

HOLDING AND ROCKING THE FULL-TERM NEONATE:
THE IMMEDIATE AND RESIDUAL EFFECTS ON BEHAVIORAL STATE
AND HEART RATE

By Timothy R. Marshall

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Committee members:

Philip Sanford Zeskind, Chairperson

David W. Harrison

Golde I. Holtzman

Robert Lickliter

Albert W. Prestrude

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(ABSTRACT)

This study explored infants' immediate and residual responses to holding and rocking, and how these responses relate to previously proposed mechanisms to explain long term benefits found when infants are repeatedly exposed to tactile and vestibular stimulation. This form of stimulation has been proposed to increase infants' ability to control and organize 1) their behavioral state, 2) their arousal and autonomic functioning, or 3) that there is no clear relationship between immediate responses and long term benefits.

Behavioral state and heart rate were collected on 40 infants who were randomly assigned to either a control group where infants were briefly repositioned twice but otherwise lay undisturbed for 90 minutes or an experimental group where infants were held and rocked for 30 minutes during the middle of a 90 minute observation. Results of analyses showed that, when infants were held and rocked they 1) displayed a lower Heart Rate Mean and Standard Deviation, 2) displayed a lower Mean Heart Rate During Active Sleep, 3) spent less time in a Fuss-Cry State, 3) were less likely to cry continuously, and 4) displayed nominally Smoother State Transitions and greater Stability Within

States. Following the cessation of the rocking stimulus infants in the Experimental Group 1) displayed a lower Mean Heart Rate, 2) displayed a lower Mean Heart Rate while in a Quiet Alert State, 3) were more likely to spend some time in a Quiet Sleep State, and 4) were less likely to cry continuously. In addition, all infants displayed Smoother State Transitions, and greater Stability Within States during the first 30 minutes than during the final 30 minutes of the observation. Finally, across the 90 minute observation the infants who were not rocked spent progressively more time in a Quiet Alert State, whereas infants who were rocked spent less time in a Quiet Alert State. The results were the most consistent with the hypothesis that the mechanism leading to both the immediate and residual effects of the stimulation was an increase in control and organization of infants' arousal and autonomic functioning.

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INTRODUCTION

First time parents rapidly discover the calming effects of rocking their crying newborn. Picking-up and placing an infant to the shoulder, then gently swaying back and forth in a rocking motion is a time honored method of quieting a crying child (Bowlby, 1969). These parental actions stimulate a variety of sensory systems within the infant including: the vestibular system (detecting the position and motion of their head relative to gravity and acceleration), the proprioceptive system (information about the relative position of their body segments to one another and about the position of their body in space), the tactile system (detecting the sensation of touch), the visual system, (the changing view from the change in position), the auditory system (sounds produced by the parent), the olfactory system (the smell of the adult) and the thermoregulatory system (through body warmth). Studies with human infants (Brackbill, 1971; Korner & Thoman, 1970, 1972) and comparative studies with other species (Hofer, 1984) show that activating these sensory systems has the ability to alter infants' behavior and physiology. For example, Korner (Korner, 1964; Korner & Thoman, 1970, 1972) has shown that vestibular and proprioceptive stimulation brought about by a rocking motion is particularly potent at quieting an infant and bringing the child to a state of quiet alert or to a sleep state.

Besides these immediate responses to stimulation, research on full term and preterm human infants shows that repeated or continuous exposure to a rocking motion has long term effects on behavioral state development (Barnard, 1973; Barnard & Bee, 1983; Burns, Deddish, Burns &

Hatcher, 1983; Edelman, Kraemer & Korner, 1982; Korner, Ruppel & Rho, 1982; Korner, Schneider, & Forrest, 1983), motor development (Clark, Kreutzberg, & Chee, 1977; Burns, et al., 1983), and intellectual development (Barnard, 1987). Exactly how rocking an infant has such a wide impact on a child's development is still speculative. However, some suggest that effective stimulation or intervention acts with the infant's internal systems to regulate and organize either a specific physiologic or behavioral system or a group of systems. These changes then lead to some form of change in the central nervous system. The altered central nervous system then feeds back to affect other internal and external systems and augments the infant's long term development (Als, Tronick & Brazelton, 1979; Brazelton, 1984a).

Barnard (1987) and Horowitz (1987) have suggested that during the preterm and newborn periods of human development effective stimulation or intervention programs function through regulating and organizing behavioral states. These changes in the organization of behavioral states then provide the base for changes in the newborn's physiology. Alternatively, comparative studies with isolate-reared animals suggest that maternal stimulation, including tactile, vestibular and proprioceptive stimulation, plays an essential role in regulating an infant's physiological arousal (Mason, 1970, 1979; Levine & Stanton, 1984). These changes then provide the base for changes in the infant's sleep and wake patterns. A similar mechanism is suggested for human infants (Levine & Stanton, 1984).

Regardless of whether the primary mechanism of change is the organization of behavioral states or physiologic arousal, it seems likely that both physiologic arousal and behavioral state are somehow being altered by stimulation to bring about long-term changes. Yet the actual pattern of organization or regulation occurring within these human systems is largely unspecified. One avenue for examining the form of regulation and organization occurring as a result of a rocking is provided by examining the infant's immediate response to stimulation. However, as Hofer (1984) points out, the infant's acute or immediate response pattern may be entirely independent of their long term response. Thus, not only are the immediate responses to stimulation important, but the infant's response patterns, once the stimulation is removed, are informative for identifying organizational changes occurring within the infant.

The purpose of the current study was to examine the regulating and organizing effects brought about by the normal caregiving action of picking up and gently rocking newborn infants. Previous studies show that both the behavioral state and indices of autonomic functioning of the infant display an immediate response this form of stimulation. Longer term studies have also found that repeated or continuous rocking stimulation affects the development of infants' behavioral state. In addition, both changes in physiology and behavioral state may be important for regulating and organizing other systems within developing infants. Therefore the current study examined newborns' immediate

physiological and behavioral state responses to being held and rocked, and the infant's residual response once the stimulation was removed.

Before developing specific hypotheses with regard to the immediate and residual effects of picking up and rocking newborns the following sections will be reviewed: 1) how much holding and rocking a healthy newborn receive in a typical caregiving environment; 2) what is currently known about both immediate and long term effects of providing infants with rocking; 3) the mechanisms by which various models describe how stimulation changes behavior and physiology; and 4) what is the relationship between the immediate and long term effects of rocking stimulation?

Typical Stimulation

For most children, being born in a western "civilized" culture means spending much of the first year of life cached away in a crib, lying undisturbed for long periods of time (Kennell & Klaus, 1983). Experience with this system of early child care begins soon after birth. Standard nursery procedures allow infants to lie undisturbed for as long as four hours between scheduled feedings. This caching system follows children into their parents' home. Parents may pick up a newborn only when he or she cries or when the parents feel it is time for the child to be fed or have the diaper changed. As a result, in the United States parents hold or touch infants less than 33 percent of the day time hours during the first three months of life (around 5 hours) and only 16 percent of the day by nine months. In comparison, mothers in the rural

areas of Guatemala, Bolivia and Peru carry or hold by their infants 80 to 90 percent of the day during the first three months (12 to 14 hours) and 60 percent of the day at nine months (Kennell & Klaus, 1983).

The caching system of early child care experienced in the United States from birth onward is in sharp contrast to the conditions in utero where the fetus is constantly exposed to tactile, vestibular and proprioceptive stimulation brought about by the mother's daily activities and the functioning of her internal organs. In addition, however prevalent the caching system of early child care is today, it may be only a recent development in the history of our species. Mason (1979) has suggested that for almost all our species' existence, human infants were probably carried and nursed often, much like the pattern seen in the subsistence farming communities of Central America.

The effects of changing our system of early child care from one of carrying infants to one of caching infants have gone largely unexplored until recently. As pointed out by both Parmelee (1979) and Kennell and Klaus (1983), we still do not understand what effect these changes have had and continue to have on infant development or on maternal involvement. However, three areas of research provide information on the short and long term effects of our current system of child care. These research areas include the comparative literature in which manipulations alters the amount of movement stimulation an infant animal receives, clinical observations in which the amount and type of movement stimulation children "at risk" receive are recorded, and infant studies

in which increased movement stimulation is added to a child's routine care.

Comparative literature

Harlow (1958) was one of the first to note that baby primates isolated from their mothers soon after birth displayed aberrant behaviors similar to institutionalized human infants. Isolated baby rhesus monkeys spend much of their time huddled in a corner of their cage, clutching their own body and rocking back and forth. This occurred even if the monkeys were raised in open cages where they could see, smell, hear and even reach through the cage and touch other conspecifics. Baby monkeys provided with the contact comfort of a terry cloth covered "surrogate" did not display as extreme behavior as the completely isolate-reared monkeys, though all aspects of their social behavior remained severely affected (Harlow, 1958).

Mason (1979) and Mason and Berkson (1975) found that the most severe "autistic" like deficits could be further offset by providing the monkeys with a swinging or rocking terry cloth covered surrogate. This moving surrogate moved unpredictably up and down and around the cage. The moving surrogate raised monkeys displayed fewer self-rocking and huddling behaviors. At 2 years of age these monkeys were more visually explorative than other isolate reared monkeys. By 4 years of age the monkeys raised with the mobile surrogate showed more adequate sexual performance than those raised with stationary devices; although neither group's sexual behavior would be considered normal.

The importance of vestibular-proprioceptive stimulation has also been shown in other animals, most notably rats. For example, Thoman and Korner (1971) found that rats exposed to swaddling and rotation on a small drum decreased their activity and distress calls during the stimulation. In addition, the pups exposed to this type of stimulation had a higher percentage of early eye openings. At six days following the end of a repeated exposure to swaddling and rotation, pups were more explorative on a visual cliff test, and at weaning the pups were significantly heavier than pup not exposed to the stimulation.

Specific aspects of the maternal-infant interaction have also been shown to be associated with specific deficits in infant development. Hofer (1984) notes that infant primates and rats isolated from conspecifics show a predictable pattern of increased activity, heart rate and endocrine activity within the first few hours of isolation. These immediate responses are followed by long term decreased activity, heart rate and endocrine activity. Hofer suggests that these immediate and long term effects are the result of removing specific aspects of the normal maternal-infant interaction. For example, in rats, tactile stimulation has specifically been shown to decrease activity levels, nonnutrive sucking, and physiologic arousals, while increasing ornithine decarboxylase release (a limiting enzyme important for growth), REM sleep, and growth hormone release. Body warmth increases activity levels and increases the release of norepinephrine and dopamine. Whereas, the periodicity of maternal activity increases REM sleep and decreases physiologic arousals (Hofer, 1984). Hofer contends that the

reason we find many of these changes occurring together is that the stimulation we provide generally includes multiple regulators. In other words, when infants are held and rocked that stimulation includes tactile, vestibular, thermoregulatory and periodic components. Thus, a variety of maternal behaviors are part of the "hidden" processes of normal early social relationships that provide the infant with stimuli needed to regulate and organize their own behavior and physiology.

These studies seem to point to the fundamental importance of body contact, holding and movement stimulation for normal early development. All the old-world primates develop aberrant behaviors when reared in isolation (Reite & Short, 1983). Mason (1979) argues that if nonhuman primates were exposed to the lengthy caching behavior found in our species, they would develop more behavioral deficits than is evident in our species. Therefore Mason argues that because relatively few of our offspring develop aberrant behavior in comparison to societies where children are routinely carried, the human organism must be somehow buffered or more tolerant of variations in rearing conditions than other primates. Yet, stereotyped self-rocking and other aberrant behaviors do develop in some otherwise healthy human infants. Mason (1979) has suggested that this may reflect an individual difference in the tolerance for the lack of infant-caregiver contact found in our culture.

Infant clinical studies

Rene Spitz (Spitz, 1945; Spitz & Wolff, 1946) was one of the first to point out that some aspects of the caregiver-infant relationship are critically important for normal infant development. Spitz found that children raised in settings not allowing adequate mother-child interactions or surrogate mother-child interactions with nursing staff developed what he called "anaclitic depression" characterized by a general sadness and failure to thrive in all aspects of development. The children who remain in these settings had a very poor long-term prognoses. Many died early in life. Those that survived were mentally and physically retarded and develop self stimulatory behaviors such as huddling, self-clasping and self-rocking. However, if adequate mother-infant interactions was begun infants made dramatic and clearly discernable behavioral changes, returning to a more normal development.

Since Spitz's pioneering work, several researchers have found evidence that aberrant patterns of caregiver-infant holding and rocking are related to an increased risk for other types of psychopathology. For example, Massie (1977, 1978, 1982) found that some children who later develop symbiotic psychoses of childhood had mothers who avoided holding and rocking their children with normal close chest-to-chest contact. Massie hypothesized that these parents are unable to provide the tactile, vestibular and kinesthetic stimulation necessary for soothing their distressed child, and hence the child is unable to use the caregiver as a means of reestablishing homeostasis and anxiety reduction.

In another study, Fivaz, Martin and Cornut-Zimmer (1984) noted a different pattern of caregiver-infant holding interactions in postpartum decompensated families. Both the mothers and fathers in these families hold their infants with an unusual postural and location position in relation to parent's trunk and head. Fivaz suggests that these abnormal postural and location positionings are part of the fabric or context that places developing infants at greater risk for later psychopathology. These children are receiving abnormal tactile, kinesthetic, and vestibular stimulation along with decreased gaze interactions with their parents.

Thoman, Acebo, Dryer, Becker, and Freese (1979) have also reported on a case study in which the caregiver and the infant were asynchronous in many of their interaction patterns, particularly in the pattern of eye gaze, holding, and touching. This asynchrony reflected a lack of soothing techniques, talking, rocking and establishing eye contact while the infant was crying. At one year following birth this child displayed lower scores on the Mental Development Index, with the personality-social sub-scale being markedly lower. Although Thoman did not suggest a causal relationship between the abnormal interaction patterns and later deficits, she does suggest that this abnormal interaction pattern was part of the fabric of aberrant child development.

Finally, in a case study, Bennett (1971) described a male infant who was difficult to alert and would quickly become agitated with stimulation. By 3 weeks, this infant displayed a general irritability, cried often, and showed slow developmental progress. The nursing staff

found this child difficult to calm and when held the child would often stiffen his trunk and extremities. Bennett noted that the nursing staff attached decidedly negative attributes to the child. Bennett suggested that these negative attributes are the first step in a chain of events that could lead to child abuse. Bennett intervened by holding and gently rocking the infant for a one hour period every day for one week. With rocking, this infant became less tense when held, acquiring a more positive affect, increased sustained periods of wakefulness without crying, and was easier to engage visually. Although the nursing staff continually questioned whether such special care would spoil the child, they attached progressively less negative and more neutral attributes to the child.

Infant experimental studies

Kennell and Klaus (1983) noted that babies in cultures where infants are carried tend to cry less frequently than babies in industrialized countries. This phenomenon was originally attributed to the poor nutrition found in these countries, but many of these infants are healthy, active and responsive and still do not cry often (Barnard & Kennell, 1979). Thus, the frequency of crying seen in infants raised in our culture may be a development brought about by our child care practices. Several studies examining the effects of rocking infants serve to support this view. For example, Gordon and Foss (1966) reported that 30 minutes of rocking, in the form of swinging a bassinet, inhibited crying in healthy fullterm neonates, and Birns, Blank and

Bridger (1966) demonstrated that rocking was effective in reducing crying in neonates.

Korner (Korner, 1964; Korner & Grobstein, 1966) has also noted that when crying infants are picked up to the shoulder, they not only stopped crying but frequently became visually alert. Korner and her coworkers explored this calming effect by examining various forms of stimulation which result from picking up and holding infants. She found that vestibular-proprioceptive stimulation was the most effective in soothing and alerting infants (Gregg, Haffner, & Korner, 1976; Korner & Thoman, 1970, 1972). Partially as a result of these findings, Korner (Korner, Kraemer, Haffner, & Cospers, 1975) argued that providing preterm infants with additional vestibular-proprioceptive stimulation would provide a compensatory environment to promote infant development. Consequently, preterm infants placed on continuous gently oscillating waterbeds were found to display significant increases in sustained quiet sleep and active sleep episodes, decreases in the number of state changes, decreases in episodes of fussing and crying (Edelman, et al., 1982; Korner, et al., 1982; Korner, et al., 1983), and reduced severe apnea where there is a slowing of the heart rate (Korner, Guilleminaut, Van de Hoed, & Baldwin, 1978; Korner, et al., 1975). In addition, compared with infants placed on traditional nonoscillating incubator beds, preterm infants who remained on waterbeds for four weeks displayed more developmental progress in motoric and state organization as measured by the Neonatal Behavioral Assessment Scale (NBAS) (Burns, et al., 1983). However, not all studies of preterm infants have found

differences in the distribution of behavioral states as a result of the infants' exposure to waterbeds (Burns, et al., 1983). This may reflect small sample sizes or different subject selection criteria. Korner (1981) has noted that some severely stressed preterm infants do not benefit from being placed on waterbeds and are further stressed by the oscillations from the waterbed.

Barnard (1973) has also reported that presenting preterm infants with vestibular-proprioceptive and auditory stimulation has the immediate effect of reducing the infants' level of motoric activity, increasing time in quiet sleep, and increasing weight gain. These differences were noted when infants were exposed to a gently rocking bed while a heart beat tone was fed into their incubator. Barnard and Bee (1983) replicated and expanded on the original study finding that preterm infants exposed to various schedules of vestibular-proprioceptive stimulation display the immediate response of decreased activity and shorter activity cycles. In addition, preterm infants displayed a greater range of states as measured by the NBAS at 34 weeks conceptional age. At 34 weeks conceptional age all children were still receiving stimulation from the rocking bed, although during the administration of the NBAS the infants were not being exposed to the rocking bed stimulus. Longer term effects were also found in the days and weeks following the cessation of the treatment. At discharge from the hospital, treatment infants displayed fewer abnormal reflexes and better orientation to auditory and visual stimuli as measured by the NBAS. Follow-up data revealed that at 2 years post-treatment, the

children originally in the experimental groups exceeded the control group children in mental development as measured by the Bayley Mental Development Index (MDI). In addition, two-year-olds who had been exposed to the experimental procedures scored higher on two subscales from a modified version of the HOME (Home Observation for Measurement of the Environment) Inventory: the organization of the environment by the mother, and the variety of daily stimulation the infant received. Barnard (1987) reported that eight-year follow-up data indicate that the children from the experimental groups continued to be reliably different, scoring higher on the Wechsler Intelligence Scale for Children (WISC) and the Beery test of visual-motor integration. In summary, Barnard found that the immediate effect of exposing infants to rocking stimulation is a reduction in motoric activity levels and increased quiet states. In addition, long-term effects from exposure to this form of stimulation included reduced abnormal reflexes, increased orienting abilities, increased Bayley MDI scores and WISC scores, and alterations in the home environment.

