 2 contingency table generated by the Median Test indicated that 55% of the infants in the Intervention Group compared to 45% in the Control Group had increases in the percentages of time that they spent in Active Sleep at Time 2 that were higher than the median amount of change (see Figure 7). In contrast to the results of the Median Tests reported previously, these data do not approach significance, and the movement of the data is in a direction opposite the expected movement of scores. That is, the number of infants whose percentages of time in Active Sleep increased at Time 2 from Time 1 was not expected to be higher than the number of infants in the Control Group whose percentages of time increased at Time 2.

Rate of Change

The results of the Median Test on the difference scores indicated a nominal decrease in the rate of state

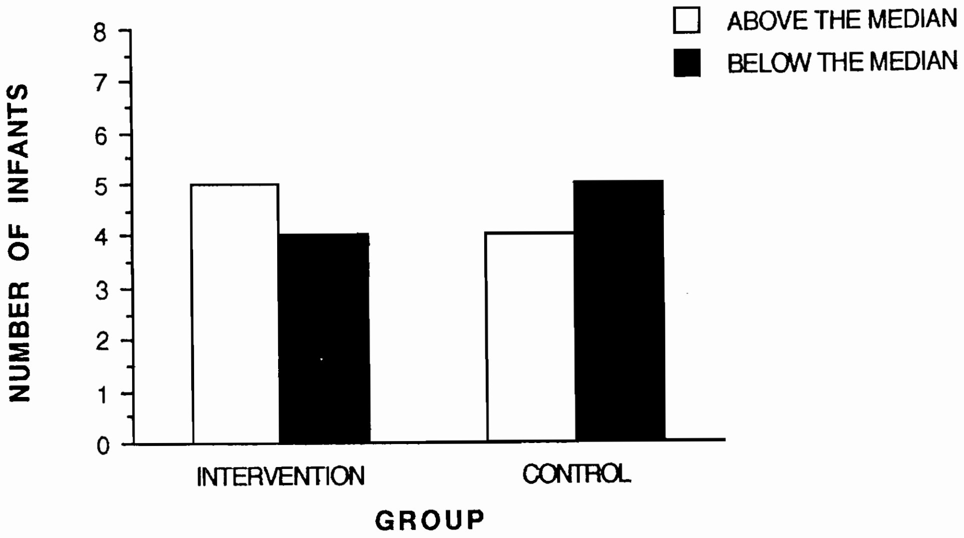


Figure 7. Active Sleep: Amount of Change. Number of infants whose changes in the percentage of time in Active Sleep were above and below the median amount of change at Time 2.

change for infants in the Intervention Group ($X^2(1)$ = 2.71, $.05<p<.10$). The 2 X 2 contingency table indicated that the number of state changes for 66% of the infants in the Intervention Group was below the median amount of change. In contrast, the rates of state changes for 33% of the infants in the Control Group were below the median amount of change (see Figure 8).

The results of the Mann-Whitney U-Test on the difference scores indicate that the amount of decrease in the rate of state change was significantly greater for infants in the Intervention Group than in the Control Group ($U(n1=10, n2=10) = 20$, $.025<p<.05$). This finding supports the prediction that infants in the Intervention Group would have fewer state changes at Time 2 than infants in the Control Group.

Visual Responsiveness

The results of both the Median Test and the Mann-Whitney U-Test of the visual responsiveness scores indicated that the scores of the infants in the Intervention Group were significantly higher than the scores of infants in the Control Group at Time 2, ($X^2(1) = 5.56$, $.005<p<.01$) and ($U(n1=10, n2=10) = 17.5$, $.01<p<.025$), respectively (see Figure 9a). These results, based upon the scores of 18 infants, support my hypothesis (#4) that providing infants with a visual stimulus would

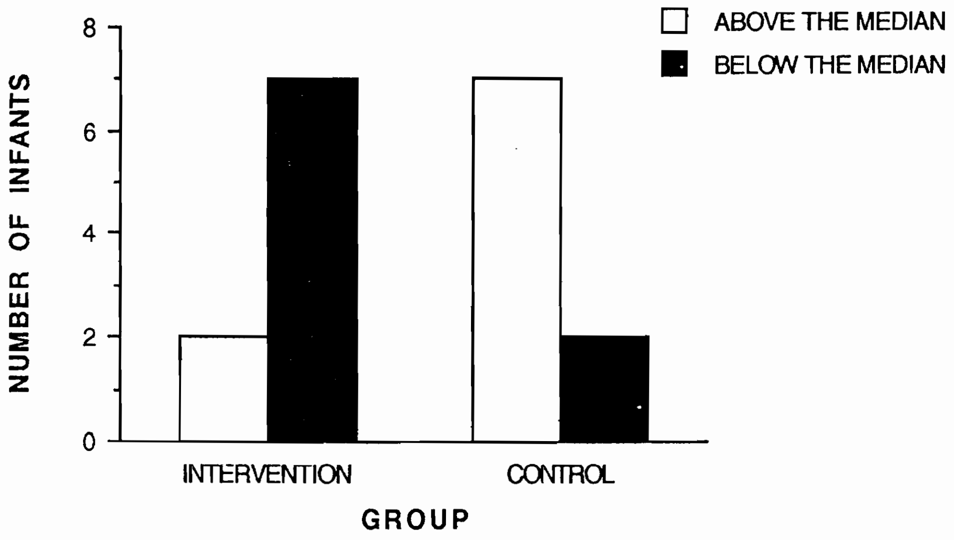


Figure 8. Rate of State Change: Amount of Change. Number of infants whose changes in the rate of state changes were above and below the median amount of change at Time 2.

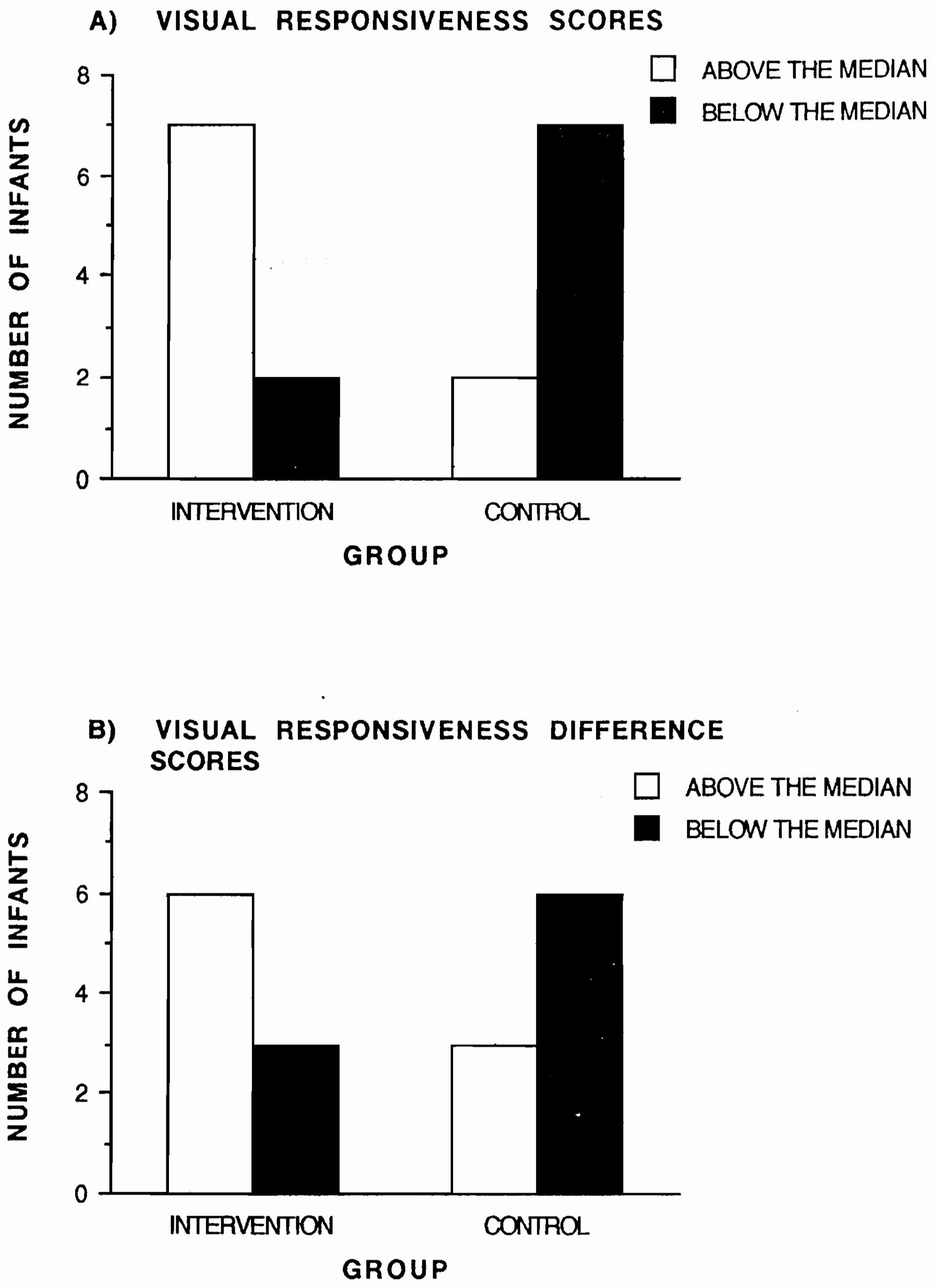


Figure 9. Visual Responsiveness Scores.

A) Number of infants whose visual responsiveness scores were above and below the median at Time 2.