Clark and his associates (1977) have also reported long-term effects of vestibular-proprioceptive stimulation, but in seven month old preambulatory children exposed to a markedly different form of stimulation. Clark exposed infants to semicircular canal vestibular stimulation in the form of infants being held in the experimenters lap in a dark room while the experimenter spun in a chair. These infants displayed improved motor skills and reflexive functioning after 16 sessions stimulation delivered over 4 weeks.

In contrast to the above studies, other studies have not found positive effects of providing stimulation. For example, Koniak-Griffin and Ludington-Hoe (1987) examined full-term healthy newborns who received palm stroking stimulation, multimodal stimulation from a commercially-available hammock, or both forms of stimulation. The multimodal stimulation provided the infant with tactile stimulation from a synthetic sheepskin, and auditory and mild vestibular stimulation created from a battery-operated heart device tucked under the hammock. At the end of a one month treatment period during which parents placed infants in the hammock whenever the infant slept, the NBAS and the Neonatal Perception Inventory (NPI) were administered and weight gain was assessed. Treatment infants showed less mature orienting, motor and state regulation than did the control group. In addition, weight gain was not enhanced and the number of hours the infant spent awake, asleep or crying did not significantly differ according to maternal reports. There was, however, a positive correlation between the number of hours infants spent sleeping on the multisensory hammock and favorable maternal perceptions of infants' behavior as measured by the NPI.

Koniak-Griffin and Ludington-Hoe suggest that the tactile and multisensory stimulation provided a soothing effect on infants and thereby decreased the infants' ability to interact with the external environment. They go on to argue that although this form of stimulation may be desirable in preterm infants who have less mature nervous systems and may need the organization the stimuli produce, this stimulation produces adverse effects for the healthy full-term infant who may be

physiologically prepared to interact with the external environment. Thus, soothing healthy full-term infants rather than alerting infants may produce adverse neurobehavioral effects.

Interestingly, Koniak-Griffin and Ludington-Hoe's own data are not entirely consistent with their hypothesis. If the multistimulus hammock was soothing enough to decrease an infant's ability to interact with the environment, it is somewhat surprising that there was not a corresponding increase in quiet states and a decrease in alert states. Because this finding was based on parental reports it is possible the procedure may have obscured the effects on state. Other studies have reported that gently rocking beds and waterbeds do appear to increase quiet states and decrease active states in preterm infants (Barnard, 1973; Edelman, et al., 1982; Korner, et al., 1982; Korner, et al., 1983).

Another potentially interesting measure related to Koniak-Griffin and Ludington-Hoe arguments would have been generated by examining how much parental interaction and parental holding the infants in each group were receiving. If the stimulation treatment groups were being soothed by the stimuli then possibly there would be a reduction in the amount of time parents used other forms of stimulation to sooth the infant. The treatment procedure might actually be decreasing infant tactile and vestibular-proprioceptive stimulation through a decrease in parental holding and rocking.

With the exception noted above, most studies exploring the long term changes produced by rocking stimulation have found beneficial long

term changes. However, what brings about these long term changes is less clear. Pederson and Ter Vrugt (Pederson, 1975; Pederson & Ter Vrugt, 1973; Ter Vrugt & Pederson, 1973) report that the greater the acceleration of the rocking stimulation the more potent the soothing effects were on agitated infants. Increased acceleration can be produced by a more rapid rocking frequency or a greater amplitude of the rocking motion. Five minutes following the end of the rocking, treatment infants were still reliably less agitated than infants who had not received the rocking stimulation. However, within ten minutes following the end of the stimulation, the infants had returned to their baseline levels of agitation. Fifteen minutes following the cessation of the rocking, infants were exhibiting slightly higher, although not reliably different, states of agitation. Thus, either the residual effects of this form of stimulation had worn off within 10 minutes, or the measures used were not sensitive enough to the residual effects. Interestingly, in the Pederson and Ter Vrugt studies the soothing effects of less intense stimulation was dependent on the infant's initial state. This was not true, however, for higher acceleration rates of rocking. In other words, the greater the infant's agitation before stimulation, the greater the acceleration had to be in order to bring the infant to a quiet state.

Other studies have also reported that infants are differentially responsive, depending upon infants' behavioral state (Pomerleau & Malcuit, 1981; Rose, Schmidt, Riese, & Bridger, 1980). Rose, and her associates (1980) provided preterm infants with a multimodal

intervention in which infants received a tactile massage while the infant was too unstable to remove from the incubator. When the infants were well enough, they were held and rocked. After an average of 13 days of this type of stimulation, preterm infants displayed no reliable differences in resting heart rate during either active or quiet sleep. However, the preterm infants who received the intervention exhibited a significant heart rate acceleration in response to tactile stimulation during active sleep, but not during quiet sleep. Preterm infants who had not received intervention did not display reliable heart rate responses. In comparison, full term infants displayed a significant heart rate acceleration during both active sleep and quiet sleep in response to the tactile stimulation. Rose suggests that the intervention altered the infants' arousal level in some way to bring about a more mature functioning.

Pomerleau and Malcuit (1981) reported that human infants' heart rate is differentially responsive to a rocking stimulus depending upon the initial state of the infants and whether the infants respond to the stimulus with increased or decreased motoric activity. In their study infants, responded to 10 seconds of rocking with heart rate decelerations, but only when the initial state of the newborn was alert or crying and the infant responded to rocking with reduced motor activity. Heart rate accelerations were observed when the initial state of the newborn was alert or crying and when the newborn responded to rocking with increased motor activity. Heart rate accelerations were also observed when the initial state of the newborn was in a sleeping

state regardless of motor activity. Thus, in this study the initial behavioral state of infants and infants' motor reaction differentiated babies' heart rate response to rocking.

Several points should be noted about this study. First, Pomerleau and Malcuit noted that several infants responded to the rocking stimulus with motoric and heart rate acceleration on some trials, while responding with motoric and heart rate deceleration on other trials, even though the individual trials were separated by only a few minutes. Although noting this finding, the researchers did not offer a suggestion why this phenomena might have occurred. Second, comparative studies with nonhuman primates have noted that heart rate deceleration is a response to maternal holding and rocking (Seiler, Cullen, Zimmerman, & Reite, 1979), as is a decrease in motoric activity levels (Kaplan, 1970). In addition, Brackbill (1971) reported that several forms of continuous stimulation decreases heart rate; although, vestibular stimulation was not one of the forms of stimulation she examined. Thus, one important difference between the Pomerleau and Malcuit study and comparative studies might concern the length of the stimulation period in which heart rate was being measured. In the comparative studies, heart rate was generally measured over a period extending beyond the 10 second intervals examined by Pomerleau and Malcuit. In support of this suggestion, Pomerleau and Malcuit suggest that the infants' response to the rocking stimulus reflect the organism's attempt to restore balance, lost at the stimulus onset.

Review of what is currently known about holding and rocking infants

In the previous three sections the current literature on what is known about providing infants with increased vestibular-proprioceptive stimulation associated with holding and rocking was reviewed from comparative animal studies, clinical observations, and infant stimulation studies. The forms of the vestibular-proprioceptive stimulation varied substantially, and it appears that some differences exist, depending upon the form of stimulation the infant receives, the conceptional age of the infant when the stimulation is given, and the initial state of the infant at the start of the stimulation. Nonetheless, there are some generalizations that can be made about the short and long term effects of providing infants with movement stimulation. The immediate effects of providing infants with vestibular-proprioceptive stimulation in the form of holding and rocking is to reduce crying and general motor activity while increasing sleep states and quiet alert. Gentler forms of vestibular-proprioceptive stimulation also have the immediate effect of increasing sleep states and decreasing crying, fussiness, state changes, general activity, the length of activity cycles and apneic incidence. In addition, the comparative literature suggests that there might be decreases in heart rate, body temperature, motoric activity and cortisol levels. Longer term effects from repeated or continuous exposure to stimulation has been shown to bring about more mature motor skills and fewer abnormal reflexes, in both preterm and full term infants. The long term effects of vestibular-proprioceptive stimulation on preterm infants include

improved state organization and orientation abilities on the NBAS, higher Bayley mental development index scores, higher WISC scores, and reliable differences on the HOME examination. However, if the vestibular-proprioceptive stimulation is very mild, the results for full term infants may be less mature state organization, orientation and motor functioning. Finally, the comparative literature and clinical observations suggest that long term effects of critically reduced or severely inappropriate parental holding and rocking of infants might be a decrease in activity, heart rate and cortisol levels with the potential for very long term effects of increased risk for psychopathology and severe social and cognitive deficits.

Models of how holding and rocking infants change behavior and physiology

Als, Tronick and Brazelton (1979) have introduced a general model of how stimulation effects the developing child. They contend that a healthy infant elicits from adult caregivers the stimulation the infant needs to maintain its current organization or functional homeostasis. An example, of this type of elicitation and caregiver stimulation occurs when the infant cries and the caregiver picks-up, holds and rocks the infant. According to Als and her coworkers, the infant progresses through a series of organizational or functional homeostatic agendas during the first months of life. The agenda in which the infant must progress in order to develop normally, includes controlling their physiological system, then gaining basic control over their motor system, followed by gaining control over their states of consciousness,

and leading to developing the ability to interact socially. Gaining control or organizing and maintaining functional homeostasis over an agenda provides the infant with a necessary base to facilitate the emergence of the next organizational and homeostatic agenda, where the infant is more capable of incorporating and adapting to changes in the environment. This model takes the form of a feedback system, where the developing organism is embedded in interactions with caregivers and other people in the environment. Caregiver stimulation can interact with an infant's internal systems to regulate and organize the physiologic or behavioral systems and lead to developmental changes in the infant's central nervous system. These changes then feed back to effect other systems, such as a wider range of behavioral states or a greater ability to interact socially. Alternatively, caregiver stimulation can also be out of synchrony with an infant's internal systems, in which case the infant will actively defend itself from these stimuli by either "shutting them out" through falling asleep or becoming inattentive and unresponsive, or trying to elicit more appropriate stimulation from the caregiver.

Korner (1987) suggests that researchers should consider what type of stimulation is relevant for an infant at their specific conceptional age before designing an intervention or stimulation program. For example, Korner (1979) argues that since the vestibular system is one of the first sensory systems to develop (Gottlieb, 1971; Turkewitz & Kenny, 1982), and since the fetus receives considerable vestibular and proprioceptive stimulation in utero, gentle vestibular-proprioceptive

stimulation is appropriate for preterm infants, whose normal developmental environment has been abruptly disrupted. Although, as pointed out by Scarr-Salapatek and Williams (1973), birth irreversibly alters the functioning of many of the infant's physiological systems, such as in the respiratory and digestive system, Korner (1979) notes it is not evident that sensory or neurological functioning of the infant changes appreciably with birth. Korner therefore concludes that a gently oscillating waterbed is an appropriate intervention for preterm infants.

If Korner's analysis is applied to the full term infant then continuing to provide gentle vestibular-proprioceptive stimulation through oscillating waterbeds or the multisensory hammocks in the days and weeks following 40 weeks conceptional age may be an entirely irrelevant stimulation for the full term infant who would not normally be exposed to such stimulation. The results from the Koniak-Griffin and Ludington-Hoe (1987) study appear to support this hypothesis. If however, our species developed in an environment where the young were held and carried for long periods of the day, and since the visual system has developed substantially by 40 weeks conceptional age (Gottlieb, 1971), then more intense forms of stimulation that alert the infant may be more relevant. Such stimulation is provided when an infant is picked-up, held, and rocked.

The model of development proposed by Als and her associates (1979), allows for predictions to be made about the infant's immediate responses to a relevant stimulation by finding what agenda the infant is

in at present. For example, if the infant's current agenda is in organizing the behavioral states then relevant stimulation should produce a wider range of behavioral states and a greater ability to interact socially. However, the relationship between continuous or repeated stimulation to the changes that develop in the infant after days, weeks or months after the cessation of the stimulation is less clear. Brazelton (1984a) suggests that the stimulation may affect the infant through acting with internal systems to regulate and organize either a specific physiologic or behavioral system or several systems, leading to some form of change in the central nervous system which then later becomes obvious. However, Brazelton does not suggest which systems are being organized.

Three different approaches have been proposed that specify the nature of the relationship between immediate and long term responses to stimulation. First, Barnard (1987) and Horowitz (1987) have suggested effective stimulation aids infants in controlling and organizing their behavioral state. Infants' long term response to stimulation reflects this organization and the way the organized state system provides the base upon which other systems can develop. Second, Mason (1970) and Levine and Stanton (1984) have suggested that effective stimulation allows the infants to regulate their physiologic arousal and maintain their autonomic homeostasis. Infants' long term response to stimulation reflects this regulation and the other systems that have developed because of the regulation of arousal and autonomic functioning. Finally, Hofer (1984, 1987) has suggested that stimulation is multimodal

affecting multiple regulators of somewhat independent behavioral and physiological systems. Hofer contends there is no primary mechanism driving an infant's immediate and long term response to stimulation.

State as a primary mechanism

Although Barnard (1987) states that we do not fully understand the pathways by which the long term effects to stimulation occur, she suggests that effective stimulation aids infants in regulating their behavioral state. This regulation then allows for more rapid physical and neurological development. This ultimately leads to better parent-infant interactions and cognitive performance (Barnard & Bee, 1983). More specifically, Barnard (1987) defines regulation and modulation of behavioral state as the ability to get smoothly from one state to another, maintain the organization within a state, increase the range of behavioral states, and increase the length of time in alert states.

Horowitz (1987) has also suggested that intervention programs that have been shown to be beneficial for the developing infant most likely had their effects by helping infants organize their states and thereby fostering the maturation of the central nervous system. Specifically, Horowitz argues that the organization of the behavioral state should be reflected in smoother state-to-state transitions, greater ability to handle state variability, and an increase in the stability of the behavioral states, which apparently means increasing the length of time infants spends in a state without brief state interruptions. Horowitz suggests that this form of state organization then enhances the

acquisition and elaboration of universal II behaviors; that is, behaviors that individuals usually develop over a long period of time but require specific environmental stimulus feedback to shape. An example of a universal II behavior would be language development. According to Horowitz, the stimulation that caregivers provide infants with, or the specific content of intervention program may be less important, especially in the earliest months of life, than whether the stimulation or intervention facilitates behavioral state organization and modulation.

Both Barnard and Horowitz argue that infants' immediate responses to stimulation should reflect some form of state organization elicited by the stimulation, which should then allow infants to better regulate or organize their own behavioral state once the stimulation has been removed. Some research on vestibular-proprioceptive stimulation does lend some support to this hypothesis. For example, studies have shown that infants' immediate response to rocking stimulation is an increase in sleep states and alert states, while decreasing in crying, fussiness, and the number of state changes. Then once the specific stimulation has been removed, preterm infants display improved state regulation and greater range of states as measured by the NBAS.

However, other studies have not supported the premise of an altered behavioral state leads to long term benefits. For example, Koniak-Griffin and Ludington-Hoe (1987) found less mature state regulation in full term infants once very mild vestibular-proprioceptive stimulation was removed. In addition, Pederson (1975) and Pederson and

Ter Vrugt (1973) conducted the only studies that have specifically reported infant state frequencies immediately following the cessation of a rocking stimulus. In these studies the immediate organizing effects of the stimulus was to reduce states of agitation in infants, yet within 10 minutes following the cessation of the stimulus the infants' were displaying pre-stimulus levels of agitation. Thus, the organization of infants' states of agitation during stimulation did not appear to last beyond the cessation of the stimulation. Potentially, the measures used by Pederson and Ter Vrugt were not as sensitive to alterations in behavioral state. Studies have not yet examined the smoothness of state transitions or the stability of the behavioral states in response to rocking or stimulation, nor have studies specifically examined whether the indices of immediate state organization are enhanced once the stimulation is removed.

Arousal and autonomic homeostasis as a primary mechanism

In contrast to the above proposal, several authors have suggested that normal maternal ministering, which includes vestibular-proprioceptive stimulation brought about by rocking, aids infants in regulating their physiological arousal and maintaining their autonomic homeostasis, allowing for "normal" development to occur (Mason 1970; Walsh & Cummins, 1975; Levine & Stanton, 1984). However, if infants are restricted from interacting with their mothers for long periods of time, then alterations in infant arousal result in an impairment of autonomic homeostasis, resulting in abnormal development. From this perspective,

benefits seen from intervention studies reflects how stimulation aids infants in regulating their arousal. There is also some support for premise. For example, Levine and Stanton (1984) have noted that when infant monkeys explore their environment and interact with other conspecifics, their arousal level generally goes up. Infants' response to this arousal is to vocalize or increase activity levels, both of which generally leads to maternal contact. The maternal contact then brings about a reduction in arousal. This arousal reduction allows for more explorative behavior, which over the long term, brings on increased central nervous system maturation and more rapid development.

Another example of this system, but with human infants can be seen in caregiver-infant interactions surrounding infant crying. Zeskind and his associates (Lester & Zeskind 1979; Zeskind, 1983; Zeskind & Field, 1982) have suggested that an infant's cry reflects a continuum of infant arousal. When an infant responds to a painful stimulus, the infant's sympathetic nervous system activity results in increased infant arousal. The increased infant arousal leads to the infant crying with a higher pitch and with durational components classically defined as a pain cry (Zeskind, Sale, Maio, Huntington & Weiseman, 1985). This cry sound is then perceived by caregivers as more urgent, arousing and aversive (Zeskind et al., 1985). In addition, infants producing these cries are more likely to receive caregiving responses of being picked up and rocked or stroked (Zeskind & Collins, 1987). This caregiving response then reduces the infant's arousal, which results in a reduction of the infant's crying and an increase in the infant's alertness.

Further support for the hypothesis the regulation of arousal is the primary mechanism driving both the immediate and long term response to movement stimulation comes from the comparative literature of nonhuman primates and rodents. Comparative animal studies have shown that close mother-infant contact aids infants in regulating their level of arousal as measured by serum cortisol levels (Gunnar, Gonzalez, Goodlin, & Levine, 1981), heart rates (Seiler, et al., 1979), motoric activity levels (Kaplan, 1970), and body temperature (Reite, Short, Kaufman, Stynes, & Pauley, 1978).