B) Number of infants whose changes in visual responsiveness were above and below the median amount of change at Time 2.

result in more developed visual skills.

The results of a Median Test indicate a nominally higher increase in the amount of change in visual responsiveness scores for infants in the Intervention Group ($X^2(1) = 2.71$, $.05<p<.10$; see Figure 9b). Moreover, the results of a Mann-Whitney U-Test using the difference scores in visual responsiveness at Time 2 from Time 1 indicated that the improvement in the scores of the infants in the Intervention Group was significantly larger than the amount of improvement in visual skills of the infants in the Control Group ($U(n1=10, n2=10) = 21.5$, $.025<p<.05$). These findings also support the hypothesis (#4) that the visual skills of infants in the Intervention Group would be more developed·than those of infants in the Control Group at Time 2.

Summary

The results of these nonparametric analyses indicated that the infants in the Intervention Group significantly decreased the number of state changes that they experienced at Time 2 from Time 1. Although not statistically significant, infants in the Intervention Group experienced nominal increases in their state stability scores and in the percentage of time that they spent in Quiet Sleep. In addition, the visual responsiveness scores of the infants in the Intervention

Group were significantly higher and showed significantly more improvement than the scores of infants in the Control Group. These findings indicate that the presence of the visual stimulus affected the development of visual skills of the infants in the Intervention Group.

DISCUSSION

Perhaps the most important findings of the present study were that statistically significant differences were revealed between the two groups of infants in their visual skills and in the regularity of the organization of their behavioral states. Specifically, preterm infants who received exposure to a visual stimulus had higher visual responsiveness scores and significant decreases in their rates of state change than preterm infants who did not receive exposure to the visual stimulus. Although these findings suggest an influence of the visual stimulus on the development of visual skills and behavioral states in preterm infants, this interpretation must remain tentative until further research is undertaken with larger sample sizes.

In addition to these findings, this study also documented an unusually high state stability score of an infant with a known disability. To the extent that higher state stability scores have been associated with developmental outcome that is unrelated to disability or dysfunction, this finding suggests that the state stability score may not consistently predict developmental outcome accurately.

The finding that sensory input provided by the visual stimulus facilitated the development of the visual sensory modality extends the work of other investigators who have found that supplemental auditory experience facilitates the functioning of the auditory system (Katz, 1971). The observed effects of the visual stimulus on the visual skills of the infants in this study can be viewed in several different ways.

First, some investigators have described the disruptive effects of untimely stimulation on the development of other sensory modalities (e.g., Gottlieb et al., 1989). Premature visual stimulation, for example, has been found to disrupt or interfere with the functioning of olfactory (Kenny & Turkewitz, 1986) and auditory systems (Lickiter, 1990a, 1990b). Whether the visual stimulus employed in this study affected the development of sensory modalities other than visual is unknown. The functioning of other sensory modalities, such as the auditory sense, was not measured in this study. Future investigations that include measures of functioning in other sensory modalities would help clarify the issue concerning possible disruption among the sensory systems as a function of premature visual experience.

Importantly, the sensory experience that the infants in this study experienced was not typical of most sensory "stimulation" manipulations. Typical interventions that have provided particular forms of sensory stimulation have not usually considered the infant's state or level of activity at the time of the stimulation. That is, bodies are rubbed (Field et al., 1986), tapes are played (Katz, 1971), or babies are rocked (Koniak-Griffin & Ludington-Hoe, 1987) at regular intervals regardless of the infant's activity. In this study, the infant was able to self-regulate the amount of sensory input by either attending to the visual stimulus or not attending to the stimulus. The infants were not subjected to a standardized routine of sensory stimulation. As discussed previously, preterm infants have been observed to seek sensory input when they are motorically organized or use sensory input in order to stabilize various subsystems of functioning following a period of disorganization (Als et al., 1982). Preterm infants have also been observed to prefer more complex visual patterns when they are not highly aroused (Gardner & Karmel, 1983). Thus, a difference between this and many other studies of infant stimulation is an element of self-regulation that may have contributed to the infant's behavioral organization and visual responsiveness.

Interestingly, infants who were not able to control the amount of stimulation that they received have also indicated that they were affected by the intervention. For example, infants who experienced tactile and kinesthetic stimulation increased the amount of time that they spent in Quiet Sleep (Barnard, 1973). Although some (e.g., Als et al., 1982; Ramey in Tronick, Scanlon, & Scanlon, 1987) have argued that self-regulation is an important component of behavioral organization, others have argued that a "challenge" (Spinelli and Tronick in Tronick et al., 1987) or a "stressor" (Tronick et al., 1987) may facilitate the infant's behavioral organization. Further research that investigates the differences between the effects of self-regulated or imposed sensory experience on the infant's behavioral organization is required to clarify this issue.

In contrast to the significant results revealed in the nonparametric analyses of visual responsiveness, the parametric analyses of behavioral state did not indicate significant differences between the two groups of infants at either Time 1 or Time 2 as a function of the intervention (see Appendix E). Nonparametric procedures did however indicate a significant difference between the groups in the rate of state changes, and nominal differences in the state stability scores and the percentages of time spent in Quiet Sleep. Recall that nonparametric procedures do not rely upon estimates of the mean and variance as do parametric procedures. Because of the large amount of variability among the scores and the small sample size in this study, the nonparametric statistical procedures may more accurately assess the differences between the two groups of infants. However, the interpretation that the presence of the visual stimulus influenced the development of the infant's behavioral states must remain tentative not only because of the amount of variability among the scores, but also because of the small sample size.

The decrease in the number of state changes experienced by the infants who were exposed to a visual stimulus at the time of the second observation reflects an increase in the length of uninterrupted time that the infants spent in their behavioral states. Extended periods of time in behavioral states affords the opportunity for further integration and coordination of the infants' subsystems that may result in enhanced behavioral organization (Als et al., 1982; Thoman, 1986), and may be reflected in higher state stability scores (Thoman, 1986) and extended periods of time in Quiet Sleep (Barnard, 1987). In this light, the findings that infants who were exposed to the visual stimulus did not have significantly higher state stability scores or spend more time in a quiet sleep state than infants who were not exposed to the stimulus are unexpected.

One way in which to view the discrepancy among the results of the measures of behavioral state is that the observed increase in the length of uninterrupted states (i.e., fewer state changes) represents the first step in a series of events that will eventuate in general improvement in the organization of behavioral states. That is, longer periods of time in particular states may provide the opportunity for further integration of the components of behavioral state that may eventually culminate in higher state stability scores and longer lengths of time in Quiet Sleep. The nominal increases in the state stability scores and percentages of time spent in Quiet Sleep by the infants who were exposed to the stimulus provides tentative support for this interpretation.

A related interpretation concerns when the effects of an intervention may be realized. For example, preterm infants who were provided mechanized bears during their hospital stay sought physical contact with the bears (Thoman, Ingersoll, & Acebo, 1991). The bears' bodies expanded and contracted rhythmically ("breathing") to match each individual infant's respiratory rate. The immediate effect of proximity to the bears was an entrainment of the infants' irregular breathing patterns to the more regular "respiratory" rates of the bears. Although no differences were noted in the infants' behavioral states at discharge, infants who had been provided a bear during their hospital stay had significantly lengthier bouts of Quiet Sleep at 4-week follow-up assessments than infants who were not provided a bear. Thoman and her colleagues concluded that the infants' neurobehavioral organization was facilitated as a function of the intervention, and that these effects extended beyond the intervention period into post-term age. In this study, the immediate effects of the visual stimulus may be seen in the measure of visual responsiveness and in the rate of state change. The nominal effect of the stimulus that is evident in the measures of state stability and amount of time in Quiet Sleep may become stronger over time (similarly to the Thoman et al. (1991) study).

Als and Duffy (1983) have described the development of synchrony between infant and caregiver in their social interactions that appears to facilitate the behavioral organization of the infant. Put simply, a caregiver provides sensory stimulation to an infant who is moderately aroused and seeking environmental input. When the infant becomes overstimulated, the caregiver ceases to stimulate the infant, thereby helping the infant to "reset". As a consequence of repeated experiences such as attending and resetting, the behavioral components that are particular to each experience become better integrated and coordinated. The result of better integrated behavioral components is enhanced behavioral organization.

Given this view, infants whose visual skills are more developed may be better able to participate in the initial stages of a synchrony between the infant and the environment that may eventually culminate in better behavioral organization. Whether the preterm infants in this study who were provided a visual stimulus and whose visual skills were more developed would indeed experience increased behavioral organization is speculative. Further work is necessary to assess these possibilities.

An additional finding of this study suggests that developmental outcome cannot be consistently predicted accurately from the face value of a state stability score. Previously, investigators who have calculated state stability scores have found a relationship between the scores and developmental outcome. A high state stability score indicates that the infant is spending stable or consistent amounts of time in an individual distribution of behavioral states. This stability has been thought to reflect a level of neurological integrity that affords consistency, and has been associated with more optimal developmental outcome (e.g., Thoman, 1986). For example, Thoman and colleagues (1981) have reported that infants with state stability scores above the median score had not developed any known developmental disorders after 2 1/2 years. Conversely, a low level of consistency that is reflected in a low state stability score has been associated with neurological dysfunction and developmental disability. Infants with low scores, for example, have subsequently experienced a variety of developmental disorders (Thoman et al., 1981; see Appendix F).

However, Tynan (1986) has described an infant with poor autonomic control and cardiac abnormalities who was lethargic, but whose behavioral state profile was stable (state stability score: 124.50). This stable behavioral state profile was believed to reflect an adaptive pattern of a stressed infant who was conserving physiological resources with extended sleep periods. For this infant, a stable behavioral state profile was not indicative of known medical and behavioral abnormalities.

In this study, I have found an unusually high state stability score (1153.71, see Appendix G) in an infant who was known to have an abnormal EEG. Further evaluation of this infant revealed that on only 2 occurrences (i.e., 1 minute) of a 4-hour observation period was the infant in any state other than Active or Quiet Sleep (see Subject #05, Appendix D, for a graphic representation). Although Tynan (1986) may argue that the consistency of states experienced by this infant is an adaptive response (i.e., that this compromised infant is handling environmental demands by conserving his resources) Als and Duffy (1983) have argued that preterm infants experience self-induced sensory deprivation and an over-reliance on the exclusion of environmental stimulation that is not adaptive and that negatively affects their development. Als and Duffy, for example, would argue that this particular infant (with a state stability score of 1153.71) is not experiencing the modulation of attention that is necessary for balanced functioning among the infant's subsystems. Although either interpretation may be correct, the important point to be made is that in this case, a high state stability score is generated in an infant who is known to be compromised neurologically and to be unresponsive to environmental input. This finding does not support the assumption that higher state stability scores reflect optimal levels of neurological functioning and are predictive of developmental outcome that is unrelated to disability.

The state stability score of a second infant in this study who was also known to have an abnormal EEG was 2.32 (see Appendix G). Further investigation of the percentages of time that this infant spent in a distribution of behavioral states indicates little consistency (see Subject #06, Appendix D, for a graphic representation). This finding may be interpretted as a low state stability score that reflects little consistency among the percentages of time that the infant spends in behavioral states, and is also representative of a developmental disability (abnormal EEG). This interpretation supports those of other investigators who have also found low state stability scores in compromised infants (e.g., Tynan, 1986).

These two extreme scores (2.32 and 1153.71) represent two opposite situations in infants with known disabilities. A low score reflects little consistency in the percentages of time spent in behavioral states, while a high score reflects little modulation in the percentages of time spent in sleep states. These findings indicate that low state stability scores may more accurately portray the developmental status of the infant than high scores. That is, low scores indicate little consistency among the percentages of time spent in behavioral states that may reflect a compromised neurological system. High scores may represent consistency in behavioral states in infants who are _either_ neurologically intact and very consistent, or are compromised neurologically and rarely change their behavioral states.

An important point to be made is _not_ that the state stability score developed by Thoman and colleagues (1981) provides unreliable information concerning the underlying neurophysiological functioning of the infant, or that the score should not be used predictively. Rather, in addition to the face value of the state stability score, the actual distribution of the percentages of time among the behavioral states should be considered. Further, these findings indicate that the state stability score should not be used independently of other information. An accurate assessment of an infant's medical and behavioral status should include measures of the organization of behavioral state (consistency and regularity) as well as medical diagnoses, measures of cardiac and respiratory activity, eye and body movements, and social and interactive capabilities. Specific measures may include the amount of weight gained (Field et al., 1986), length of hospitalization (Zeskind & Iacino, 1984), number of apneic and bradycardic episodes (Korner et al., 1975), and the use of general behavioral assessment scales such as APIB (Als et al., 1982)

The prenatal, perinatal, and postnatal events that are experienced by the preterm infant may shape the infant's behavioral organization in a manner that is different from that of full-term infants (Booth et al., 1980). Scarr-Salapatek and Williams (1973) have suggested that sensory processing in preterm infants differs from that of full-term infants as a function of the environment in which they find themselves. Parmelee (1976) has argued that the preterm infant's behaviors represent a "...disturbance of brain organization..." (p. 509) that may not be indicative of neurological abnormalities, but of a developmental pathway that is different from that of full-term infants. In support of this position, preterm infants have shown behaviors that are indicative of the behavior of older infants (such as increased periods of time in Quiet Sleep; Thoman et al., 1991) and also of younger infants (such as increased amounts of time in Active Sleep; Booth et al., 1980). In this study, infants who were provided a visual stimulus were more likely to increase the amount of time that they spent in Active Sleep than infants in the Control Group, although this difference did not approach significance. Paradoxical findings of apparent "maturity" (an increase in Quiet Sleep) in some behaviors and "immaturity" (an increase in Active Sleep) in other behaviors may indicate that preterm infants do not simply develop faster or slower than full-term infants, but that preterm infants have a unique developmental course that is not yet well understood.

Preterm infants need to be understood in terms of being "preterm", rather than being viewed as immature full-term infants. Als and colleagues (1982) have argued that the task for the caregiver of the preterm infant is to understand the infant's current organization, and to track the infant's development so that interventions that are sensitive and appropriate may be developed. This understanding requires that new standards of comparison be developed within the population of preterm infants, and that instruments based upon the capabilities of preterm infants be developed. In addition to long-term follow-up of infants at high risk for developmental delays, the development of these standards and instruments will depend upon long-term follow-up of healthy preterm infants (i.e., infants who are not at high risk for developmental delay, and who are, consequently, not followed long-term).

Unfortunately, follow-up assessments on the infants in this study have not been planned. This study, however, has contributed to the puzzle of preterm infant development by assessing the effects of a controlled environmental manipulation on the organization of the infants' behavioral states and visual skills. In addition, this study has also addressed the significance of low and high state stability scores and self-regulation of sensory input. Much more study is required to better understand the development of preterm infants and the features of the environment that may affect their development.

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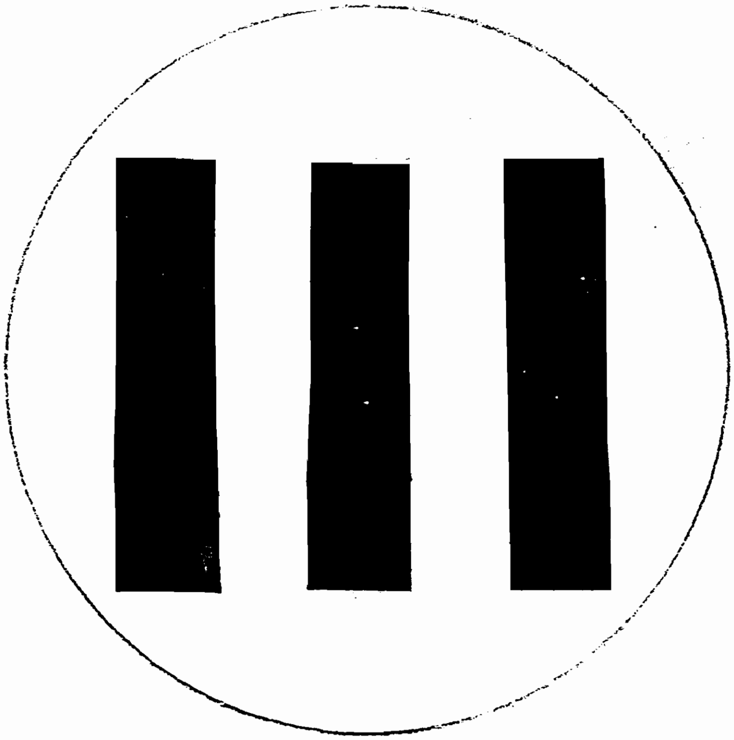
Appendix A
Visual Stimulus



Appendix B

State Scale*

Behavioral States: Behavioral states were judged on the basis of muscle tone, motor activity, respiration, eye-opening, and eye movement.

Unclassified Sleep: The infant's eyes are closed, and the infant is judged to be asleep.

Sleep-Wake Transition: The infant shows behaviors of both wakefulness and sleep. There is generalized motor activity, and although the eyes are typically closed, there may be a rapid opening and closing of the eyes. Brief fussy vocalizations may occur.

Drowse: The infant's eye are "heavy-lidded," opening and closing slowly, or open but dazed in appearance. The level of motor activity is typically low, and respiration fairly even.

Alert: The infant's eyes are alert and scanning. Motor activity is typically low, but the infant may be active.

Nonalert Waking Activity: The infant's eyes are usually open, dull, and unfocussed. Motor activity varies but is typically high. During periods of high-level activity,

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*From "Behavioral states of premature infants: Implications for neural development and behavioral development", by D.H. Davis and E.B. Thoman, 1987, Developmental Psychobiology, 20, p. 29.

the eyes may close.

Fuss or Cry: The infant is fussing or crying. The intensity of the vocalizations ranges from at least 2 brief fuss sounds to breathless crying.

Active Sleep: The infant's eyes are closed. Respiration is uneven and primarily costal in nature. Sporadic motor movements occur, but muscle tone is low between these movements. REMs occur intermittently in this state.

Quiet Sleep: The infant's eyes are closed, and respiration is relatively slow and is abdominal in nature. A tonic level of motor tone is maintained, and motor activity is limited to occasional startles, sigh sobs, or other brief discharges.