Research on human infants has also shown that the immediate response to movement or rocking stimulation is a decrease in motoric activity, and states of agitation as defined by less crying and more quiet states. In addition, Pomerleau and Malcuit (1981) have shown that human infants respond to rocking with heart rate alterations. Although the direction of these alterations is not in a direction suggesting decreased arousal. Studies with human infants have not yet shown that infants' immediate response to vestibular-proprioceptive stimulation is a regulation of arousal as measured by decreased heart rate, cortisol levels or temperature. Human studies also have also not examined whether there are residual effects of stimulation that reflect continuing regulation of arousal.

No primary mechanism

Hofer (1984; 1987) has argued that most stimuli are complex multimodal stimuli that effect multiple biologic mechanisms or system

regulators. Hofer contends that many of these regulators are at least partially independent, so different immediate responses may reflect that different biologic regulators are being altered by the multimodal stimulation. In addition, infants' long term response to stimulation may be regulated by mechanisms that are independent of the immediate responses or alternatively, reflect a complex interaction of multiple regulators acting on the interrelated systems. Thus, some of an individual's immediate responses to stimulation may be independent of longer term responses, whereas, other long term responses may reflect some combination of changes we see in the immediate responses. Hofer (1984) contends that the reason we generally see both the immediate and long term changes occurring together, is that the stimulation we have provided includes multiple regulators of infant behavior and physiology.

Support for Hofer's hypothesis comes mostly from animal research, which has shown that different aspects of a nonhuman infant's response to isolation rearing can be altered by providing the offspring with different forms of stimulation. For example, Hofer (1975) found that thermal, tactile, and olfactory aspects of mother-infant interactions, when presented alone or together, act to exert long term control over infant hyperactivity. However, rocking and inversion, which primarily provide vestibular stimulation, were ineffective for controlling hyperactivity. In addition, Hofer (1984) points out that the immediate effects of isolation rearing, where maternal stimulation is removed, is to increase activity, heart rate and cortisol levels, yet the long term effects are a decrease in activity, heart rate and endocrine activity.

Hofer (1987) interprets these findings as offering support for the premise of partially independent systems being altered by the removal of maternal stimulation. As infants adjust to the immediate responses, the long term effects of stimulation removal begin to emerge.

Evidence from human studies is less clear. However, Hutt, Lenard and Prechtl (1969) and Ashton (1973) have noted that behavioral states are partially independent of measures of arousal. In addition, even within the organization of behavioral state a certain independence between immediate and long term response seems to occur. For example, preterm infants display an immediate response to rocking by increasing time in sleep states (Barnard, 1973); while the long term effects include increasing orienting abilities, with more alertness (Barnard & Bee, 1983). Nevertheless, the human infants' response to stimulation has not been examined in detail to determine if the immediate and the longer term responses to stimulation reflect partially independent systems. The clearest support for this premise would be found if the major indices of altered state and arousal organization were present only during stimulation while after stimulation a unique combination is present.

Reflection on the different proposed mechanisms

Some differences between the perspectives that infants' response to stimulation result from the regulation of state or alternatively, the regulation of arousal and autonomic functioning, is a level of analysis problem. One perspective focuses on several behavioral and

physiological changes indicating organization in behavioral state, while the other focuses on changes in physiology indicating organization in arousal and autonomic functioning. The levels of analysis problem can become an issue when researchers begin looking for specific infant responses to the stimulation. By evaluating one perspective researchers might choose to examine only those measures relevant to the perspective taken. This approach would exclude the ability to evaluate the proposal that changes in physiology are partially independent of changes in behavior and that the immediate and long term responses are partially independent.

Regardless of whether one views the primary mechanism driving immediate and long responses to vestibular-proprioceptive stimulation as the organizational changes in state or arousal, or even if the short and long term responses are viewed as independent, there remains the implication that some residual effects continue to influence infants once the stimulation has been removed. This must be the case if later long term differences are found in the behavior and physiology of infants. Yet these residual effects have not been consistently examined in studies.

Review and rationale

Previous research with human, nonhuman primate and rodent infants have identified both immediate and long term responses to a variety of different forms of vestibular-proprioceptive stimulation. Most these studies have found responses generally interpreted as being beneficial

for infants, such as more mature behavioral and physiological responses by infants. However, a study by Koniak-Griffin and Ludington-Hoe (1987) found that full term human infants exposed to mild vestibular-proprioceptive stimulation exhibit less mature orienting, motor and state regulation on the NBAS. Using Als, et al. (1979) model of infant development and Korner's (1979, 1987) analysis, in which the infant's conceptional age and the stimulation relevant for that age is considered, it seems possible that the form of stimulation used by Koniak-Griffin and Ludington-Hoe was irrelevant for normal development in full term infants. This is the conclusion reached by Koniak-Griffin and Ludington-Hoe (1987). A more relevant form of vestibular-proprioceptive stimulation for the full-term infant might be produced by picking-up, holding and rocking infants.

Three mechanisms have been offered to explain the relationship between the infants' immediate and long term responses to stimulation. Some suggest that stimulation aids the infant in regulating and organizing behavioral states, while others argue that stimulation aids the infant in regulating and arousal and maintaining autonomic homeostasis. The regulation and organization of both behavioral state and arousal have then been suggested to provide the basis for the infants' long term response to stimulation. Still others have suggested that there might not be a primary mechanism. Rather, the various responses found, both long term and immediate, are brought about by changes in regulatory systems that are at least partially independent. Previous research provides some support for all three premises.

However, previous studies do not provide enough evidence to determine which mechanism most accurately reflects the immediate response during the stimulation, and what if any residual responses can be identified once the stimulation has been suspended.

Interestingly, previous research has typically not used the same dependent variables to measure both the immediate and long term responses. For example, Barnard (1973) reported that infants' immediate response to rocking stimulation was a change in frequency of behavioral states, including, increased quiet sleep and decreased activity. In a later study, Barnard and Bee (1983) reported that the long term response to a similar rocking stimulus was improved state regulation and greater range of states as measured by the NBAS. The few studies that have examined the same dependent variables in infants during the stimulation and following the cessation of the stimulation found that the immediate organizing effects of reduced states of agitation in response to a rocking stimulation were no longer noticeable within 10 minutes following the cessation of the stimulation (Pederson, 1975; Pederson & Ter Vrugt, 1973). These examples show that we still do not understand the relationship between infants' immediate and residual responses to stimulation.

The purpose of the current study was to examine the immediate and residual responses of infants who are held and rocked. In order to assess the relationship between the immediate and residual responses, infants were examined before, during and after the presentation of holding and rocking, using the same dependent variables throughout the

observation procedure. The dependent variables in the current study measuring behavioral state organization were: the number of 30 second epochs in which infants were observed in each of the six states, the Stability of States, the Range of States, and Smoothness of Transitions Between States.

The behavioral state scale generally reported in previous studies has been the scale used in the NBAS (Brazelton, 1984b). This state scale contains six states: Quiet Sleep, Active Sleep, Drowsy, Quiet Alert, Active Alert, and Crying. In the current study this state scale was also used.

The Stability of Behavioral States generally refers to a decrease in the number of short state interruptions and an increase in the length of time the infant spends in a state (Barnard, 1987; Horowitz, 1987). In the current study, Stability of States was measured by finding the number of brief state interruptions occurring within each 30 minute period. Finally, when an infant's behavioral state changes from, for example, Quiet Sleep to Active Sleep, the infant will frequently appear vacillate between the two states for several minutes before clearly displaying the indices of being in Active Sleep. The Smoothness of Transitions Between States generally refers to a decrease in the number of vacillations between states at state transitions (Barnard, 1987; Horowitz, 1987).

In addition, heart rate measures were used as a noninvasive index of autonomic functioning. The heart rate measures used include: the Mean Heart Rate and Heart Rate Standard Deviation, the Mean Heart Rate

Within States, the Number of Peaks in the Heart Rate spectral density function, and the Frequency of the Highest Peak in the heart rate spectral density function. Many researchers have suggested that heart rate reflect the complex interaction between the parasympathetic and sympathetic divisions of the autonomic nervous system in response to both external and internal stimuli (Baust & Bohnert, 1969; Cabal, Siassi, Zamini, Hodgman, & Hon; 1980; Fox, 1983; Porges, 1974; Reite, et al., 1978; Seiler, et al., 1979; Zeskind, 1985; Zeskind & Field, 1982). An examination of heart rate mean and heart rate variability may provide information on the general arousal and autonomic functioning in the newborn. In addition, differences in heart rate and responsiveness of heart rate to stimulation have also been found depending upon the infant's state (Campos & Brackbill; 1973; DeHaan, Patrick, Chess, & Jaco, 1977; Harper, Hoppenbrouwers, Sterman, McGinty & Hodgman, 1976; Lewis, Bartels & Goldberg, 1967; Pomerleau & Malcuit, 1981). Thus, heart rate within states was also collected, in order to get a clearer understanding of heart rate changes and possibly alterations in heart rate independent of the infants' behavioral state. Finally, as a measure of the temporal organization of variability in autonomic activity the number of peaks in the heart rate spectral density function, and the frequency of the highest peak in the heart rate spectral density function were examined (Bohrer & Porges, 1982; Zeskind, Goff, & Marshall, 1987; Zeskind, Marshall & Goff, 1988) (See Appendix 2).

Anticipated results

Vestibular-proprioceptive stimulation has been shown to alter the amount of time infants are in various behavioral states, even though, the form of stimulation given infants varies substantially across studies. Thus, it was proposed that current study should partially replicate this finding. Specifically, the immediate response to holding and rocking infants should be to increase in the amount of time they are in the sleep states and the Quiet Alert State. The infants in the Experimental group should also spend less time in the Crying State and the Active Alert State. The amount of time infants are in a Drowsy State has not been reported as being responsive to stimulation programs, thus no reliable differences were anticipated in the frequency of this state. In addition, Barnard (1987) and Horowitz (1987) have suggested that effective stimulation programs should alter infants' behavioral state organization. Thus, as an immediate response to rocking and holding, infants in the Experimental Group should display greater Stability of States, greater Range of States, and Smoother Transitions Between States.

Comparative animal studies and human studies have reported that infants display decreases in heart rate and heart rate variability in response stimulation. Therefore, infants in the current study should display decreased Mean Heart Rate and decreased Heart Rate Standard Deviation. However, heart rate may be differentially responsive to stimulation during different behavioral states (Pomerleau & Malcuit, 1981; Rose, et al., 1980). Thus, heart rate should be more responsive

to stimulation during the Active Sleep State. In addition, Zeskind, et al. (1987, 1988) have reported differences in the number of peaks in the spectral density function of heart rate with infants who seem to have a more organized autonomic nervous system. In addition, the location of the highest value in the spectral density function of heart rate may be responsive to stimulation. Therefore, in response to the stimulation infants should display a greater Number of Peaks in Spectral Density Function of Heart Rate and the Highest Peak in the Heart Rate Spectra should be at a different frequency.

A decrease in the infants' Mean Heart Rate mean could indicate increased parasympathetic activation. A decrease in the infants' heart rate variability could represent either parasympathetic dominance without the sympathetic rebound or an increased balance in the homeostatic process between parasympathetic and sympathetic systems. The latter would be supported by finding a greater Number of Peaks in the Spectral Density Function of Heart Rate, indicating a greater number of small periodic corrections in the balance of parasympathetic and sympathetic activation rather than large swings. Alternatively, a decrease in the heart rate variability during the treatment period followed by an increase in the heart rate variability in the posttreatment period would be more consistent with parasympathetic dominance during the stimulus presentation with sympathetic rebound following the removal of the stimulus. In addition, the mean heart rate and heart rate variability should change together if the decrease represents parasympathetic dominance.

If the response to stimulation is an increase in behavioral organization, then some of the state measures should be reliably different during the period following the cessation of the stimulus. Because other studies have not found a reduction in agitation states, infants in the current study may not display differences in the number of epochs in each state once the stimulus has been removed. The other measures of change in behavioral state may be more sensitive to organizational changes. If this is the case then the Stability of States, Range of States, and Smoothness of Transitions Between States may continue to be reliably different once the stimulus has been removed and should reflect the same differences as identified during the presentation of the stimulus.

Finally, Rose et al. (1980) has reported that preterm infants exposed to a tactile massage, holding and rocking do not exhibit resting heart rate differences during a period following the stimulation. Heart rate may be more responsive to immediate stimuli and therefore significant differences in heart rate may not be found during the period following the cessation of the stimulus. However, to the extent that the number of peaks and the highest peak in the heart rate spectral density function identify differences in arousal or autonomic functioning, infants in the current study should display a greater Number of Peaks in Heart Rate Spectra and potentially the Highest Peak in the Heart Rate Spectra will be at a different frequency during and following the cessation of the stimulus. These difference should also

reflect the same organization pattern identified during the presentation of the rocking stimulation.

Hypotheses

1. While infants are being held and rocked they will display an increase in the amount of time they spend in Active Sleep, Quiet Sleep and Quiet Alert while decreasing the amount of time they spend in the Active Alert and the Crying states.
2. While infants are being held and rocked they will display a greater Stability of States, a greater Range of States, and Smoother Transitions Between States compared with infants who are not held and rocked.
3. While infants are held and rocked they will have a lower Mean Heart Rates and a lower Heart Rate Standard Deviations compared with infants who are not rocked.
4. Infants' Heart Rate will be more responsive to stimulation while the infants are in Active Sleep. Therefore, while infants are in Active Sleep and while they are held and rocked, they will have a lower Mean Heart Rate compared with infants in Active Sleep who are not held and rocked.
5. While infants are being held and rocked they will have more Peaks in their Heart Rate Spectral Density Function compared with infants who lie undisturbed in their cribs.
6. The greater Stability of States, greater Range of States, and Smoother Transitions Between States found in infants who have been

held and rocked will continue to differentiate infants who have or have not been held and rocked for 30 minutes following the cessation of the stimulus.

7. Infants who have been held and rocked will continue to display an increased number of Peaks in their Heart Rate Spectral Density Function compared with infants who have not been rocked for 30 minutes following the cessation of the stimulus.

Methodology

Subjects

The subjects for this study were originally to be selected from the normal newborn nursery at Montgomery Regional Hospital; however, because of continuing low census only three subjects were obtained from this hospital. This included two infants in the Control Group (not rocked) and one infant in the Experimental Group (rocked). The remaining 37 infants were selected from the normal newborn nursery at Roanoke Memorial Hospital. Because of hospital policy constraints infants from Roanoke Memorial Hospital were born to mothers attending a social services prenatal care clinic for the indigent.

Informed consent for participation in this study was sought from the neonates' mothers during the initial hospital stay following the birth of their infant (see Appendix 1). The experimenter briefly described to the parents the purpose and procedures of the study and answered questions that arose. The experimenter clearly stated that participation in this study was voluntary and the parents could withdraw their child from participation at anytime.

Infants included in this study met the following criteria: 1) gestational age of 37 to 42 weeks, 2) birthweight greater than 2500 grams, 3) Apgar scores at one and five minutes of at least 5, 4) singleton birth, 5) no indication of central nervous system anomalies on standard physical and neurological examinations, 6) no indication of small fetal growth patterns, as defined as having a ponderal index below 2.29 (Miller & Hassanein, 1971), and 7) the infants were between 12 and 120 hours of age. In addition, because differences have been reported

between breast and bottle fed infants (Zeskind, et al., 1988), male and female infants (Rose, et al., 1980), and cesarean section and vaginally delivered infants (Emde, Swedberg, & Suzuki, 1975), the ratios for these three variables were kept the same for both Experimental and Control Groups. Thus, forty neonates who met the above criteria were selected for inclusion in two groups. Twenty infants were in a Control Group. The remaining twenty infants were in an Experimental Group where the infants were held and rocked during the Treatment Period.

Procedure

On data collection days the decision whether to collect infants for inclusion in either the Experimental or Control Groups was made before entering the hospital. Upon entering the nursery infants were evaluated to determine whether they met the seven criteria listed above. Of the infants meeting these criteria one or two infants were selected and the mothers were approached for permission to include their child in the study. The first 30 infants were randomly selected from infants meeting the above criteria without regard to feeding type (bottle or breast fed), gender, delivery type (cesarean or vaginal delivery), circumcision or race. The remaining 10 infants were selected to ensure equal ratios of feeding type, gender, delivery type, circumcision and race between Control and Experimental Groups (see Table 1).

At Montgomery Regional Hospital six of nine mothers approached for permission to observe their infant refused to allow their infant to participate in the study. In contrast, one of forty-five mothers

Table 1.

Characteristics of Infants in the Control and Experimental Groups

Variables	Control Group		Experimental group	
	Mean	(SD)	Mean	(SD)
Apgar 1 minute	8.1	(1.09)	7.7	(.99)
Apgar 5 minute	8.9	(.55)	9.1	(.30)
Birth Weight (grams)	3752	(578)	3645	(412)
Gravida	2.1	(1.42)	2.1	(1.22)
Gestational Age (weeks)	39.2	(1.07)	39.0	(1.07)
Infant Age (hours)	38.0	(22.56)	35.1	(25.20)
Maternal Age (years)	24.4	(7.04)	21.5	(4.18)
Parity	.8	(1.09)	.7	(.86)
Ponderal Index	2.65	(.26)	2.64	(.22)
Circumcised (no.)	4		4	
Caesarian Section (no.)	8		8	
Feeding type (Breast/Bottle)	5/15		4/16	
Gender (female/male)	11/9		11/9	
Race (black/white/oriental)	5/14/1		5/15/0	
Time of observation (AM/PM)	8/12		6/14	

refused to allow their infants to participate at Roanoke Memorial Hospital. The difference in refusal rates might be due to the differing rates of mothers rooming-in with their infants. Of the six refusals at Montgomery Regional Hospital four were rooming-in with their infants. In addition, the nurses at Roanoke Memorial Hospital often encouraged mothers to participate in this study.

Previous studies at Roanoke Memorial Hospital (Zeskind, et al., 1988) and pilot data collected at Montgomery Regional Hospital indicated that if infants were not provided with some form of intervention 20% to 40% of the infants would cry for at least five minutes during a 90 minute period. In both of these hospital settings neonates are usually not allowed to cry continuously for long periods of time without some form of intervention. This also reflects the pattern of intervention typically found in home environments where parents attempt to calm infants who cry for longer than several minutes (Bowlby, 1969). Preliminary observations at both Roanoke Memorial Hospital and Montgomery Regional Hospital indicate that following a feeding if infants cried for longer than several minutes the nursing staff would attend to the child by holding and rocking the child, checking and changing the child's diaper, readjusting the child's position and reswaddling the child, giving the child a pacifier, or giving the child a "Rock-a-Bye Bear" that provides auditory stimulus resembling womb sounds.