Appendix C

One Portion of APIB Package VI: Attention/Interaction*

Attention to Inanimate Object (Inanimate Visual)

Orienting Capacity (A)

Scoring

1) Does not focus on or follow stimulus
2) Stills with stimulus and brightens
3) Stills, focuses on stimulus when presented, brief following
4) Focuses on stimulus, follows for 30-degree arc, jerky movements
5) Focuses and follows with eyes horizontally and/or vertically for at least a 30-degree arc. Smooth movement, loses stimulus but finds it again
6) Follows for 30-degree arcs with eyes and head. Eye movement smooth
7) Follows with eyes and head at least 60 degrees horizontally, maybe briefly vertically, partially continuous movement, loses stimulus occasionally, head turns to follow

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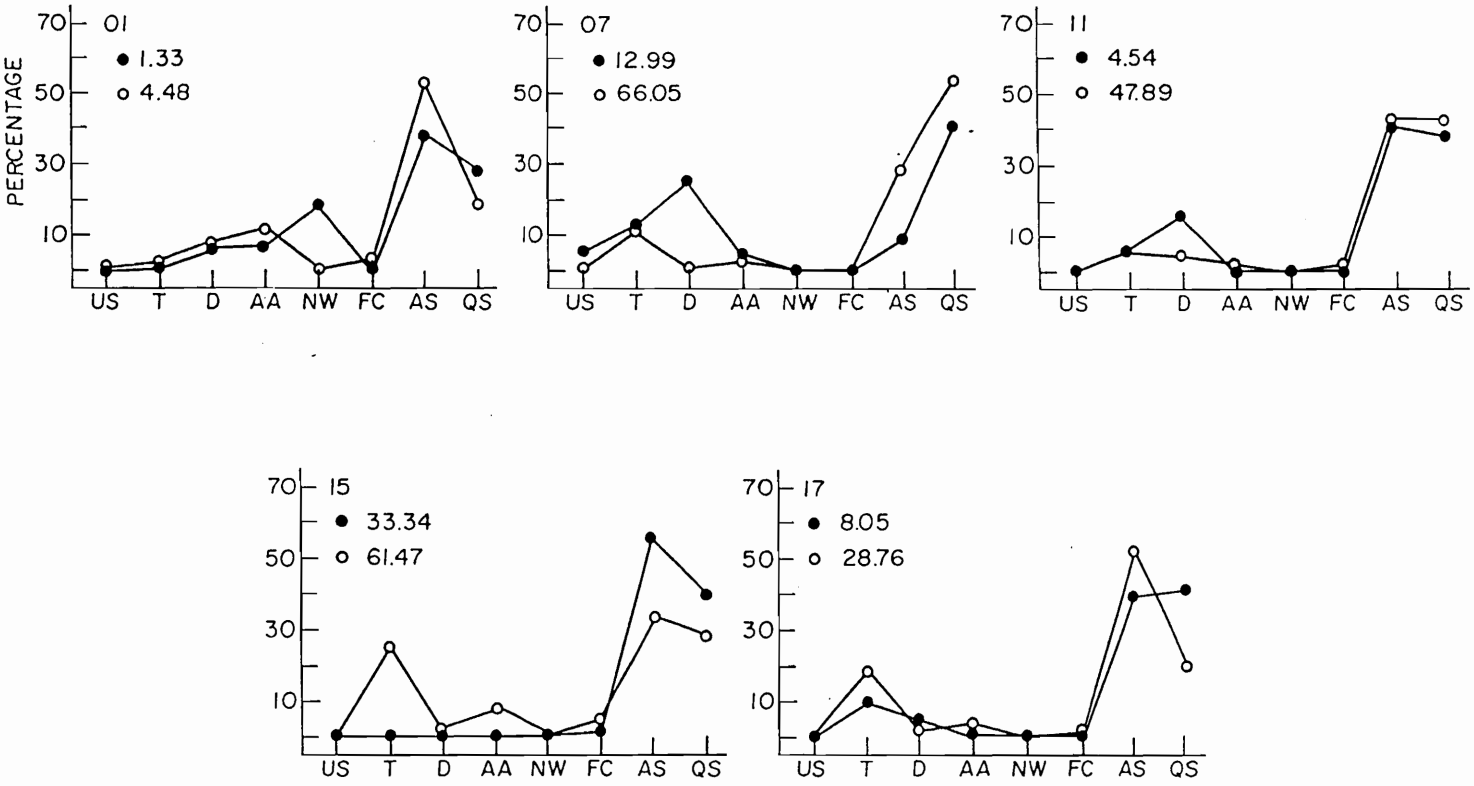
*From "Manual for the assessment of preterm infants' behavior (APIB)", by H. Als, B.M. Lester, E.Z. Tronick, and T.B. Brazelton, 1982, in H.E. Fitzgerald, B.M. Lester, & W. Michael (Eds.), _Theory and Research in Behavioral Pediatrics_ (pp. 65-132). New York: Plenum Press.

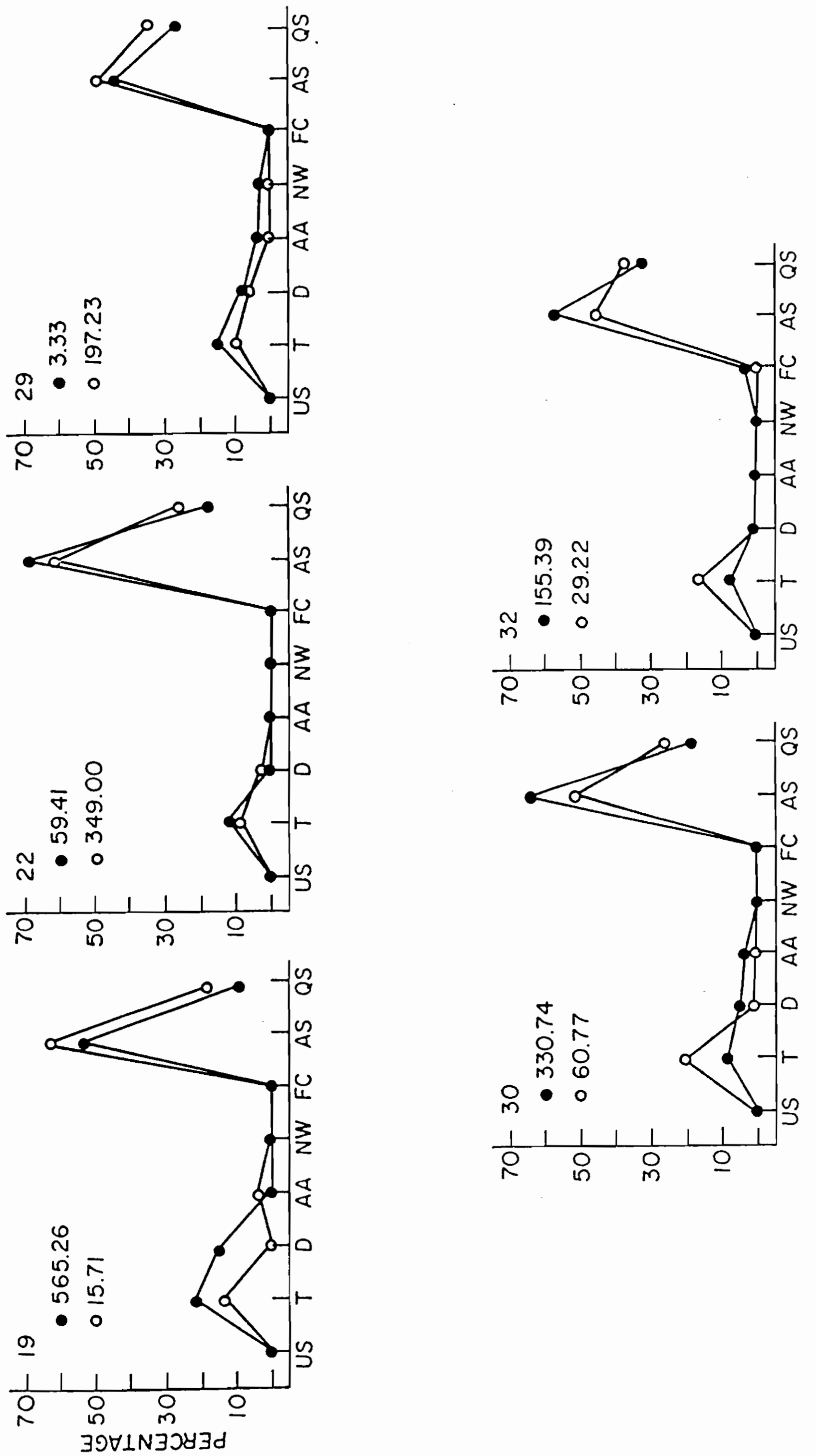
8) Follows with eyes and head at least 60 degrees horizontally and 30 degrees vertically
9) Focuses on stimulus and follows with smooth, continuous head movements horizontally, vertically, and in a circle. Follows for at least 120-degree arc