In order to reflect normal parenting and nursing staff procedures a criterion was established where infants crying continuously for longer

than 2 minutes were given a pacifier. In addition, if an infant cried for longer than 5 continuous minutes after being given a pacifier, the child would be attended to by the experimenter who would attempt to calm the infant by changing diapers, or holding and rocking the child, thus ending the observation session. Eleven percent of the infants were lost due to crying (5 of 46). Three of these infants were in the Control Group and 2 were in the Experimental Group. The 2 infants in the Experimental Group who were lost due to crying, were lost during the final 30 minutes of observation (after they had been rocked). In addition, one infant in the Control Group was lost because the mother withdrew the child when the mother's family came to visit.

The infant observation sessions began within 30 minutes after the infants' return to the main nursery from feeding. Three electrodes from a digital cardiac-respiratory monitor were attached to the infants: two electrodes were placed on the chest above each nipple, the other electrode was placed on the lower right quadrant at the lateral costal margin. After electrode placement, infants were given a 2 to 5 minute period of adjustment before the observation period began.

Infant observation sessions at Montgomery Regional Hospital were obtained in a corner of the main nursery. At least two other infants were in the main nursery during these observation sessions. During all three infant observations another infant cried during the observation session. Inspection of the data did not reveal obvious effects on the observed infant's behavioral state or heart rate. Infant observation sessions at Roanoke Memorial Hospital were obtained in a room separate

from the main nursery where the observed infant was the only infant in the room.

Infants in both the Control and the Experimental Groups were observed for a 90 minute period. During the 90 minute observation period heart rate and behavioral state was collected every 30 seconds by two trained observers. One observer monitored infant state while the other observer recorded state and heart rate. The observer monitoring behavioral state was always unaware of the hypotheses of the study. The 90 minute observation began with a 30 minute Pretreatment Period in which infants in both the Experimental and Control Groups lay undisturbed in their bassinets while heart rate and behavioral state were collected. Following the Pretreatment Period the 20 infants in the Experimental Group were picked up and placed in a supine position cradled in the experimenter's arms. He was careful not to disrupt the electrodes on the infant's chest. For the next 30 minutes (Treatment Period) the infants in the Experimental Group were held and gently rocked. The same experimenter was used for all infants. The rocking frequency ranged from 25 to 37 strokes per minute with an average displacement of 7 inches (range 4 to 10 inches). The regularity of the rocking and the displacement was allowed to vary in order to reflect "normal" rocking patterns. At the end of the Treatment Period the infants in the Experimental Group were carefully returned to their bassinets where they lay undisturbed for a 30 minute Posttreatment Period.

The 90 minute observation period began for the 20 infants in the Control Group with the 30 minute Pretreatment Period where the infants lay undisturbed in their bassinet. Following the Pretreatment Period these infants were picked up and repositioned, but then returned to their bassinet to remain undisturbed for the 30 minute Treatment Period.

At the end of the 30 minute Treatment Period the infants in the Control Group were again picked up, repositioned and returned to their bassinet for the remaining 30 minute Posttreatment Period. During all three periods behavioral state and heart rate were recorded.

Interobserver reliability of behavioral state was obtained during 12.5% of the completed observation sessions (2 of 20 infants in the Control Group and 3 of 20 infants in the Experimental Group). Interobserver reliability for behavioral state was assessed through independent observer records on the same infant. A raw interobserver reliability of 88% (range 77% to 96%) was attained with a chance corrected reliability kappa of 83% (range 72% to 92%) (Cohen, 1960). Behavioral state was determined using the criteria set by the Newborn Behavioral Assessment Scale (NBAS) (Brazelton, 1984b). This state scale is briefly described in Table 2.

Data Reduction of Behavioral State

The above procedure produced three time series for heart rate and three time series for behavioral state for each infant, two time series the Pretreatment Period, two time series for the Treatment Period, and two time series for the Posttreatment Period. The time series contained

Table 2

Defining Characteristics for the Behavioral State Scale

- State 1 Quiet Sleep with regular breathing, eyes closed, no eye movements, no spontaneous activity except startles or other tremulous jerky movements with rapid suppression of startle activity.
- State 2 Active Sleep with generally irregular breathing, eyes closed, rapid eye movement can be observed under closed lids. The level of activity is generally low with random movements and startles. Sucking movements occur off and on.
- State 3 Drowsy or semi-dozing state where the eyes may be open or closed, eyelids fluttering and activity level is variable with interspersed mild startles. Movement is generally smooth and fussing may or may not be present.
- State 4 Quiet Alert, an awake state where the infant seems to focus attention on objects in the environment. There is generally a minimal amount of motor activity.
- State 5 Awake Activity where eyes are open and there is considerable motor activity with thrusting movements of the extremities. Fussing is usually present.
- State 6 Crying is continuously present.

60 epochs. The dependent variables in the analyses of behavioral state included the number of 30 second epochs in which infants were observed in Quiet Sleep (State 1), Active Sleep (State 2), Drowsy State (State 3), Quiet Alert State (State 4), Active Alert State (State 5), and Crying State (State 6). Additional dependent variables in the analysis of behavioral state included the Range of States infants were observed in, the Stability of States, and the Smoothness of Transitions Between States. Range of States was defined by the number of different states observed during each observation period. Thus, the minimum value was one for infants who remained in a single state throughout the 30 minute period, and the maximum value was six for infants who progressed through all six states during the period.

Increasing Stability of States generally refers to a decrease in the number of brief state interruptions and increased length of time the infant spends in a state (Barnard, 1987; Horowitz, 1987). In the current study, Stability of States was defined by the number of brief state interruptions occurring within each 30 minute period. In order to calculate the number of brief state interruptions a five-observation moving median filter was first applied to each 30 minute state time series. Prechtl (1982, Prechtl & O'Brien, 1982) has suggested that this type of filter should be applied to state time series, because states should reflect stable phenomena rather momentary irregularities. The number of state interruptions was then calculated by counting the number of state epochs the moving median filter changed.

The Smoothness of Transitions Between States refers to a decrease in the number of vacillations between states when infants change states. In the current study, Smoothness of Transitions Between States was calculated by identifying the state transitions in the filtered time series. Then using the unfiltered time series the total number of state changes occurring in the five epochs immediately surrounding each transition was calculated. Range of states, total state transitions, and state transitions at state changes were analyzed using multivariate procedures.

Another multivariate analysis examined the number of 30 second epochs in which infants were observed in each state. Because the sum of epochs is always 60, inclusion of the number of epochs in each of the six states violates the assumption that the variables are computationally independent (Bray & Maxwell, 1988). In other words, if the number of epochs seen in five of the states is specified we know exactly how many epochs will be in the sixth state. Since no a priori predictions about the Drowsy State (State 3) could be made, this state was dropped from the design, allowing for the assumption of independence. In addition, the distributions for the Active Alert State (State 5) and the Crying State (State 6) were highly skewed and leptokurtic. To improve their distributional characteristics, and because of the conceptual similarities between the two states, these two states were combined into a state, here after called the Fuss-Cry State. The resulting multivariate analysis included the number of 30 second epochs in the

Quiet Sleep State, Active Sleep State, Quiet Alert State, and the Fuss-Cry State.

Data Reduction of Heart Rate

The dependent variables in the analysis of heart rate include the Heart Rate Mean, the Heart Rate Standard Deviation, the Heart Rate Mean Within States, the Number of Peaks in the heart rate spectral density function, and the Frequency of the Highest Peak in the heart rate spectral density function. The Number of Peaks and the Frequency of the Highest Peak in the spectral density function of heart rate were calculated by subjecting each 30 minute heart rate time series to a Blackman-Tukey discrete Fourier (spectrum) analysis using a Hanning window with a bandwidth of .10 (Chatfield, 1984). Previous work indicates that a window of this length generates an acceptable trade off between resolution of the spectrum and inconsistent variation (Goff, 1985). Spectral analysis partitions the total variance into independent components in the frequency domain. The linear trend in the heart rate time series was removed before the heart rate spectra were computed in order to improve the stationarity of the time-series (see Gottman, 1981). The Number of Peaks in the spectral density function was calculated by counting the number of local high values (or peaks) in the spectral density values that were above the 95% confidence interval for the theoretical cumulative distribution of white noise as determined by a Kolmogorov-Smirnov test (see Chatfield, 1984; Jenkins & Watts, 1968).

Finally, not all infants showed every state during the 30 minute

periods. Therefore, the analyses of the Heart Rate Mean Within States was based on a different number of infants for each state. Only infants displaying at least one epoch of a particular state across all three periods (Pretreatment, Treatment and Posttreatment) were included in the analysis of Heart Rate Mean Within State. Five separate analyses were run comparing the group differences for Heart Rate Within each State.

Data Analyses

Richards (1980), Graham and Jackson (1971), and Wilson (1967) have argued that when analyzing heart rate as well as other physiological measure of infants, the pretreatment period or baseline measures should be covaried from the posttreatment measures because of the law of initial values. The law of initial values states that the posttreatment heart rate level is partially determined by the prestimulus heart rate level, such that, when the heart rate is high during the pretreatment period the acceleratory response that the stimulus might incur is smaller than if the pretreatment heart rate was low. Similarly if the pretreatment heart rate is low then the deceleratory response the stimulus might incur is smaller than if the pretreatment heart rate was high (Wilder, 1958). Analysis of covariance attempts to adjust the posttreatment scores in order to remove the affect of the initial value. (Bock, 1975).

For the current study, Multivariate analysis of covariance was investigated, however, it was decided that the current data were not suited for MANCOVA. Specifically, meaningful interpretation of MANCOVA

assumes homogeneity of linear regression coefficients (Algina, 1982; Barcikowski, 1983). If the pretreatment and the posttreatment scores within the control and experimental groups are not linearly related, or if the slope of the regression lines are significantly different then the use of MANCOVA is questionable (Barcikowitz, 1983). Using the procedure outlined by Barcikowitz (1983) a test of homogeneity of the within cell regression coefficients was rejected for all four of the main multivariate analyses. This finding shows heterogeneity of regression coefficients. Although Richards (1980) has suggested alternative methods for the analysis of covariance when there is heterogeneity among regression coefficients, there appears to be little agreement on how to interpret these methods (Bray & Maxwell, 1985; Keppel, 1982). This being the case, a modified Doubly Multivariate approach to repeated measures analysis was considered the most appropriate for the current data (Stevens, 1986; Vasey & Thayer, 1987).

The Doubly Multivariate repeated measures design calculates Multivariate test statistics on the multivariate analysis of variance (MANOVA) approach to repeated measures. Using the MANOVA approach to repeated measures avoids the assumptions of equal variances and covariances for all levels of the within-subjects factors. This assumption is made to enable the pooling of sums of squares across multiple levels when using the analysis of variance (ANOVA) repeated measures design (Davidson, 1972; McCall & Appelbaum, 1973). An alternative approach to MANOVA was suggested by Huynh and Feldt (1970) who devised a correction for interpreting the ANOVA repeated measures

design when the assumption of homogeneity of covariance is not met. Using the Huynh-Feldt correction, multivariate test statistics are calculated on the ANOVA approach to repeated measures and the multivariate test statistics are interpreted by adjusting the degrees of freedom.

At present, there is some debate over whether the MANOVA approach to repeated measures or a corrected ANOVA approach offers the best trade-off in keeping the type I error rate low while still proving ample power (keeping the type II error rate low) when the sample sizes are moderate (Hertzog & Rovine, 1985; Vasey & Thayer, 1987). O'Brien and Kaiser (1985) argue that neither procedure is uniformly more powerful than the other or even usually the most powerful. Monte Carlo studies comparing the MANOVA and corrected ANOVA approaches to repeated measures designs indicate that when the number of subjects per cell minus the number of contrasts used in the MANOVA is greater than 20 then the MANOVA approach tends to be more powerful; alternatively when the number of subjects per cell minus the number of contrasts is less than 6 then the corrected ANOVA approach tends to be more powerful (Davidson, 1972). Between 20 and 6 neither approach is consistently more powerful (Ruchkin, 1987). In the current study, number of subjects minus the number of contrasts range from 12 in the MANOVA for the number of epochs in each state to 16 in the MANOVA for Heart Rate Mean and Heart rate Standard Deviation. Thus, a modified Doubly Multivariate approach to repeated measures was used to analyze the current data as suggested by Stevens (1986) and Vasey and Thayer (1987). This procedure initially

uses the MANOVA approach to repeated measures because it avoids the assumption of homogeneity of covariance. If this test was significant then it allowed the greatest degree of confidence for significance. If the MANOVA approach was not significant then a corrected ANOVA approach to repeated measures was used allowing only slightly less confidence in the significance.

Design

The analyses of the dependent variables for behavioral state and heart rate between Control and Experimental Groups and across the 3 periods were compared using four 2 (Group) X 3 (Period) Doubly Multivariate repeated measures design with repeated measures on the 3 periods. The dependent variables in the first 2 (Group) X 3 (Period) Doubly Multivariate repeated measures design included the number of epochs in Quiet Sleep, Active Sleep, Quiet Alert, and the Fuss-Cry State. In the second design the dependent variables included the Range of States, the Smoothness of Transitions Between States, and the Stability of States. In the third multivariate analysis included the dependent variables, Heart Rate Mean and Heart Rate Standard Deviation. The final multivariate analysis included the Number of Peaks and the Frequency of Highest Peak in the spectral density function as the dependent variables. In addition, MANOVA for repeated measures was used to analyze Heart Rate Within the five states. Because five MANOVA's for Heart Rate Within State were done, a two step procedure was used where

MANOVA's with $p < .01$ was accepted as significant, and $p < .05$ was accepted as a nominal difference.

RESULTS

A comparison of the demographic information on infants in the Control and Experimental Groups showed no reliable differences between the groups. The effects of time of day that the data was collected, morning or afternoon, were examined for their influence on the dependent variables. No reliable differences were found. In addition, Multivariate analyses of the dependent variables indicated that there were no reliable differences between infants in the Control and the Experimental Groups during the Pretreatment Period. These analyses provided support for the assumption of random assignment of infants between the Control and Experimental Groups.

Number of Epochs in the Behavioral States

The Group means and standard deviations of the number of 30 second epochs infants were observed in each behavioral state are presented in Table 3 (also see Figures 1 2 and 3). The first multivariate analysis of the behavioral state measures examined the number of 30 second epochs in which infants were observed in Quiet Sleep, Active Sleep, Quiet Alert, and the Fuss-Cry State. As can be seen from Table 4, this multivariate analysis yielded a reliable Group (Experimental and Control) by Period (Pretreatment, Treatment and Posttreatment) interaction ($Wilks=.612$, $F(8,31)=2.45$, $p<.035$). A reliable univariate Group by Period interaction was then found in the Fuss-Cry State, while nominal Group by Period interactions were found in the Quiet Alert State and the Active Sleep State. A Bonferroni correction method for determining the significance of multiple univariate tests following a

Table 3.

Group Means and Standard Deviations of the Number of Epochs Infants were Observed in Each Behavioral State

	Pretreatment		Treatment		Posttreatment	
	Mean	(St.Dev.)	Mean	(St.Dev.)	Mean	(St.Dev.)
Quiet Sleep						
Control	13.25	(15.13)	19.55	(20.82)	12.70	(14.23)
Experimental	14.95	(14.92)	23.25	(16.89)	18.75	(12.97)
Active Sleep						
Control	39.10	(14.16)	25.05	(15.87)	30.80	(18.21)
Experimental	29.10	(17.12)	30.00	(17.86)	34.10	(16.41)
Drowsy						
Control	3.45	(3.91)	4.50	(6.36)	5.05	(7.63)
Experimental	7.70	(12.27)	2.15	(4.77)	1.75	(3.43)
Quiet Alert						
Control	1.55	(3.27)	3.15	(4.83)	5.20	(8.85)
Experimental	4.05	(9.70)	3.35	(8.59)	1.10	(2.75)
Active Alert						
Control	1.40	(2.58)	4.30	(6.83)	3.60	(5.09)
Experimental	2.30	(5.81)	.55	(2.46)	2.50	(5.54)
Crying						
Control	1.25	(2.92)	3.45	(5.37)	2.65	(5.07)
Experimental	1.90	(4.67)	.70	(2.90)	1.80	(3.38)
Fuss-Cry						
Control	2.65	(4.52)	7.75	(9.86)	6.25	(8.30)
Experimental	4.20	(7.88)	1.25	(5.36)	4.40	(8.67)

Note: 60 epochs in each treatment period.

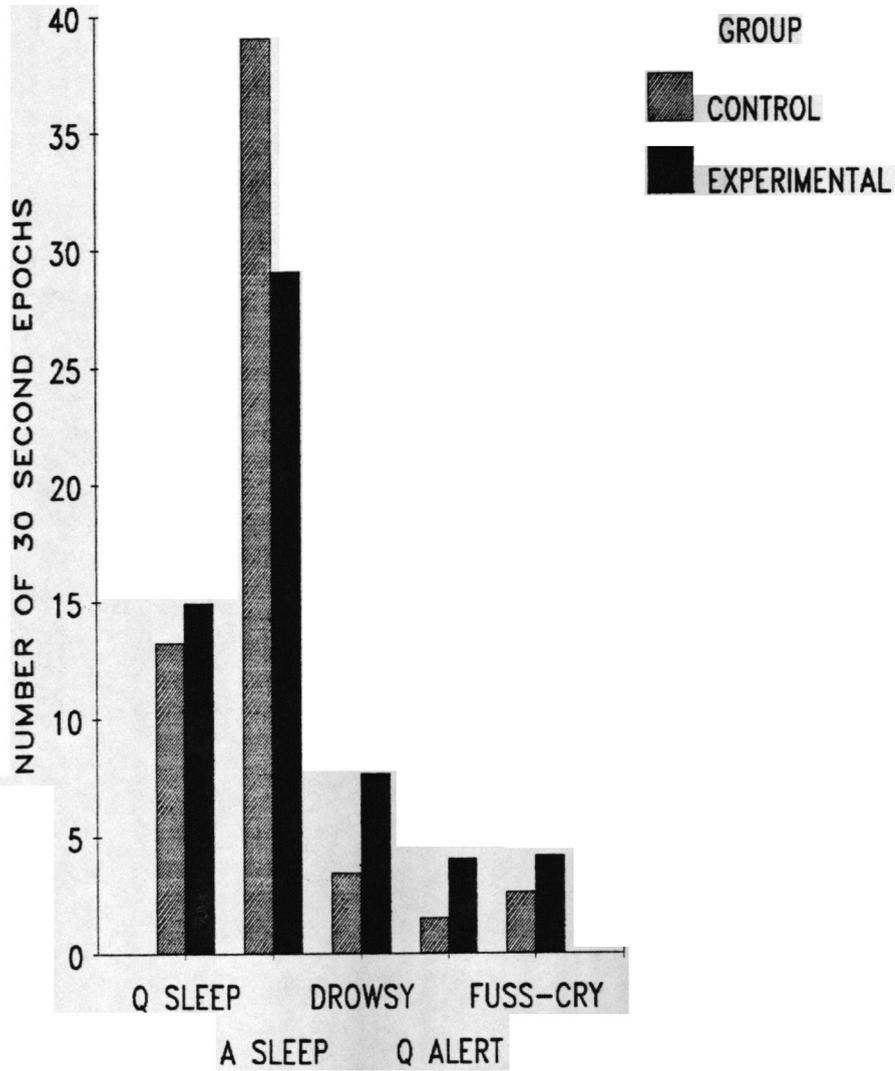


Figure 1. Mean number of epochs that infants were observed in each state during the pretreatment period.