Appendix D
Profiles of Behavioral State



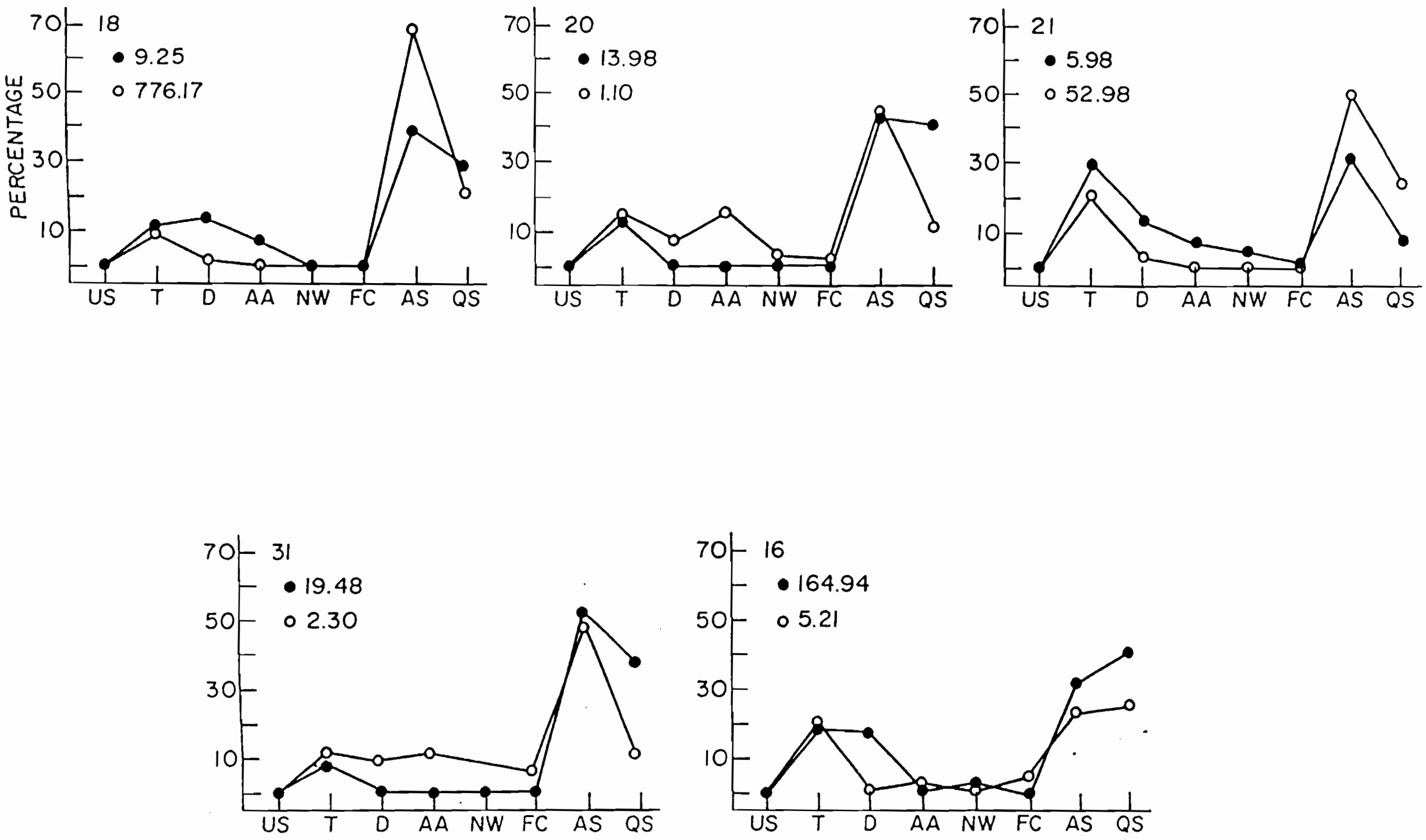
Percentages of time spent in each state by infants provided a visual pattern (the Experimental Group or Group 1) at Time 1 (●——●) and Time 2 (○——○), with corresponding state stability scores. Behavioral states are Unclassified Sleep (US), Transition (T), Drowsy (D), Active and Alert (AA), Nonalert Waking (NW), Fuss and Cry (FC), Active Sleep (AS), and Quiet Sleep (QS).

Appendix D (continued)
Profiles of Behavioral State



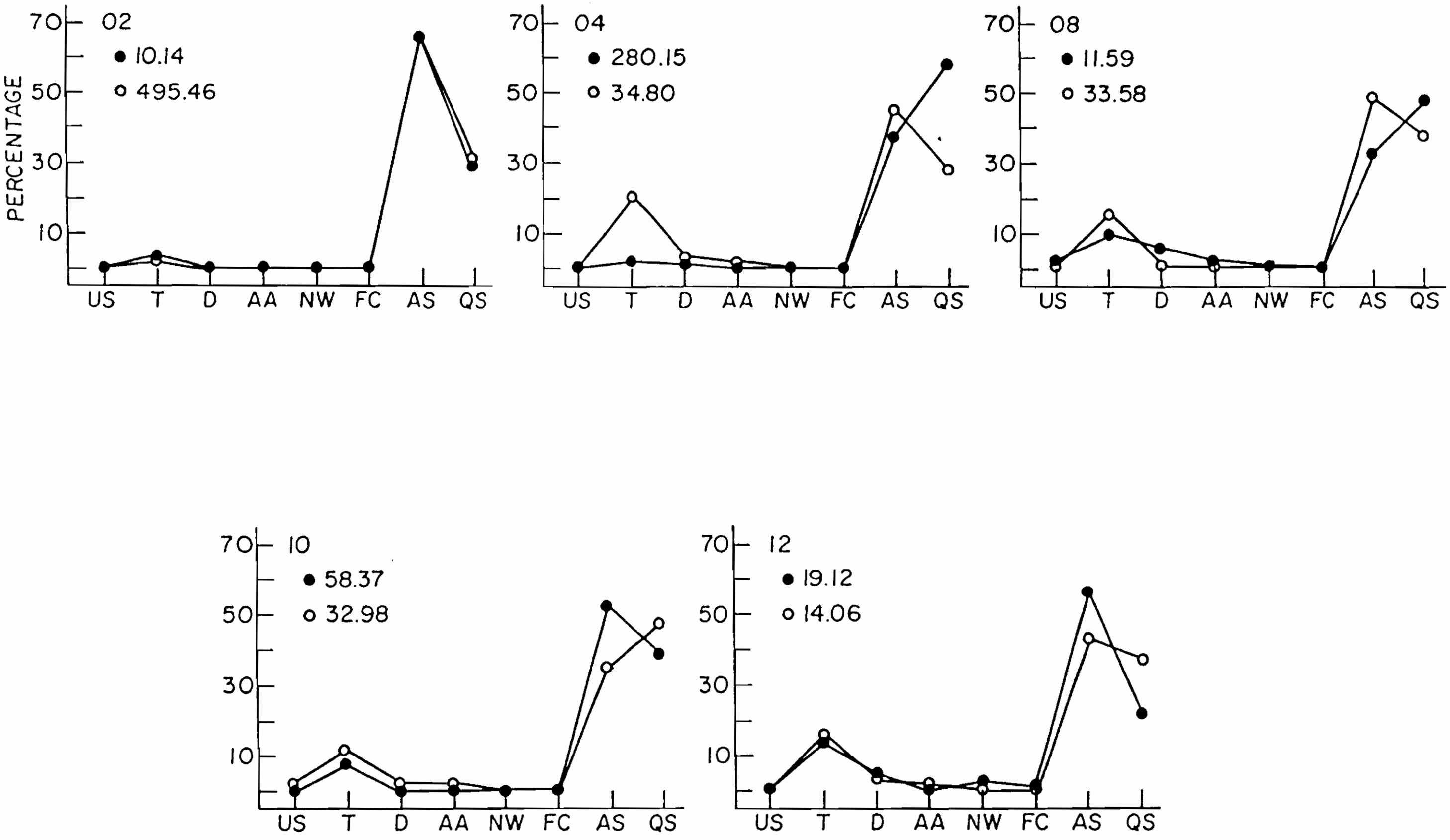
Percentages of time spent in each state by infants provided a visual pattern (the Experimental Group or Group 1) at Time 1 (●——●) and Time 2 (○——○), with corresponding state stability scores. Behavioral states are Unclassified Sleep (US), Transition (T), Drowsy (D), Active and Alert (AA), Nonalert Waking (NW), Fuss and Cry (FC), Active Sleep (AS), and Quiet Sleep (QS).

Appendix D (continued)
Profiles of Behavioral State



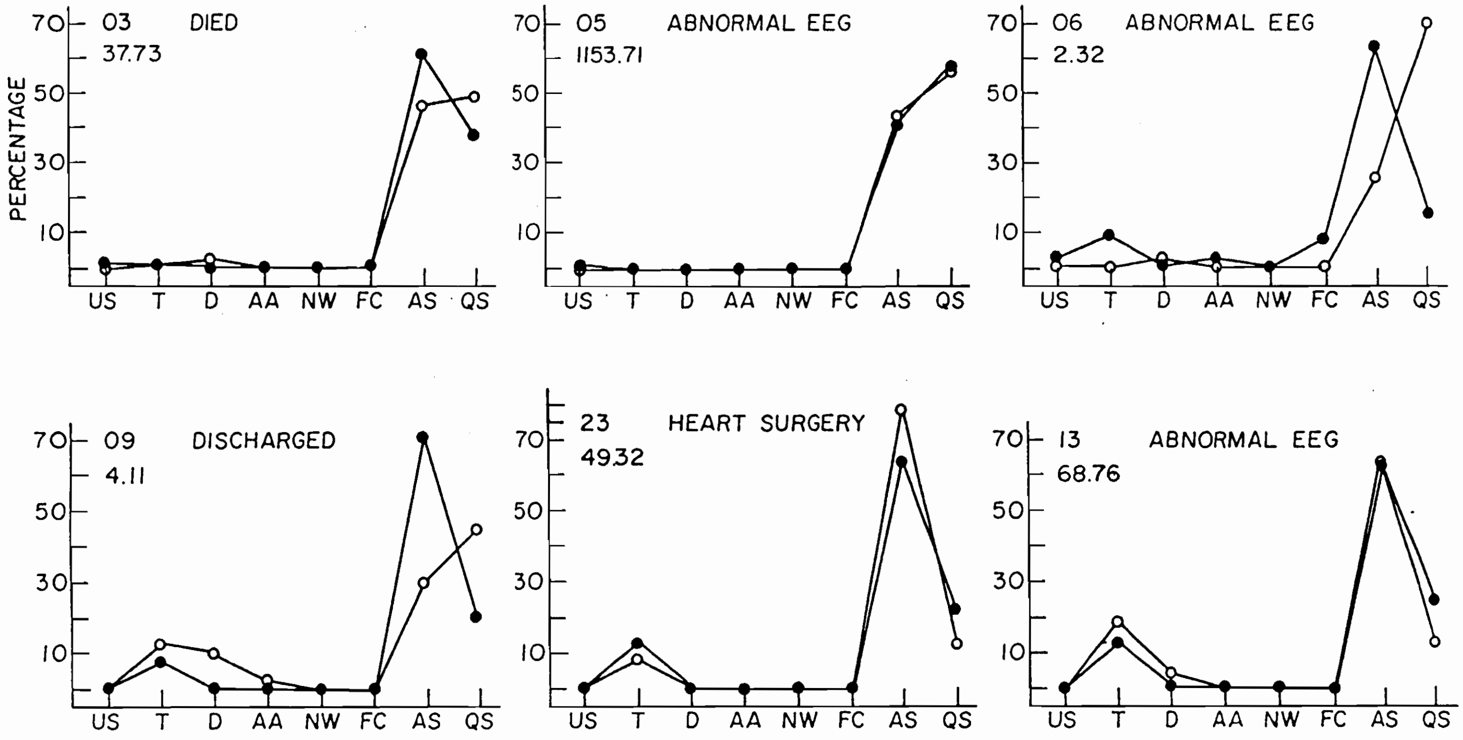
Percentages of time spent in each state by infants not provided a visual pattern (the Control Group or Group 2) at Time 1 (●——●) and Time 2 (○——○), with corresponding state stability scores. Behavioral states are Unclassified Sleep (US), Transition (T), Drowsy (D), Active and Alert (AA), Nonalert Waking (NW), Fuss and Cry (FC), Active Sleep (AS), and Quiet Sleep (QS).