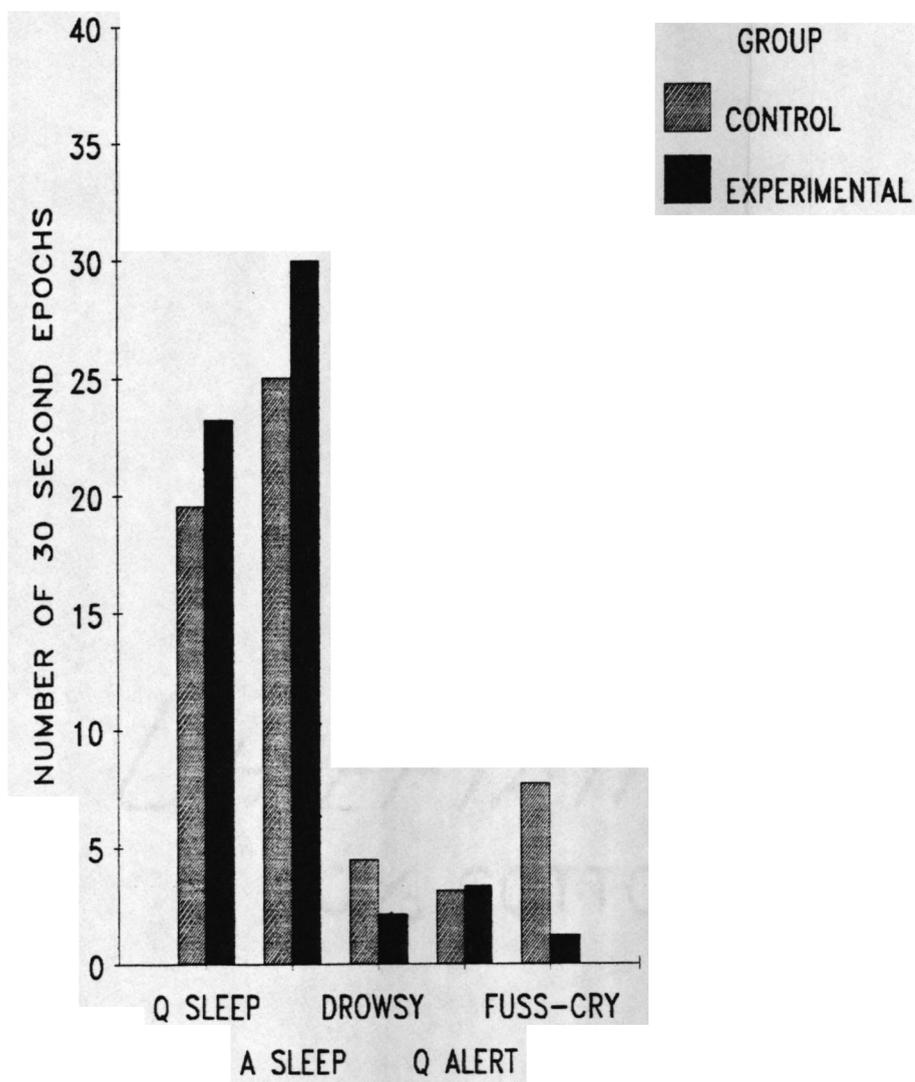


Figure 2. Mean number of epochs that infants were observed in each state during the treatment period.

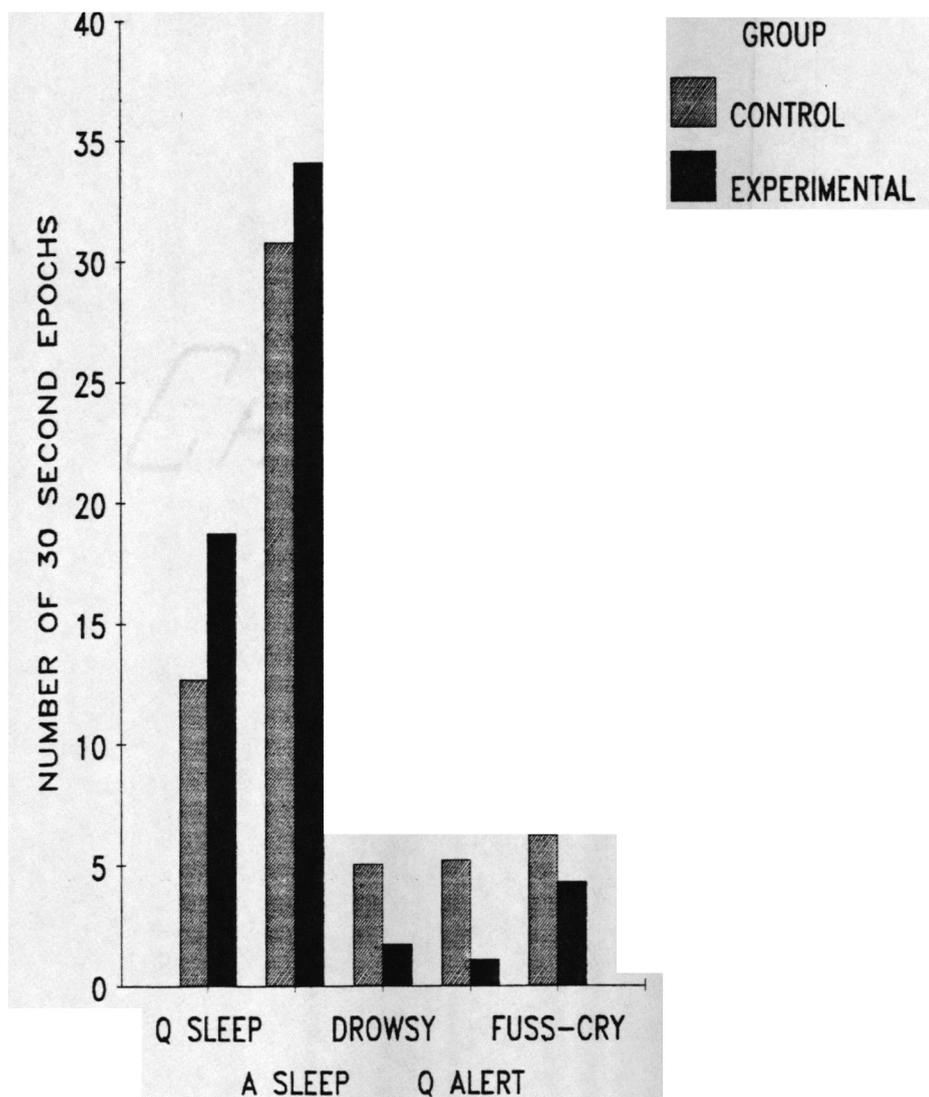


Figure 3. Mean number of epochs that infants were observed in each state during the pretreatment period.

Table 4.

MANOVA for Number of Epochs Infants Spent in Each State

Source	df	Wilks	F	p <
Group	4	.920	.76	.56
Period	8	.705	1.65	.160
Group x Period	8	.612	2.45	.035

Table 4A.

Univariate Group x Period Interactions for the Number of Epoch Infants Spent in Each State

Source	Sums of Squares	df	F	p <
Quiet Sleep	94.8	2	.15	.855
Error	23034.7	76		
Active Sleep	1343.7	2	2.85	.064
Error	17912.8	76		
Quiet Alert	224.5	2	3.34	.041
Error	2551.7	76		
Fuss-Cry	325.8	2	5.54	.006
Error	2236.4	76		

Note: The Bonferroni corrected alpha level = .012

significant MANOVA was used to determine significance of these univariate analyses (Bray & Maxwell, 1989; Hertzog & Rovine, 1985; Ramsey, 1980).

Because the assumption of sphericity was not violated for the repeated measures analysis of the Fuss-Cry State (Huynh-Feldt epsilon = 1.0), the Quiet Alert State (Huynh-Feldt epsilon = .94) or the Active Sleep State (Huynh-Feldt epsilon = 1.0) the Newman-Keuls procedure was considered appropriate for pairwise comparisons (Hertzog & Rovine, 1985). The Newman-Keuls comparisons on the Fuss-Cry State showed that infants in the Control Group had reliably more epochs of the Fuss-Cry State during the Treatment Period compared with the Pretreatment Period. In contrast, the infants in the Experimental Group spent reliably less time in the Fuss-Crying State during the Treatment Period compared with infants in the Control Group during the Treatment and the Posttreatment Periods. The Newman-Keuls pairwise comparisons did not indicate reliable differences in number of epochs infants spent in the Active Sleep State or the Quiet Alert State. However, profile analyses on the group means for the number of epochs infants spent in the Quiet Alert State revealed that the infants in the Control and the Experimental Groups differ in the direction of their linear slopes ($F(1,38) = 4.82$, $p < .034$) (See Figure 4). Specifically, across the 90 minute observation infants in the Control Group displayed an increase in the number of epochs in the Quiet Alert State, while the infants in the Experimental Group displayed a decrease in the number of epochs in the Quiet Alert State across the 90 minute observation.

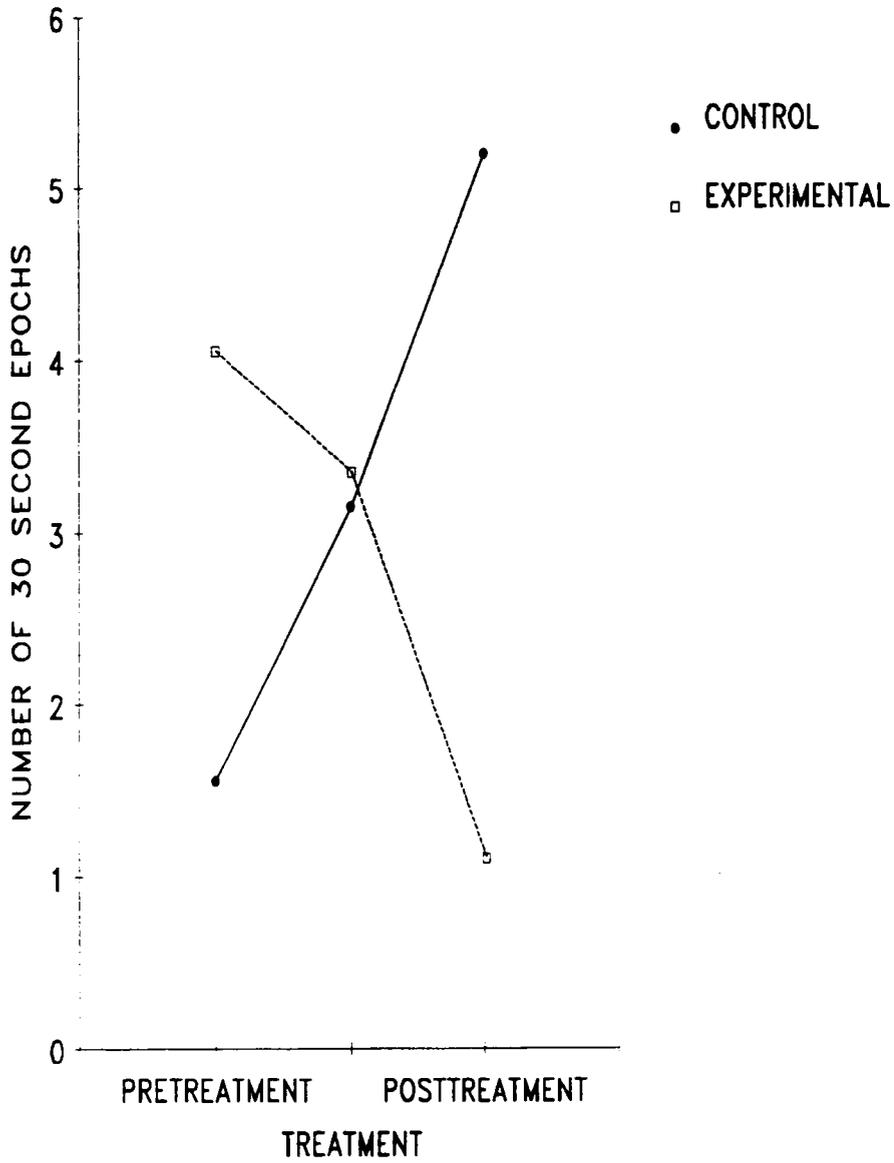


Figure 4. Mean number of epochs that infants were observed in Quiet Alert during the three treatment periods.

Even though a priori predictions were not made concerning the number of epochs infants would spend in the Drowsy State, analyses were conducted to examine potential group differences. These analyses revealed a nominal Group by Period interaction (Wilks=.846, $F(2,37)=3.36$, $p<.046$). In contrast to several other states sphericity did not hold in order to make pairwise comparisons (Huynh-Feldt epsilon = .73). Because of the equal cell sizes between the Control and the Experimental Groups a Tukey multiple comparison procedure with an unpooled error estimate was considered appropriate (Keselman & Keselman, 1988). Tukey comparisons showed that the infants in the Experimental Group had reliably more epochs in the Drowsy State during the Pretreatment Period than during Posttreatment Period. No other pairwise differences were reliable.

The results of the first multivariate analyses that examined the number of 30 second epochs in which infants were observed in the Quiet Sleep State, Active Sleep State, Drowsy State, Quiet Alert State, and the Fuss-Cry State. These analyses showed that during the Treatment Period the infants in the Experimental Group spent less time in the Fuss-Cry State compared with infants in the Control group during either the Treatment Period or the Posttreatment Period. In addition, across the 90 minute observation infants in the Control Group displayed an increase in the number of epochs in the Quiet Alert State, while the infants in the Experimental Group displayed a decrease in the number of epochs in the Quiet Alert State. Finally, infants in the Experimental

Group had more epochs in the Drowsy State during the Pretreatment Period than during Posttreatment Period.

Number of Infants observed with Epochs in the Behavioral States

In addition to the findings based on the mean number of epochs infants were observed in the behavioral states, the number of infants who were observed to display at least one 30 second epoch within each behavioral state was analyzed. Not all infants reached every state during all three 30 minute periods. Ten (10) 2 (Control and Experimental Group) by 2 (number of infants who either did or did not display at least one epoch in the behavioral state) chi-square analyses were conducted. One analysis was conducted for each behavioral state during both the Treatment and Posttreatment Periods. These analyses showed that during the Treatment Period the distribution of infants who displayed at least one epoch in the Quiet Alert State was different for the Control Group compared with the Experimental Group ($X^2(1)=4.29$, $p<.038$). Fewer infants in the Experimental Group displayed at least one epoch in the Quiet Alert State ($n=3$) compared with the infants in the Control Group ($n=9$). In addition during the Treatment Period the distribution of infants who displayed at least one epoch in the Fuss-Cry State was different for the Control Group compared with the Experimental Group ($X^2(1)=6.14$, $p<.013$). Again, fewer infants in the Experimental Group displayed at least one epoch in the Fuss-Cry State ($n=2$) compared with the infants in the Control Group ($n=9$).

During the Posttreatment Period the distribution of infants who displayed at least one epoch in the Quiet Sleep State was different for the Control Group compared with the Experimental Group ($X^2(1)=10.0$, $p<.002$). All 20 of the infants in the Experimental Group displayed at least one epoch in the Quiet Sleep State, whereas 12 of the infants in the Control Group displayed at least one epoch in the Quiet Sleep State. Accepting an experimentwise Bonferroni correction of the significance level ($\alpha =.0062$) for the chi-square analyses, the difference in the number of infants reaching the Quiet Sleep State during the Posttreatment Period was reliable.

The difference distributions seen in the number of infants reaching the Quiet Sleep State between the Control and Experimental Groups were explored further. Two (2) 3 (Pretreatment, Treatment and Posttreatment Periods) by 2 (number of infants who either did or did not display at least one epoch in the behavioral state) chi-square analyses were conducted. One analysis was conducted for the Control Group another for the Experimental Group. The chi-square analysis for the Control Group did not identify reliable differences in the distributions across the three Periods ($X^2(2)=1.43$, $p>.48$). However, the chi-square analysis for the Experimental Group showed that the distribution of infants who displayed at least one epoch in the Quiet Sleep State was reliably different across the three Periods ($X^2(1)=6.14$, $p<.05$). Fifteen infants in the Experimental Group displayed at least one epoch in the Quiet Sleep State during the Pretreatment period, 18 infants in the Experimental Group displayed at least one epoch in the Quiet Sleep

State during the Treatment Period, and all 20 infants in the Experimental Group displayed at least one epoch in the Quiet Sleep State during the posttreatment Period.

The chi-square analyses showed that while the Experimental infants were being held and rocked they were less likely to display at least one epoch in the Quiet Alert State or the Fuss-Cry state. Then during the Posttreatment period infants in the Experimental group were more likely to have at least one epoch in the Quiet Sleep State.

Range of States, Stability of States, and Smoothness of Transitions Between States

The Group means and standard deviations of the Range of States, Stability of States, and Smoothness of Transitions Between States are presented in Table 5 (also see Figure 5, 6 and 7). The multivariate analysis examining the dependent variables of the Range of States, Stability of States and the Smoothness of Transitions Between States are presented in Table 6. There was a significant Period effect for these variables ($Wilks=.675$, $F(6,33)=2.64$, $p<.033$). Inspection of the univariate contrasts for the Period effects indicates differences in the Stability of States and the Smoothness of Transitions Between States were reliable. Specifically, during the Pretreatment Period all infants displayed reliably greater Stability of States than during the Posttreatment Period. During the Pretreatment Period the infants also displayed Smoother Transitions Between States than during the

Table 5.

Means and Standard Deviations of the Range of States, Stability of States and the Smoothness of Transitions Between States

	Pretreatment		Treatment		Posttreatment	
	Mean	(St.Dev.)	Mean	(St.Dev.)	Mean	(St.Dev.)

Range of States						
Control	3.20	(1.32)	3.40	(1.70)	3.15	(1.63)
Experimental	3.20	(1.40)	2.50	(1.10)	3.15	(1.56)
Stability of States						
Control	3.75	(3.58)	5.85	(4.81)	6.05	(5.46)
Experimental	3.85	(3.83)	2.85	(3.05)	5.50	(4.84)
Smoothness of Transitions Between States						
Control	1.70	(2.51)	3.05	(3.41)	3.60	(4.39)
Experimental	1.85	(2.70)	1.15	(2.48)	2.20	(3.56)

Note: For Stability of States and Smoothness of Transitions Between States, smaller values reflect greater stability and smoothness.

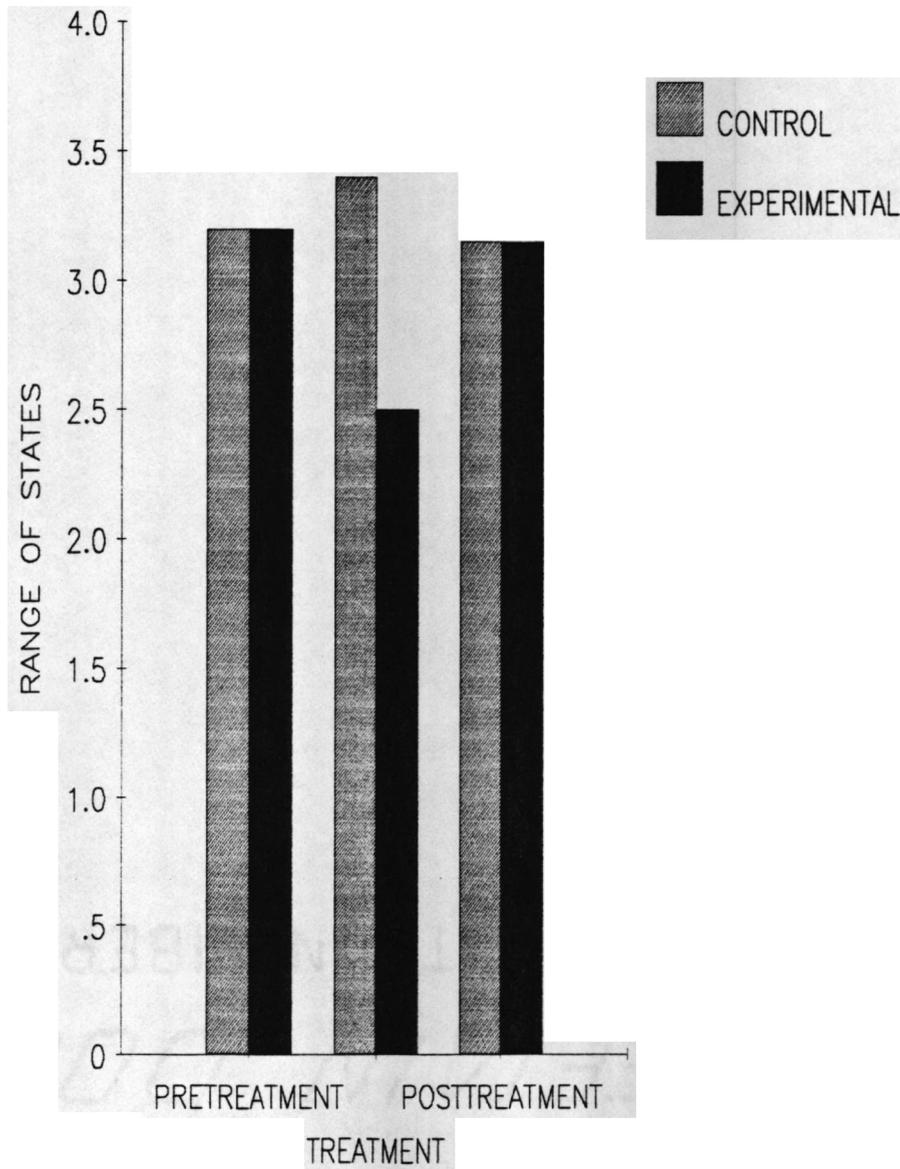


Figure 5. Mean Range of States for the three treatment periods.

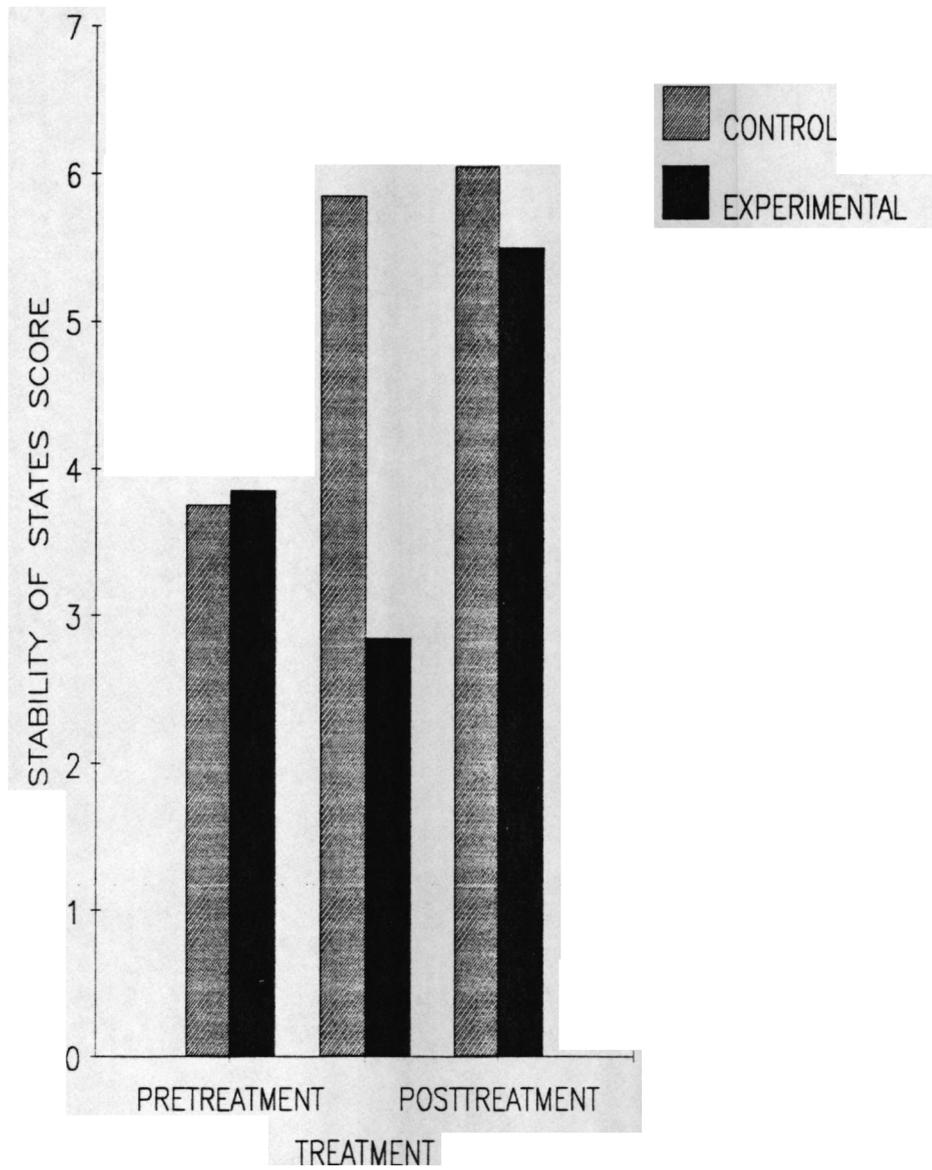


Figure 6. Mean Stability of States scores for the three treatment periods

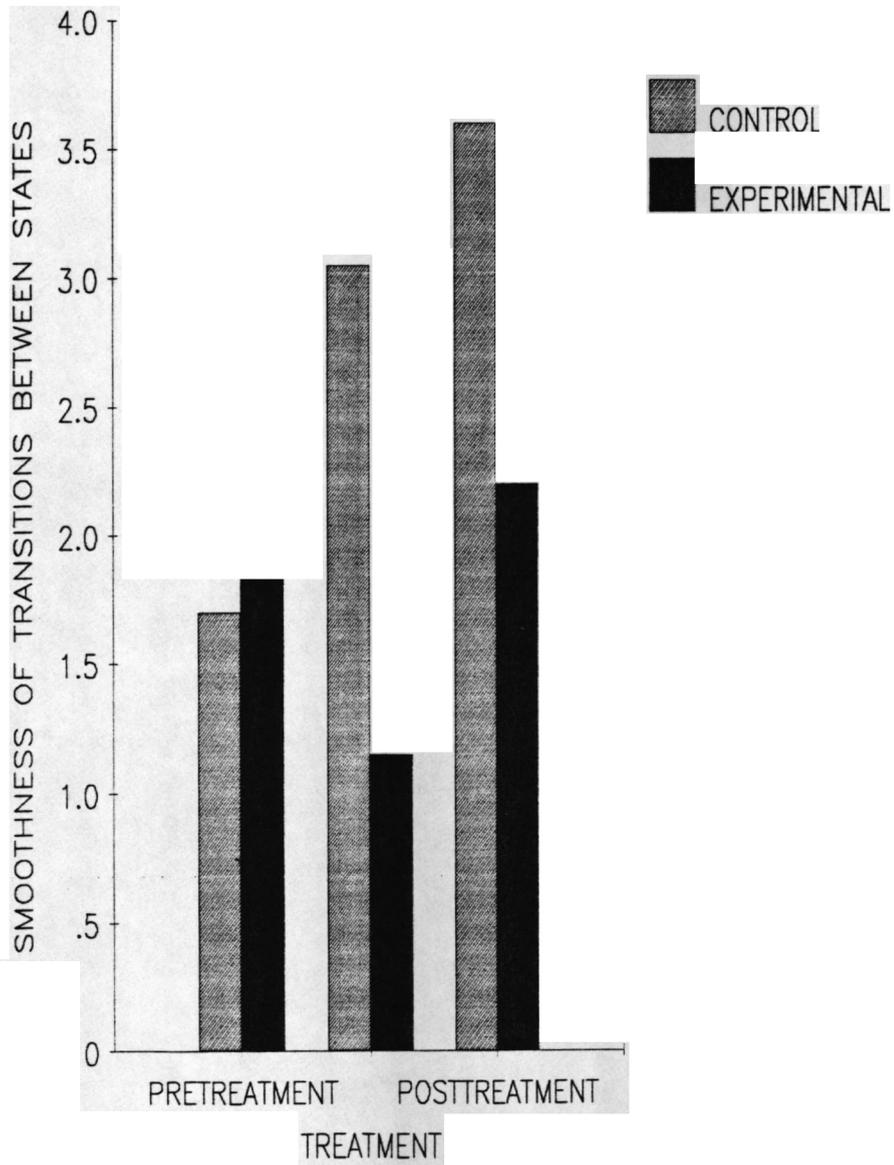


Figure 7. Mean Smoothness of Transitions Between States scores for the three treatment periods.

Table 6.

MANOVA for the Range of States, Stability of States and the Smoothness of Transitions Between States

Source	df	Wilks	F	p <
Group	3	.961	.48	.694
Period	6	.675	2.64	.033
Group x Period	6	.774	1.60	.177
Huynh-Feldt corrected				
ANOVA Group x Period	2.6	.825	2.49	.076

Table 6A.

Univariate Period Effect for Range of States, Stability of States and the Smoothness of Transitions Between States

Source	Sums of Squares	df	F	p <
Range of States	1.4	2	.70	.499
Error	75.9	76		
Stability of States	83.1	2	4.64	.013
Error	680.8	76		
Smoothness of Transitions				
Between States	26.8	2	3.16	.048
Error	322.3	76		

Note: The Bonferroni corrected alpha level = .017

Table 6B.

Univariate Group x Period Interaction for Range of States, Stability of States and the Smoothness of Transitions Between States

Source	Sums of Squares	df	F	p <
Range of States	5.4	2	2.70	.073
Error	75.9	76		
Stability of States	53.4	2	2.98	.057
Error	680.8	76		
Smoothness of Transitions				
Between States	22.8	2	2.69	.074
Error	322.3	76		

Note: The Bonferroni corrected alpha level = .017

Posttreatment Period, though this effect was nominal at the Bonferroni corrected significance level.

In addition, the multivariate analyses examining the Range of States, Stability of States and the Smoothness of Transitions Between States revealed a nominal difference in the Group by Period interaction using the Huynh-Feldt correction of the ANOVA approach to repeated measures (Wilks=.825, $F(2.6,63)=2.49$, $p<.076$); although, the MANOVA approach to repeated measures for the Group by Period interaction indicated no reliable differences (Wilks=.774, $F(3.66)=1.60$, $p<.177$). Nominal univariate Group by Period interactions were then found for the Range of States, Stability of States and the Smoothness of Transitions Between States when the Bonferroni correction was not considered (see Table 6B). Newman-Keuls pairwise comparisons were performed on the dependent variables as exploratory analyses. These comparisons showed that the infants in the Experimental Group had greater Stability of States during the Pretreatment Period compared with the infants in the Control Group during the Pretreatment Period. In addition, the infants in the Experimental Group had greater Stability of States and Smoother Transitions Between States during the Treatment Period than the infants in the Control Group during the Posttreatment Period. The infants in the Experimental Group also had greater Stability of States during the Treatment Period than during the Posttreatment Period. No reliable pairwise differences were found for the Range of States. Because of the nominal nature of the overall analyses these post hoc comparisons should be interpreted cautiously.

These results showed that as the 90 minute observation progressed infants in both the Experimental and the Control Groups displayed less Stability of States and fewer Smooth Transitions Between States. In addition, tentative support was found to suggest that while infants were held and rocked they displayed greater Stability of States and Smoother Transitions Between States.

Mean Heart Rate and Heart Rate Standard Deviation

The Group means and standard deviations of the infants' Mean Heart Rate and Heart Rate Standard Deviations are presented in Table 7 (also see Figures 8 and 9). The multivariate analysis of Mean Heart Rate and Heart Rate Standard Deviation revealed a reliable Group by Period interaction using the Huynh-Feldt correction of the ANOVA approach to repeated measures (Wilks=.8595, $F(2.6,98)=2.95$, $p<.043$); although the MANOVA approach to repeated measures revealed a nominal Group by Period interaction (Wilks= .8027, $F(4,35)=2.15$, $p<.095$). A reliable univariate Group by Period interaction was then found for both Mean Heart Rate and Heart Rate Standard Deviation using the Bonferroni correction for interpreting significance (see Table 8).

Newman-Keuls pairwise comparisons were considered appropriate because sphericity was not violated (Mean Heart Rate Huynh-Feldt epsilon = 1.0; Heart Rate Standard Deviation Huynh-Feldt epsilon = .93). Pairwise comparisons of the Mean Heart Rate revealed that during the Pretreatment Period infants in the Experimental Group had reliably lower Mean Heart Rates compared with infants in the Control Group during the

Table 7.

Means and Standard Deviations of the Infants Mean Heart Rate and Heart Rate Standard Deviation

	Pretreatment		Treatment		Posttreatment	
	Mean	(St.Dev.)	Mean	(St.Dev.)	Mean	(St.Dev.)

Mean Heart Rate						
Control	127.8	(11.6)	133.0	(11.4)	131.1	(12.8)
Experimental	124.7	(12.9)	121.9	(11.7)	124.8	(13.8)
Heart Rate Standard Deviation						
Control	12.0	(7.25)	14.9	(10.7)	13.6	(7.6)
Experimental	12.6	(7.11)	9.3	(5.8)	12.6	(7.1)

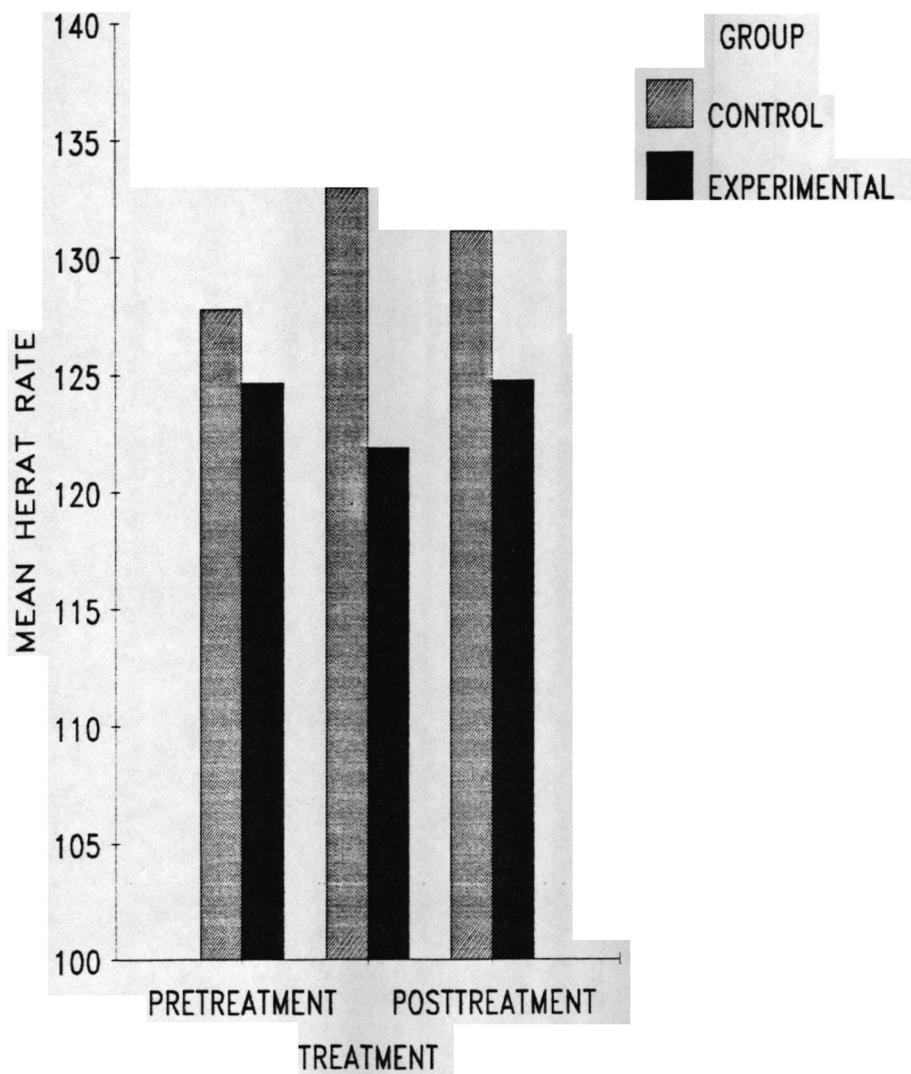


Figure 8. Mean of the infants' mean heart rate for the three treatment periods.