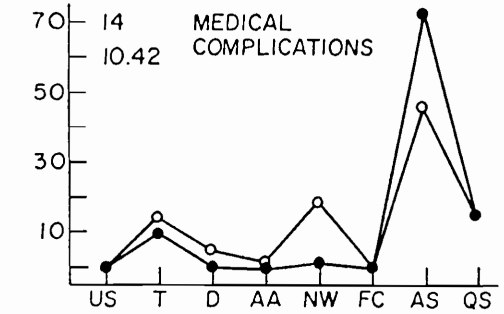
Appendix D (continued)
Profiles of Behavioral State



Percentages of time spent in each state by infants not provided a visual pattern (the Control Group or Group 2) at Time 1 (●——●) and Time 2 (○——○), with corresponding state stability scores. Behavioral states are Unclassified Sleep (US), Transition (T), Drowsy (D), Active and Alert (AA), Nonalert Waking (NW), Fuss and Cry (FC), Active Sleep (AS), and Quiet Sleep (QS).

Appendix D (continued)
Profiles of Behavioral State





Behavioral state profiles of infants who were later excluded from the study (Group 3) during the first 2-hour observation period (●—●) and the second 2-hour observation period (○—○), and the corresponding state stability score at the initial observation (Time 1).

Appendix E

Parametric Analyses

State Stability Score

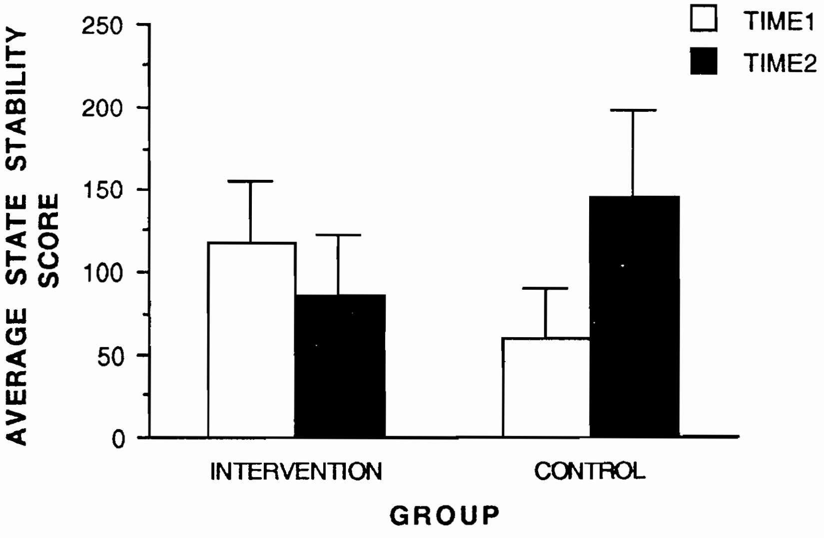
No significant main effects were revealed in the 2 (Intervention versus Control Group) by 2 (Time 1 versus Time 2) repeated measures ANOVA for group (F(1,18) = 0.00, p>.05), time (F(1,18) = 0.20, p>.05), or their interaction (F(1,18) = 0.91, p>.05). These results indicate that the state stability scores of the two groups of infants did not differ significantly at either Time 1 or Time 2.

A second 2 (Intervention versus Control Group) X 2 (Time 2 versus Time 2) repeated measures ANOVA using 18 infants (9 in each group) also did not reveal a significant main effect for group (F(1,16) = 0.09, p>.05), or time (F(1,16) = 0.20, p>.05), or in their interaction (F(1,16) = 0.04, p>.05). The results of these two analyses support my hypothesis that the state stability scores of the two groups of infants would be comparable at the beginning of the study (Hypothesis #1a), but do not support my prediction that the scores of the infants in the Intervention Group would be higher than those of infants in the Control Group at Time 2 (Hypothesis #1b).

Although the results of the first ANOVA indicated that the state stability scores of the two groups of infants did not differ statistically at Time 1, the means for the two groups were not equal (Intervention Group mean: 117.44; Control Group mean: 59.30; see Figure 10a). The standard errors reflect a large amount of variability (Intervention Group: 59.63; Control Group: 28.91; see Figure 10a) among the scores that may cause the means to fluctuate. When the two unusually high state stability scores (one in each group) were excluded from the second repeated measures ANOVA, the means again do not differ significantly between the infants at Time 1, but they also appear to be more comparable (Intervention Group: 67.69; Control Group: 64.86). Likewise, the standard errors indicate that the variability among the scores, although still large, is more similar for the two groups of infants (Intervention Group: 36.75; Control Group: 31.72; see Figure 10a). Thus, the results of this analysis indicate that the mean state stability scores of the two groups of infants did not differ significantly at the beginning of the study (Time 1).

Even though there were no significant effects, it is interesting to note that the mean state stability score in the secondary analysis increased for both group of infants at Time 2 (see Figure 10b), and that the amount of the increase was higher for infants in the Intervention Group (Time 1: 67.69; Time 2: 93.87) than for infants in the Control Group (Time 1: 64.85; Time 2: 74.72). In addition,

A) ALL SUBJECTS



B) WITHOUT OUTLIERS

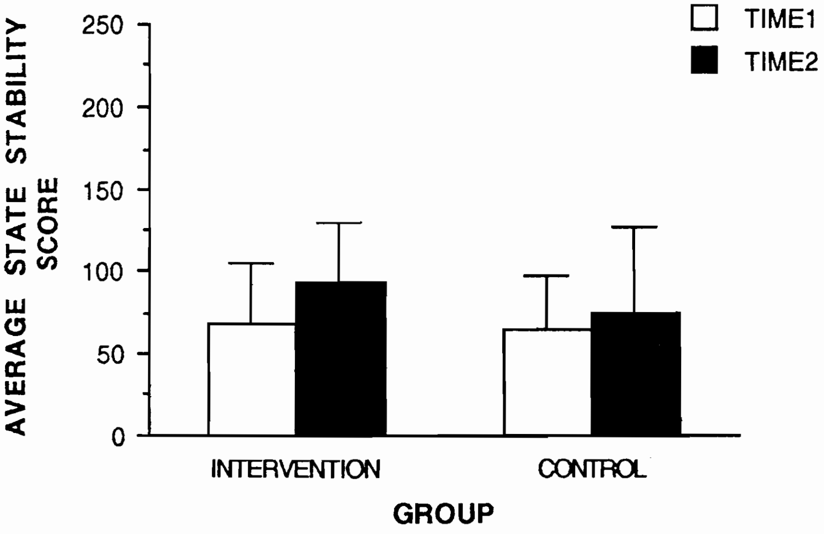


Figure 10 State Stability Scores of this Sample. Mean and standard errors of state stability scores A) for all subjects and B) for 18 subjects.

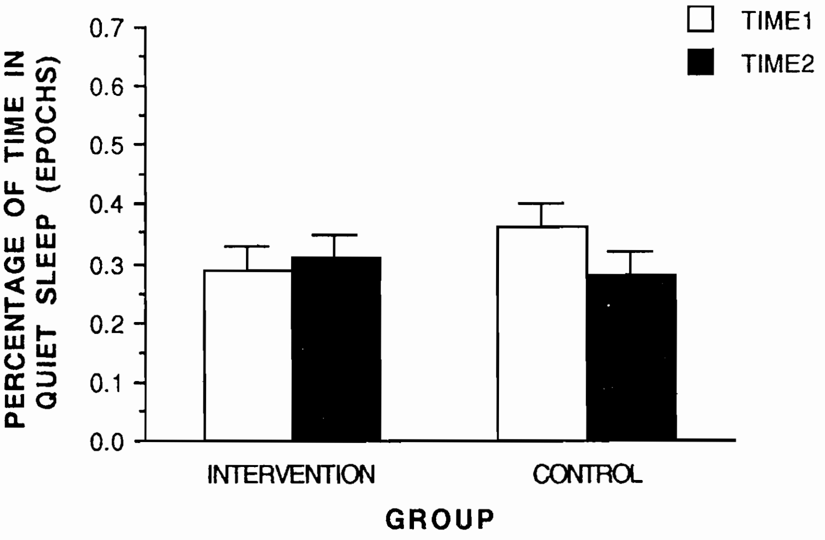
the standard error, although large, remained unchanged for infants in the Intervention Group (Time 1: 36.75; Time 2: 36.75), but increased for infants in the Control Group (Time 1: 31.72; Time 2: 52.93; see Figure 10b). This indicates that the dispersion of state stability scores was larger for infants in the Control Group than for infants in the Intervention Group at Time 2. Importantly, these differences are not statistically significant, but remain interesting because of the movement of the data in the predicted direction.