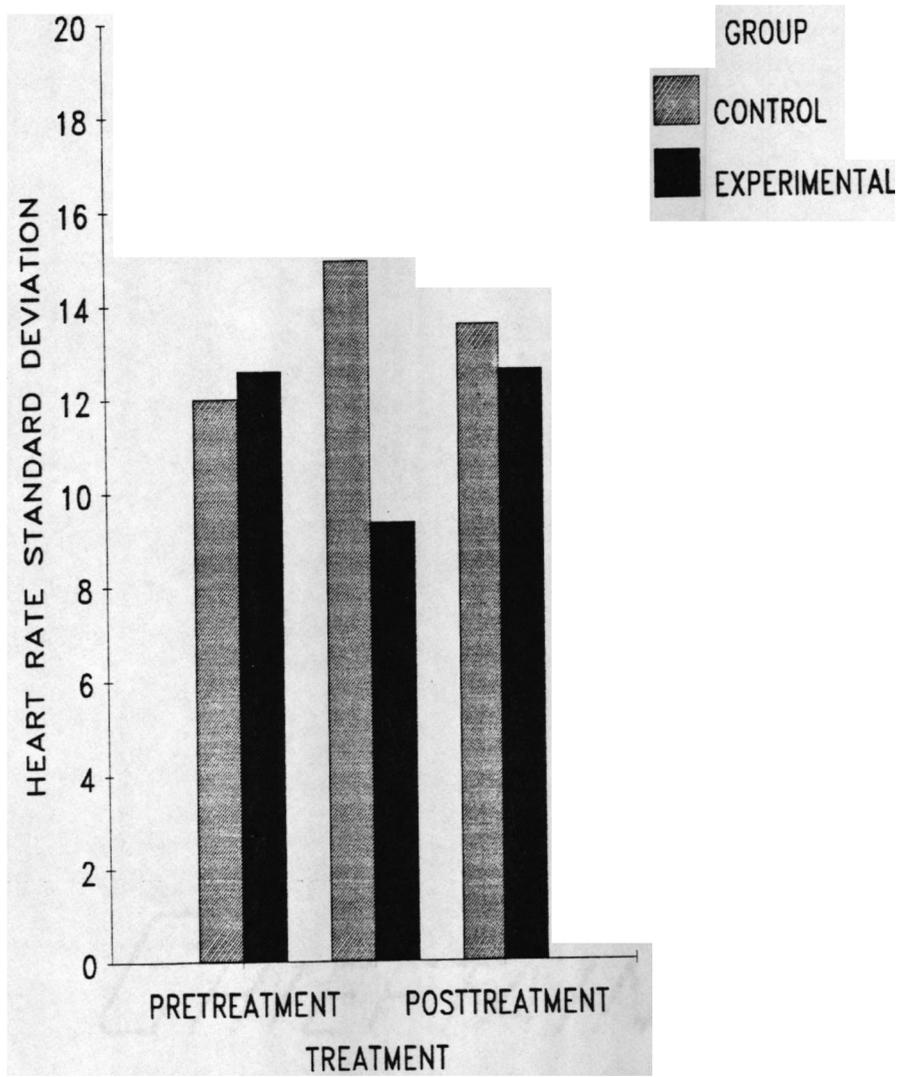


Figure 9. Mean of the infants' heart rate standard deviation for the three treatment periods.

Table 8.

MANOVA for Means and Standard Deviations of the Infants Mean Heart Rate and Heart Rate Standard Deviation

Source	df	Wilks	F	p <
Group	2	.887	2.35	.109
Period	4	.926	.70	.600
Group x Period	4	.803	2.15	.095
Huynh-Feldt corrected				
ANOVA Group x Period	2.6	.859	2.95	.043

Table 8A.

Univariate Group x Period Interaction Mean Heart Rate and Heart Rate Standard Deviation

Source	Sums of Squares	df	F	p <
Mean Heart Rate	322.2	2	3.22	.045
Error	3797.8	76		
Heart Rate Standard Dev.	205.9	2	5.94	.004
Error	1317.2	76		

Pretreatment, Treatment, and Posttreatment Periods. In addition, during the Posttreatment Period infants in the Experimental Group had reliably lower Mean Heart Rates compared with infants in the Control Group during the Treatment and Posttreatment Periods. Finally, the pairwise comparisons revealed that during the Treatment Period the infants in the Experimental Group had reliably lower Heart Rate Standard Deviations compared with the infants in the Control Group during all three Periods and compared with the infants in the Experimental Group during the Pretreatment and Posttreatment Periods.

These results showed that during the Treatment Period infants in the Experimental Group displayed lower Mean Heart Rates compared with infants in the Control Group during the Treatment and Posttreatment Periods. During the Treatment Period infants in the Experimental Group also displayed lower Heart Rate Standard Deviations compared with all other Periods for infants in both the Control and Experimental Groups. Finally, during the Posttreatment Period infants in the Experimental Group displayed lower Mean Heart Rates compared with infants in the Control Group.

Number of Peaks and the Frequency of the Highest Peak in the spectral density function of Heart rate

The multivariate analyses on the Number of Peaks in the spectral density of heart rate and the Frequency of the Highest Peak in the heart rate spectral density showed no reliable differences (see Table 9 and Figures 10 and 11). Although some infants in both the Experimental and

Table 9.

MANOVA for Number of Peaks and the Frequency of the Highest Peak in the Spectral Density of Heart Rate

Source	df	Wilks	F	p <
Group	2	.981	.35	.706
Period	4	.977	.20	.939
Group x Period	4	.971	.26	.899

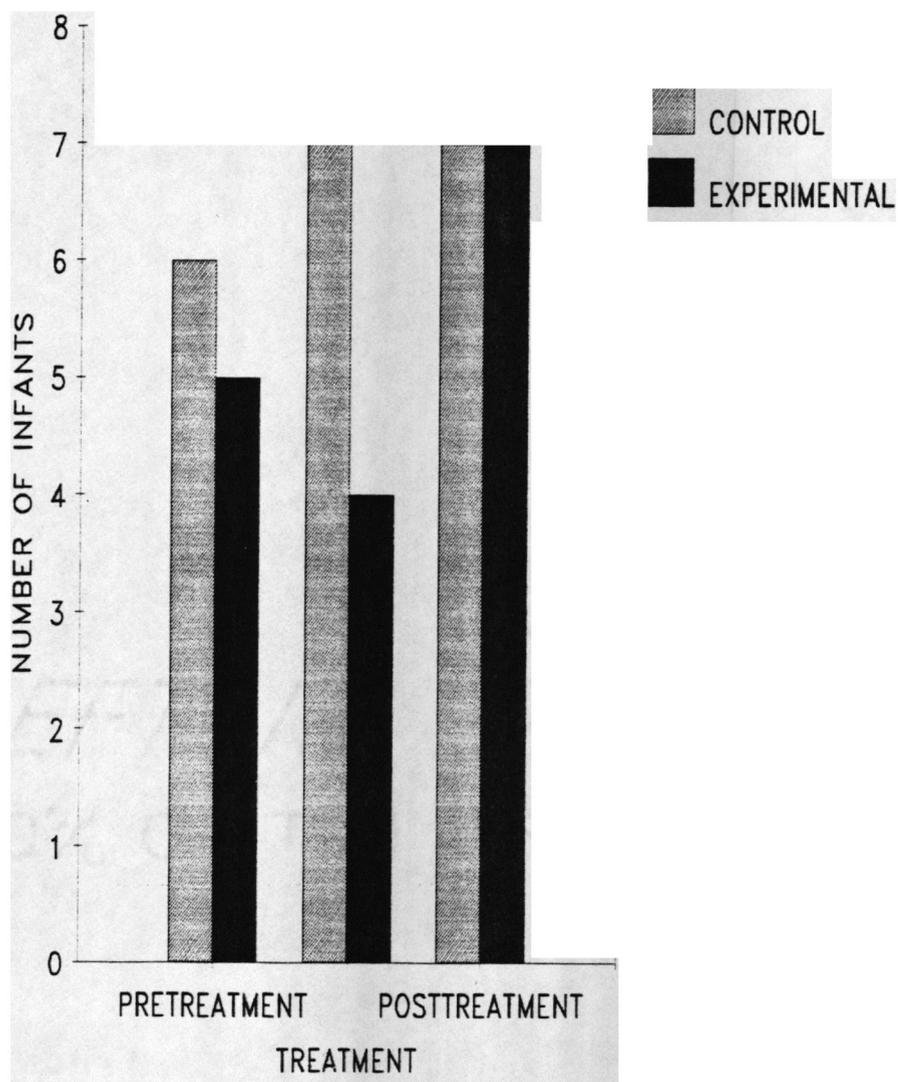


Figure 10. Number of infants with significant peaks in the spectral density function of their heart rate.

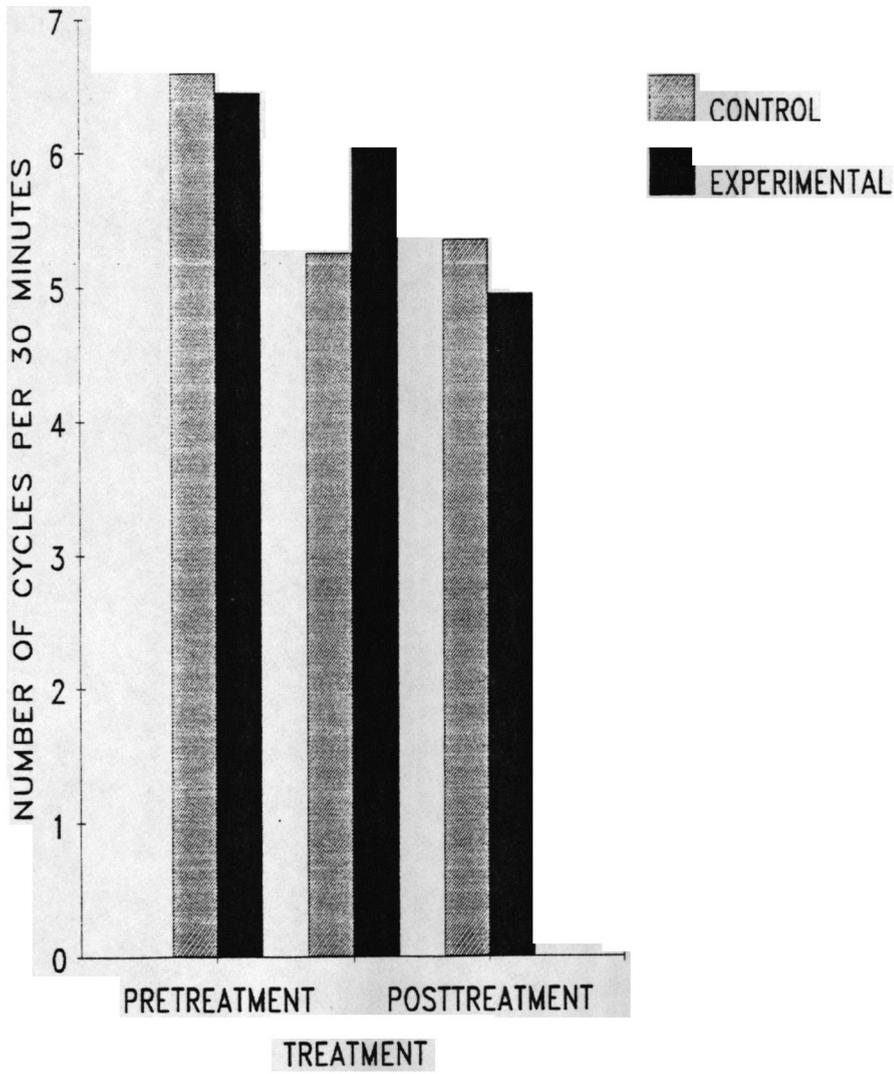


Figure 11. Mean frequency of the highest peak in the spectral density function of infants' heart rate.

Control Groups had spectral peaks above the confidence interval for white noise, neither of these dependent variables appeared to differentiate between the infants in the Control and Experimental Groups.

Mean Heart Rate Within states

As noted in the methods section five (5) 2 (Control and Experimental Groups) by 3 (Pretreatment, Treatment and Posttreatment Periods) repeated measures designs were conducted (one analysis for each of the five behavioral states) to examine Mean Heart Rate Within State. Therefore, an alpha level of .01 was accepted as evidence of a reliable difference in these analyses, and an alpha level of .05 was accepted as evidence of a nominal difference in these analyses. The five analyses of Mean Heart Rate Within the States revealed a reliable difference in the Group by Period interaction for the Quiet Sleep State ($Wilks=.510$, $F(2,18)=8.64$, $p<.002$), and a nominal Group by Time interaction during the fuss-cry state using the corrected ANOVA approach ($F(2,12)=4.30$, $p<.039$). The Newman-Keuls procedure was considered appropriate for both quiet sleep (Huynh-Feldt epsilon = .87) and the fuss-cry state (Huynh-Feldt epsilon = 1.0). The pairwise comparisons indicated that during the Pretreatment Period the infants in the control group displayed higher Mean Heart Rates Within the Quiet Sleep State compared with infants in the Experimental Group. In addition, during the Pretreatment Period infants in the Control Group displayed higher Mean Heart Rates

Within the Fuss-Cry State compared with infants in the Experimental Group.

These differences in the Pretreatment period may be the result of a self-selection process produced by the requirement of attaining the state during all three 30 minute Periods. Thus, two t-tests, one for the heart rate mean of all infants displaying epochs in the Quiet Sleep State during the Pretreatment Period (15 infants in the Control Group and 15 infants in the Experimental Group), and another for the heart rate mean of all infants displaying epochs in the Fuss-Cry State during Pretreatment Period (7 infants in the Control Group and 7 infants in the Experimental Group) were conducted. These two analyses showed no reliable differences (Quiet Sleep State, $t(28)=0.71$, $p<.50$; Fuss-Cry state, $t(12)=1.30$, $p<.22$). Taken together these findings indicate that holding and rocking infants affected the behavioral states in such a way that the infants who were observed to have epochs in the Quiet Sleep State or the Fuss-Cry State during all three Periods in the Experimental Group were different from the infants meeting the same criterion in the Control Group.

In order to further explore the Mean Heart Rate Within each State 15 independent t-tests were conducted comparing all the infants in the Experimental and Control Groups who displayed at least one epoch in the state. These tests revealed that during the Treatment Period infants in the Experimental and Control Groups had different Mean Heart Rates Within the Active Sleep State ($t(37)=2.15$, $p<.04$; infants in the control group had higher mean heart rates), and during the Posttreatment Period

infants in the Experimental and Control Groups had different Mean Heart Rates Within the Quiet Alert State ($t(12)=3.07$, $p<.01$; infants in the Control Group had higher mean heart rates). All other comparisons were non-significant ($\alpha > .15$). Given the number of tests conducted and the lack of a consistent pattern of differences across states these findings must be interpreted cautiously.

The analyses for Mean Heart Rate Within States revealed that holding and rocking infants affected the behavioral states in such a way that the infants who were observed to have epochs in the Quiet Sleep State or the Fuss-Cry State during all three Periods in the Experimental Group were different from the infants meeting the same criterion in the Control Group. In addition, a very tentative conclusion would be that during the Treatment Period the infants in the Experimental Group displayed lower Mean Heart Rates while the infants were in the Active Sleep State, and during the Posttreatment Period infants in the Experimental Group displayed lower Mean Heart Rates while the infants were in the Quiet Alert State.

Incidence of Pacifier use between Groups

As pointed out earlier, infants who cried for longer than 2 continuous minutes were given a pacifier. In order to examine the distributions of pacifier use between infants in the Control and the Experimental Groups chi-square analyses were conducted. Three chi-square analyses examined the distribution of infants who cried for 2 continuous minutes during each of the three Periods comparing the

infants in the Control and Experimental Groups (see Table 10). These analyses showed no reliable differences during the Pretreatment Period ($X^2(1)=0.53$, $p>.46$). However, during the Treatment Period a reliable difference was found ($X^2(1)=7.02$, $p<.008$), and during the Posttreatment Period a nominal difference was found ($X^2(1)=3.13$, $p<.077$).

These chi-square analyses suggest that holding and rocking infants decreased the likelihood that the infants cried for 2 continuous minutes and hence received a pacifier. The effect of holding and rocking infants was still evident during the 30 minutes following the cessation of the holding and rocking stimulus.

Because of the differential incidence of infants who cried for 2 continuous minutes and hence received a pacifier in the Control and the Experimental groups, and in order to evaluate these potential effects, the four main analyses were conducted with three groups. Group one contained 16 infants in the Experimental Group who did not cry for 2 continuous minutes. A second group contained 10 infants in the Control Group who did not cry for 2 continuous minutes, and the third group contained 10 infants in the Control Group and who cried for at least 2 continuous minutes. All the original Group (Control and Experimental) by Period (Pretreatment, Treatment and Posttreatment) interactions remained significant or nominal (Tables 11, 12, 13 and 14). Newman-Keuls comparisons revealed that for all pairwise comparisons, the infants in the Control Group who did not cry for 2 continuous minutes were not reliably different from the infants in the Experimental Group.

Table 10.

Number of Infants who Cried for 2 Continuous Minutes in the Control and Experimental Groups

Period	Control	Experimental	X ²	p <
Pretreatment				
(Cry/no cry)	6/14	4/16	.53	.46
Treatment				
(Cry/no cry)	8/12	1/19	7.02	.008
Posttreatment				
(Cry/no cry)	8/12	3/17	3.13	.077

Table 11.

MANOVA of Number of Epochs Infants Spent in Each State with 3 Groups

Source	df	Wilks	F	p <
Group	8	.527	2.83	.010
Period	8	.655	1.72	.142
Group x Period	16	.407	1.84	.050

Table 11A.

Univariate Group x Period Interactions for the Number of Epochs Infants Spent in Each State with 3 Groups

Source	Sums of Squares	df	F	p <
Quiet Sleep	2186.5	4	1.83	.134
Error	19730.2	66		
Active Sleep	3048.2	4	3.59	.010
Error	14012.2	66		
Quiet Alert	411.7	4	2.89	.029
Error	2353.1	66		
Fuss-Cry	527.5	4	4.69	.002
Error	1853.3	66		

Table 12.

MANOVA for Stability of States and the Smoothness of Transitions Between States with 3 Groups

Source	df	Wilks	F	p <
Group	6	.528	3.88	.002
Period	6	.689	2.11	.084
Group x Period	12	.600	1.36	.213
Huynh-Feldt corrected				
ANOVA Group x Period	5.4	.698	2.05	.075

Table 12A.