Percentage of Time in Quiet Sleep

The 2 (Intervention versus Control Group) by 2 (Time 1 versus Time 2) repeated measures ANOVA did not reveal a significant main effect for group ($F(1,18) = 0.15$, $p>.05$), time ($F(1,18) = 1.07$, $p>.05$), or their interaction ($F(1,18) = 0.04$, $p>.05$). These results indicate that the percentage of time that the two groups of infants spent in Quiet Sleep did not differ significantly at either Time 1 or Time 2 (see Figure 11a). This finding does not support my hypothesis (#2a) that the infants in the Intervention Group would spend more time in Quiet Sleep than the infants in the Control Group.

The results of the repeated measures ANOVA that excluded the two infants previously described also did not reveal a significant main effect for group ($F(1,16)= 0.01$,

A) ALL SUBJECTS



B) WITHOUT OUTLIERS

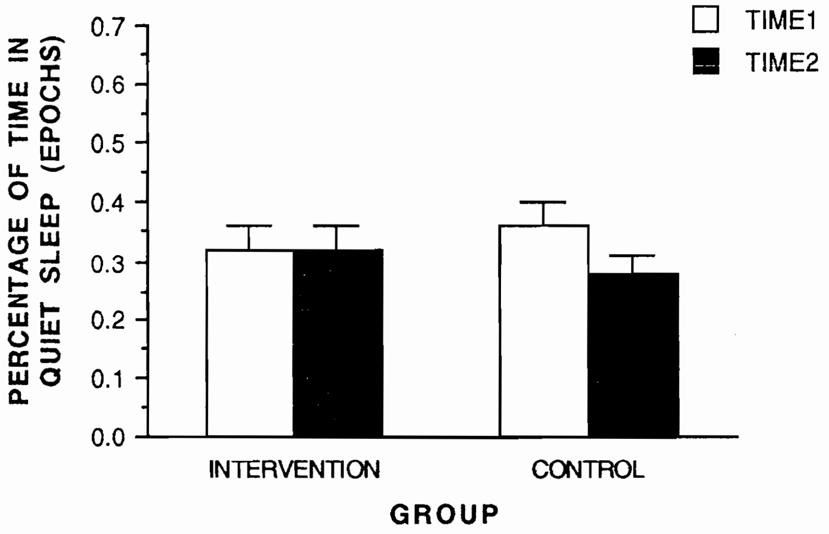


Figure 11 Quiet Sleep. Mean and standard errors of percentages of time spent in Quiet Sleep A) for all subjects and B) for 18 subjects.

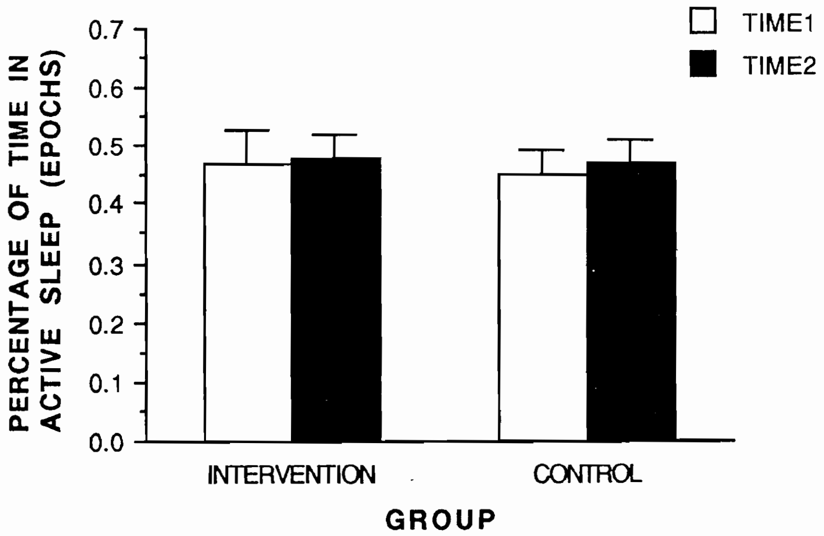
p>.05), time (F(1,16) = 1.11, p>.05), or their interaction (F(1,16) = 1.38, p>.05). These results also indicate that the percentages of time spent in a quiet sleep state were not significantly different for either group at either time (see Figure 11b).

Percentage of Time in Active Sleep

The 2 (Intervention versus Control Group) X 2 (Time 1 versus Time 2) repeated measures ANOVA did not reveal a significant main effect for group (F(1,18) = 0.08, p>.05), time (F(1,18) = 0.23, p>.05), or their interaction (F(1,18) = 0.07, p>.05). These findings did not support my prediction (Hypothesis #2b) that the infants in the Intervention Group would spend less time in an active sleep state than infants in the Control Group (see Figure 12a).

The secondary repeated measures ANOVA on 18 infants also did not reveal a significant main effect for group (F(1,16) = 0.03, p>.05), time (F(1,16) = 0.01, p>.05), or their interaction (F(1,16) = 0.00, p>.05). These findings also indicate that the percentage of time spent in Active Sleep was not significantly different between the two groups of infants at either Time 1 or Time 2 (see Figure 12b).

A) ALL SUBJECTS



B) WITHOUT OUTLIERS

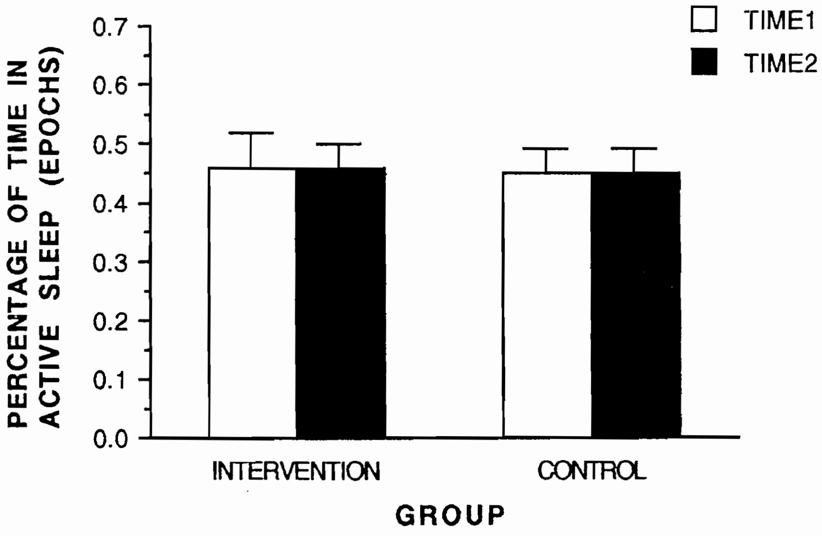


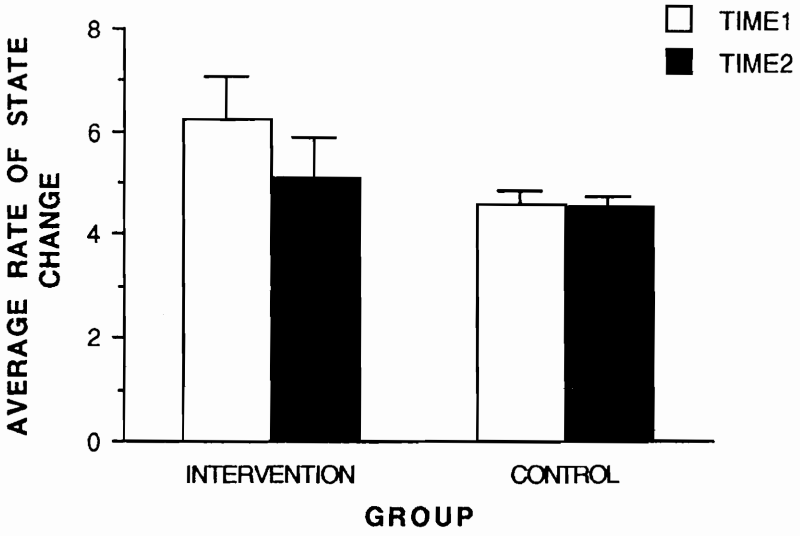
Figure 12 Active Sleep. Mean and standard errors of percentages of time spent in Active Sleep A) for all subjects and B) for 18 subjects.

Rate of State Change

The 2 (Intervention versus Control Group) X 2 (Time 1 versus Time 2) repeated measures ANOVA revealed a significant main effect for group ($F(1,18) = 5.96$, $p<.03$). This effect indicated a difference between the group means of infants in the Intervention and Control Groups that was independent of an effect of the stimulus. The higher rate of state changes for infants in the Intervention Group was unexpected. The standard errors indicate that the dispersion of the scores for infants in the Intervention Group was larger at Time 1 and Time 2 (.81 and .73, respectively) than for infants in the Control Group at Time 1 and Time 2 (.23 and .21, respectively). This large amount of variability among the rates of state change for infants in the Intervention Group may have caused the means to fluctuate; however, the reason for more variability among the rates of state changes in the infants in the Intervention Group is unknown.

Although the higher rates of state changes for infants in the Intervention Group were unexpected (see Figure 13a), it is interesting to note that the mean number of state changes decreased for infants in the Intervention Group at Time 2 (mean at Time 1: 6.24; mean at Time 2: 5.13) and remained relatively unchanged for infants in the Control Group (mean at Time 1: 4.60; mean at Time 2: 4.54; see Figure 13a). This movement of scores,

A) ALL SUBJECTS



B) WITHOUT OUTLIERS

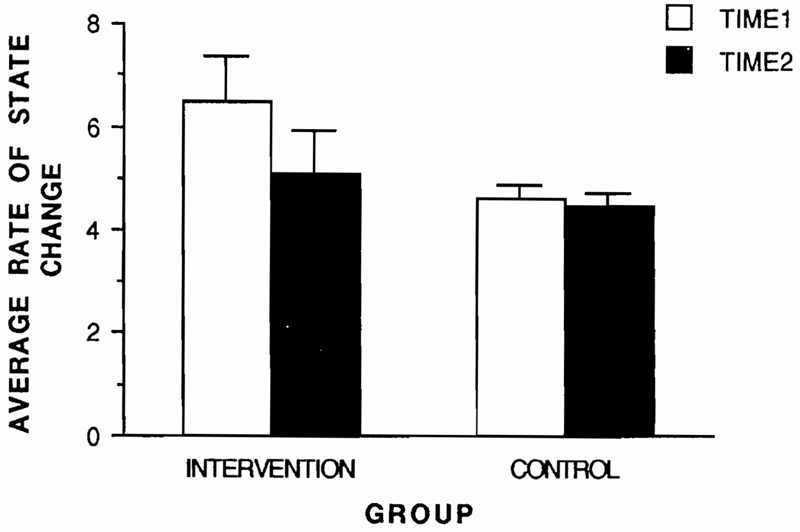


Figure 13. Rate of State Change. Mean and standard errors of the rate of state changes A) for all subjects and B) for 18 subjects.

however, may reflect the larger amount of variability in the distribution of rate of state changes for infants in the Intervention Group than for infants in the Control Group. For this decrease to be statistically significant, a main effect for time or the interaction of group by time would be revealed. This was not the case. The results of the repeated measures ANOVA did not indicate a significant main effect for either time ($F(1,18) = 0.79$, $p>.05$) or an interaction of group by time ($F(1,18) = 0.62$, $p>.05$). These results do not support my hypothesis (#3) that infants in the Intervention Group would experience fewer state changes than infants in the Control Group.

Similarly to the analysis previously reported, the results of the repeated measures ANOVA based upon the rates of state changes for 18 infants (9 in each group) also revealed a significant main effect for group ($F(1,18) = 6.33$, $p<.025$; see Figure 13b). Neither a main effect for time ($F(1,16) = 1.16$, $0>.05$) nor a significant effect of their interaction ($F(1,16) = 0.76$, $p>.05$) were revealed.

Summary

These parametric analyses of the measures of behavioral state did not reveal statistically significant differences between the two groups of infants. These unexpected results may potentially be explained by the large amount or unequal amounts of variability in the data, and by the small sample size of the study.

Appendix F

State Stability Scores of Full-term Infants**

State Stability Score	Comments*
3.09	- aplastic anemia diagnosed at 30 months
12.64	- infantile seizures at 6 months hypsarrhythmia diagnosed at 7 months severely retarded at 12 months
17.77	- died of SIDS at 3.5 months
25.22	- evidence of hyperactivity at 1 year
31.82	
31.99	- 6 month developmental quotient (DQ) of 86 30 month DQ of 76
47.09	- 6 month DQ of 83 21 month DQ of 64
47.41	
51.88	- 6 month DQ of 86 30 month DQ of 88
51.98	
58.68	
61.56	
78.49	
78.84	
83.10	
85.67	
88.67	
143.70	
160.71	
186.11	
200.00	
304.86	

*absence of comments indicates no known disorder

**From "State organization in neonates: Developmental inconsistency indicates risk for developmental dysfunction", by E.B. Thoman, V.H. Denenberg, J. Sievel, L. Zeidner, & P.T. Becker, 1981, _Neuropediatrics_, _12_, 45-54.

Appendix G

State Stability Scores for All Infants at Time 1

Group Number*	State Stability Score	Comments
1	1.33	
3	2.32	abnormal EEG
1	3.38	
3	4.11	discharged before 2nd observation
1	4.54	
2	5.98	
1	8.05	
2	9.25	
2	10.14	
2	11.59	
1	12.99	
2	13.98	
2	19.12	
2	19.48	
3	23.87	complicated medical history
1	33.34	
3	37.73	died: necrotizing enterocolitis
3	49.32	heart surgery: patent ductus arteriosus
2	58.37	
1	59.41	
3	68.76	abnormal EEG
1	155.39	
2	164.94	
2	280.15	
1	330.74	
1	565.26	
3	1153.71	abnormal EEG

*Group 1: infants in the Intervention Group
Group 2: infants in the Control Group
Group 3: infants observed only one time

Curriculum Vitae

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Education

Ph.D. Virginia Polytechnic Institute & State University, 1991
Major field of study: Developmental Psychology
Title of dissertation: *The Effect of a Visual Stimulus on Behavioral State and Visual Responsiveness in Preterm Infants*
Major Advisor: Robert Lickliter, Ph.D.

M.S. Virginia Polytechnic Institute & State University, 1986
Major field of study: Housing, Interior Design and Resource Management
Title of thesis: *Design of a Device to Provide Visual Stimulation to Infants Confined in Incubators*
Major Advisor: Jeanette E. Bowker, Ed.D.

B.A. Longwood College, 1977
Major field of study: Art; Printmaking and Graphics Concentration

Professional Experience

Spring, 1991 Adjunct Professor
Division of Social Sciences; Ferrum College
taught Learning, General Psychology, and History and Systems

1989 - 1990 Instructor
Department of Psychology; VPI & SU
taught Developmental Psychology and Principles of Psychological Research

Spring, 1989 Graduate Teaching Assistant

	Department of Psychology; VPI & SU taught Personality Psychology Laboratory
Fall, 1988	Graduate Teaching Assistant Department of Psychology; VPI & SU taught Cognitive Psychology Laboratory
1986 - 88	Graduate Teaching Assistant Department of Psychology; VPI & SU research and classroom responsibilities taught Introductory Psychology Laboratory, 1987
1985 - 86	Interior Designer Office of University Planning; VPI & SU design, selection and ordering of interior finishes and furnishings, presentations to clients, illustrations, and specs
1984 - 85	Graduate Teaching Assistant Housing, Interior Design, and Resource Management; VPI & SU research and classroom responsibilities

Professional Affiliations

Member, Society for Research in Child Development
Member, American Psychological Society
Member, American Society of Interior Designers

Honor Societies

Omicron Nu
Phi Kappa Phi
Phi Upsilon Omicron

Grants and Awards

Certificate for Performance as a Graduate Teaching Assistant; Graduate School, VPI & SU; 1990.

Academic Fellow, Commonwealth Fellows Program, Council of Higher Education Fellowship, State of Virginia; $5,000, 1988.

Graduate Research Development Project; VPI & SU. (Evaluating effects of visual stimulation on preterm infants), $300, 1985.

Housing, Interior Design, and Resource Management Faculty Scholarship; VPI & SU, 1985.

State Graduate Scholarship; VPI & SU, 1984; 1985.

Publications

Marshall-Baker, A., Field, T.M., & Roberts, J. (in preparation). Infant incubators: A critique by NICU staff members.

Marshall-Baker, A., Zeskind, P.S., Berman, S. & Casali, J.G., (in preparation). Cardiac and behavioral responsivity in preterm infants to changes in the sound pressure level during routine care inside infant incubators.

Marshall-Baker, A., Zeskind, P.S., & Bowker, J.E. (in preparation). Responses of preterm infants to controlled visual stimulation.

Presentations and Papers

Marshall-Baker, A. & Zeskind, P.S. The Effects of a Visual Stimulus on Behavioral State and Visual Responsiveness in Preterm Infants. Poster to be presented to the International Conference of Infant Studies, Miami, Fla. May, 1992.

Marshall-Baker, A., Field, T.M., & Roberts, J. Design Criteria for Incubator Design. Poster presented to the Conference on Human Development, Richmond, Va. March, 1990.

Marshall-Baker, A. Biomechanics Associated with Incubator Design. Paper presented to the 6th Virginia Developmental Forum, Norfolk, Va. November, 1989.

Marshall-Baker, A. & Zeskind, P.S. Three perspectives of NICU and incubator design. Paper presented to the 5th Virginia Developmental Forum, Ashland, Va. November, 1988.

Marshall-Baker, A. & Zeskind, P.S. Responses of preterm infants to controlled visual stimulation. Poster presented to the Conference on Human Development, Charleston, S.C. March, 1988.

Marshall-Baker, A. & Zeskind, P.S. Assessment of preterm infant responses to stationary and nonstationary visual stimulation. Poster presented to the 4th Virginia Developmental Forum, Charlottesville, Va. October, 1986.

Bowker, J.E. & Marshall-Baker, A. History where it happened. Poster presented to the Regional Interior Designer Educator's Council, Charlotte, N.C. September, 1984.

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