Univariate Group x Period Interaction for Range of States, Stability of States and the Smoothness of Transitions Between States with 3 Groups

Source	Sums of Squares	df	F	p <
Range of States	9.0	4	2.54	.048
Error	58.8	66		
Stability of States	105.0	4	3.19	.019
Error	543.6	66		
Smoothness of Transitions				
Between States	59.2	4	3.63	.010
Error	269.0	66		

Table 13.

MANOVA for Means and Standard Deviations of the Infants Mean Heart Rate and Heart Rate Standard Deviation With 3 Groups

States				
Source	df	Wilks	F	p <
Group	4	.576	5.08	.001
Period	4	.944	.44	.776
Group x Period	8	.565	2.48	.022

Table 13A.

Univariate Group x Period Interaction Mean Heart Rate and Heart Rate Standard Deviation with 3 Groups

Source	Sums of Squares	df	F	p <
Mean Heart Rate	849.7	4	4.50	.003
Error	3117.3	66		
Heart Rate Standard Dev.	358.6	4	6.17	.001
Error	957.7	66		

Table 14.

MANOVA for Number of Peaks and the Frequency of the Highest Peak in the Spectral Density of Heart Rate with 3 Groups

Source	df	Wilks	F	p <
Group	4	.664	3.63	.010
Period	4	.956	.34	.848
Group x Period	4	.811	.83	.582

Thus, the between group differences presented in the original analyses above appear to reflect differences between the infants in the Experimental Group and the infants in the Control Group who cried for 2 continuous minutes. Additional analyses between the infants in the Experimental Group who did not cry for 2 continuous minutes and infants in the Experimental Group who did cry for at least 2 continuous minutes did not reveal reliable differences; although, due to the small number of infants in the Experimental Group who cried for 2 minutes ($n=4$) confidence cannot be placed in these analyses.

Interestingly, when the MANOVA for Number of Peaks and the Frequency of the Highest Peak in the spectral density function of heart rate was conducted with three groups, that is, infants in the Experimental Group who did not cry for 2 continuous minutes, infants in the Control Group who did not cry for 2 continuous minutes, and infants in the Control Group and who cried for at least 2 continuous minutes, reliable Group differences are found ($Wilks=.683$, $F(4,64)=3.36$, $p<.015$) (see Table 13). An examination of the univariate contrasts revealed reliable differences across the three Group for the Number of Peaks in the spectral density function of heart rate ($F(2,33)=7.45$, $p<.002$). No reliable differences were found in the univariate contrast for the Frequency of the Highest Peak in the spectral density function of heart rate ($F(2,33)=1.80$, $p>.18$). Newman-Keuls pairwise comparisons revealed that the infants in the Control Group who cried for 2 continuous minutes were reliably different compared with either the infants in the

Experimental Group or the infants in the Control Group who did not cry for 2 continuous minutes.

Inspection of the data indicated two interesting phenomena, first infants in both the Control and the Experimental Groups who were observed to have at least one epoch in the Fuss-Cry State were more likely to have a significant peak in the spectral density function of heart rate, regardless of whether they received a pacifier or not. Secondly, none of the infants displaying significant peaks in the spectral density function of heart rate had more than one significant peak. Thus, chi-square analyses were conducted to examine the distribution of infants who had a significant peak in the spectral density function of heart rate and the infants who displayed epochs of the Fuss-Cry State. These analyses showed that the infants who displayed at least one epoch in the Fuss-Cry State were more likely to display a significant peak in the spectral density function of heart rate during all three periods (Pretreatment Period, $X^2(1)=7.34$, $p<.007$; Treatment Period, $X^2(1)=7.59$, $p<.006$; Posttreatment Period, $X^2(1)=5.67$, $p<.017$).

Discussion

The results of this study support and extend previous reports where infants who received tactile and vestibular-proprioceptive stimulation displayed evidence of increased organization in behavioral state and heart rate. Whereas previous studies have examined either the immediate effects or the long term benefits of stimulation on infants, the current study examined the immediate effects of stimulation on infants and the residual effects of stimulation measured during the 30 minutes directly following the cessation of the stimulation. The results of the present study showed that when infants were held and rocked they spent less time in a combined Fuss-Cry State, and tentatively they displayed Smoother Transitions Between States and greater Stability of States -- as defined by fewer brief state interruptions surrounding state transitions and fewer brief state interruptions. Following the cessation of the rocking stimulus more infants spent at least some time in Quiet Sleep. In addition, infants who were held and rocked displayed a lower Mean Heart Rate and Heart Rate Standard Deviation during the rocking. A lower Mean Heart Rate was still found after the cessation of the rocking. Tentatively, the infants who were rocked also displayed a lower Mean Heart Rate while the infant was in Active Sleep, and in the Posttreatment Period a lower Mean Heart Rate while the infant was in Quiet Alert. Finally, while the infants were rocked they were less likely to cry for at least 2 continuous minutes, thus decreasing the need for other forms of intervention or pacification. During the Posttreatment Period infants who were rocked were also less likely to cry for at least 2 continuous minutes.

Behavioral state

The behavioral states of infants were the most clearly altered by the presences of holding and rocking. Specifically, infants who were being held and rocked were in a Fuss-Cry State less often than infants who were not being held and rocked. This is obviously not a new finding. It would have been surprising and counterintuitive if a reduction in fussing and crying was not found. Mothers routinely rock their infants in order to calm them (Bowlby, 1969). However, the decreased amount of time infants spent in a Fuss-Cry State did not translate into a decrease in the 30 minutes following the cessation of rocking. This extends the findings of Pederson and Ter Vrugt (Pederson, 1975; Pederson & Ter Vrugt, 1973; Ter Vrugt & Pederson, 1973) who reported that reduced states of agitation present during rocking were not reliably found 10 minutes following the cessation of the stimulation.

Interestingly, the current study seemed to conflict with some previous findings where infants who were rocked were found to spend more time in the Quiet Alert State (Gregg, et al., 1976; Korner, 1964; Korner & Grobstein, 1966). Instead, the current study provided some support for the premise put forth by Koniak-Griffin and Ludington-Hoe (1987) that tactile and vestibular-proprioceptive stimulation decrease the infants' ability to interact with the external environment. In the current study there was a nominal trend across the 90 minute observation for the infants in the Experimental Group to spend less time in the Quiet Alert State, while an increase in the Quiet Alert State was

exhibited for infants who were in the Control Group. In addition, during the Treatment Period fewer infants in the Experimental Group had at least one epoch observed in the Quiet Alert State as compared with infants in the Control Group.

Infants have also been shown to spend more time in the Quiet Alert State when they suck on a pacifier (Field & Goldson, 1984). Thus, giving a pacifier to infants who cried for 2 continuous minutes may have increased the amount of time these infants spent in the Quiet Alert State. A comparison of the infants in the Control Group who received a pacifier and infants in the Control Group who did not receive a pacifier showed that pacifier use may have increased the infant's time in the Quiet Alert State. However, this does not explain why the infants in the Experimental Group displayed a decrease in the amount of time in the Quiet Alert State, a finding that conflicts with previous reports.

Several procedural differences could explain why earlier studies found that while infants are rocked they spend more time in the Alert States while the current study found that infants who were rocked spent less time in the Quiet Alert State. For example, in Gregg, et al. (1976) the vestibular-proprioceptive stimulation began when infants were in a Quiet Alert State and the entire procedure lasted approximately 10 minutes. In another study, Korner and Grobstein (1966) picked-up and rocked infants when they were initially crying. In the current study rocking began after 30 minutes of observation regardless of the child's behavioral state and lasted 30 minutes. In addition, in both the current study and in the Koniak-Griffin and Ludington-Hoe (1987) study,

the vestibular-proprioceptive stimulation infants received was relatively mild: that is, the acceleration was low and the displacement was no more than 10 inches. Milder forms vestibular-proprioceptive stimulation may not produce as much of an alerting response in infants, but rather may serve to calm the infant. This seems to be the case with several studies using milder forms of stimulation, which have also failed to find an alerting response to rocking stimulation in preterm infants (Barnard, 1973; Edelman, et al., 1982; Korner, et al., 1982; Korner, et al., 1983). Thus, the procedural differences regarding the infants' initial state, the length of the stimulus presentation, and the mild form of vestibular-proprioceptive stimulation may explain why infants who were rocked did not spend more time in the Quiet Alert State.

A second apparent conflict with previous findings was that the infants who were rocked did not display more time in either Quiet Sleep or Active Sleep when compared with infants in the Control Group. Although there was a nominal difference in the amount of time infants spent in Active Sleep, pairwise comparisons failed to identify reliable differences between cells. In previous reports preterm infants placed on oscillating waterbeds or gently rocking beds were found to spend more time in Quiet Sleep and Active Sleep (Barnard, 1973; Edelman, et al., 1982; Korner, et al., 1982; Korner, et al., 1983). The conflicting results between previous studies and the current study may reflect a difference in the way preterm and full-term infants respond to vestibular-proprioceptive stimulation. Alternatively, the type of

stimulation provided infants in previous studies may have been more soothing than in the current study where the infants were held and rocked.

The conflicting findings for the amount of time infants spend in Quiet Sleep or Active Sleep again cannot be attributed to the effects of giving some infants a pacifier. Infants who suck on pacifiers have been found to spend more time in quiescent states (Field, 1986; Woodson, Drinkwin & Hamilton, 1985). However, the infants in the current study who cried for at least 2 continuous minutes and hence received a pacifier, spent less time in either of the two sleep states during the Treatment period. In addition, during the Posttreatment Period the infants who received a pacifier spent reliably less time in the Active Sleep State than the infants in the Experimental Group or the infants in the Control Group who did not receive a pacifier.

Holding and rocking infants did, however, alter one measure of the sleep states. All 20 of the infants in the Experimental Group spent least one epoch in Quiet Sleep during the Posttreatment Period, whereas a significant number of infants in the Control Group did not reach Quiet Sleep. Several studies have reported that infants spend more time Quiet Sleep while presented with vestibular-proprioceptive stimulation (Barnard, 1973; Edelman, et al., 1982; Korner, et al., 1982; Korner, et al., 1983). However, no known studies have reported either an increase of the amount of time in Quiet Sleep after the removal of the stimulus, or an increase in the number of infants showing epochs of Quiet Sleep following the removal of a stimulus. An inspection of number of the

infants in the Experimental Group who were observed to have epochs in Quiet Sleep revealed a trend across the 90 minute observation where more of the infants had at least one epoch of the Quiet Sleep State as the observation progressed. No reliable trends were found for infants in the Control Group.

Several reports have noted that as more time since the last infant feeding elapses, infants spend more time fussing and crying and less time quietly sleeping (Emde & Koenig, 1969; Wolff, 1966). The infants in the Control Group somewhat fit this pattern of state occurrences. Infants in the Control Group spent more time in both the Quiet Alert and the Fuss-Cry State as the 90 minute observation progressed. However, not all infants in the Control Group fit this pattern. A subgroup of 10 infants in the Control Group spent more time in Quiet Alert, Fuss-Cry during the last 30 minutes of observation, while the remaining 10 infants in the Control Group did not display these reliable differences. The subgroup of infants who fit the pattern cried for at least 2 continuous minutes at some point during the 90 minute observation period and hence received a pacifier. A comparison of the infants in the Control Group who cried and those who did not, based on demographic information, failed to identify differences between the two subgroup.

Besides the above findings on number of epochs in various states the infants in both the Experimental and Control Groups displayed greater Stability of States and Smoother Transitions Between States during the initial 30 minute Pretreatment Period than during the final 30 minute Posttreatment Period. Although not reported previously, this

finding appears to be another effect induced by the time elapsed since the last infant feeding. A nominal difference was also found between infants in the Experimental Group and infants in the Control Group during the Treatment Period on the measures of Stability of States and Smoothness of Transitions Between States. A tentative conclusion would be that rocking increases the stability of the behavioral states and the smoothness of state-to-state transitions, as predicted (Barnard, 1987; Horowitz, 1987). However, no reliable between group differences were found in the Posttreatment Period in either Stability of States or Smoothness of Transitions Between States. Interestingly, infants in the Control and the Experimental Groups did not differ in the Range of States; although, Barnard and Bee (1983) have found a greater Range of States in rocked infants. In contrast to the current study, Barnard and Bee used preterm infants, a slightly different form of rocking stimulation, and measured the range of states using the NBAS. Any one of these three differences may explain why Barnard and Bee found a greater Range of States but the current study did not.

Heart rate

Picking-up, holding and rocking infants also altered measures of the infants' heart rate. Both Mean Heart Rate and Heart Rate Standard Deviation were significantly lower while infants were being held and rocked when compared with infants in the Control Group during the Treatment Period. During the Posttreatment Period, infants in the Experimental Group displayed lower Mean Heart Rates than infants in the

Control Group. These findings are in line with previous reports where repetitive and continuous stimulation decreased infants' heart rate and increased the regularity of the infants' heart rate (Brackbill, 1971, Brackbill, Adams, Crowell & Gray, 1966). Interestingly, Hofer (1984) has noted that primate and rat infants show an increased heart rate during the first few hours of isolation where they lack both external tactile and vestibular-proprioceptive stimulation. In addition, Seiler and his associates (1979) noted that primate infants responded to maternal holding and rocking with a deceleration in heart rate. Thus, heart rate deceleration in response to holding and rocking can be found across several species.

However, group means comparing infants in the Experimental and Control Groups did not find differences in the Number of Peaks in the heart rate spectral density function, or the Frequency of the Highest Peak in the heart rate spectral density function. Although some infants in both the Experimental and the Control Groups displayed spectral peaks above the confidence interval for white noise, there was no evidence that the rocking stimulus altered these patterns.

This particular pattern of results is consistent parasympathetic activation. Specifically, the decreased Mean Heart Rate mean during both the Treatment and Posttreatment periods indicates of parasympathetic activation. However, the results also supports the hypothesis of an increased balance in the homeostasis process between parasympathetic and sympathetic systems during the holding and rocking. If the decreased Heart Rate Standard Deviation was due only to the

parasympathetic activation then heart rate standard deviation should be more closely tied to the mean heart rate. This was not the case. Unfortunately, the Number of Peaks in the Spectral Density Function of Heart Rate was not significant in either the Treatment or the Posttreatment periods. If there were significantly more peaks in heart rate spectral density function during the Treatment period, when the Heart Rate Standard Deviation was decreased, then there would have been the greatest support for the hypothesis of increased balance. Because of the strong relationship between behavioral state and heart rate in human infants, several have authors argued that Heart Rate Within States provides clearer information on the effect of stimulation on heart rate (Campos & Brackbill, 1973; Dehann, et al., 1977; Harper, et al., 1976; Pomerleau & Malcuit, 1981; Von Bargen, 1983). The results of analyses on Heart Rate Within States did not identify a consistent pattern of results such as would be found if several states displayed higher or alternatively lower mean heart rates. However, the infants in the Experimental Group displayed lower Mean Heart Rates Within the Active Sleep State during the Treatment Period compared with infants in the Control Group during the Treatment Period. In the Posttreatment Period infants in the Experimental Group displayed lower Mean Heart Rates Within the Quiet Alert State compared with infants in the Control Group. Although these findings should be viewed tentatively because of the number of comparisons made, the lower Mean Heart Rate Within the Quiet Sleep State during the Treatment Period was predicted a priori. In addition, this finding is compatible with previous findings showing

greater heart rate responsiveness during active sleep (Pomerleau & Malcuit, 1981; Rose, et al., 1980).

However, the finding of lower Mean Heart Rates Within the Quiet Sleep State for infants who were held and rocked contrasts with the findings of Pomerleau and Malcuit (1981) who reported heart rate accelerations due to rocking when infants were in sleeping states. Pomerleau and Malcuit argued that their findings reflect the organism's attempt to restore a homeostatic balance that is lost at the stimulus onset. Thus, infants may initially respond to rocking with heart rate acceleration, however, when initial response is averaged in across a 30 minute period this effect cannot be found. The current findings are more in line with the findings of Rose, et al. (1980) who reported that preterm infants given 13 days of tactile and vestibular stimulation displayed no reliable differences in resting heart rate during either Active or Quiet sleep.

The differential rate of pacifier use among the infants may have affected the results of Heart Rate Within States. Several authors have reported that when infants are given a pacifier, there are noticeable effects on heart rate (Gregg, Clifton & Haith, 1976; Nelson, Clifton, Dowd, & Field; 1978). A comparison of only the infants who did not receive a pacifier in both the Control and Experimental Groups helped to clarify this issue. During the Treatment Period infants in the Experimental Group who did not receive a pacifier displayed lower Mean Heart Rates Within both the Quiet Sleep State and the Active Sleep State compared with infants in the Control Group who did not receive a

pacifier. In addition, During the Posttreatment Period infants in the Experimental Group who did not receive a pacifier displayed higher Mean Heart Rates Within the Fuss-Cry State compared with infants in the Control Group who did not receive a pacifier. These differences were not found in a comparison of infants in the Control Group who received a pacifier and the infants in the Experimental Group who did not receive a pacifier. Thus, having given some infants a pacifier appeared to have lowered the Mean Heart Rate Within States for infants; however, because of the number of comparisons made and the post hoc nature of these analyses, these results should be viewed tentatively.

Rocking and the use of pacifiers

Infants who were held and rocked displayed fewer instances of extended crying compared with infants in the Control Group. This was evident in that fewer of the infants in the Experimental Group cried for at least 2 continuous minutes, and hence, reduced the incidence of pacifier use in this group. In a typical nursery environment, such as found at Montgomery Regional Hospital or Roanoke Memorial Hospital, and as found in typical home environment, newborns are generally not allowed to cry for extended periods of time without intervention. The intervention given newborns following a feeding in the hospital setting includes changing the infant's diaper, readjusting the infant's position and reswaddling, picking-up and rocking the infant, or giving the infant a pacifier. The results of the current study showed that one effect of picking-up, holding and rocking infants was to decrease the number of

infants who cried for extended periods, and hence decrease the infant's chance of receiving other forms of intervention, such as a pacifier to suck on. Previous studies have noted that providing infants with a pacifier reduced heart rate, reduced crying, and produced effects similar to rocking (Field, 1986; Field & Goldson, 1984; Gregg, et al., 1976; Nelson, et al., 1978). Thus, having provided some infants with a pacifier may have reduced the significance of the findings in the current study, however, not providing crying infants with some form of intervention would not reflect our "normal" pattern of child care in either the hospital or the home environments.

Previous studies have found that the marked and robust effects of pacifier use in infants who had recently undergone a circumcision were found to be short lived, as infants typically return to baseline levels within 25 seconds of pacifier removal (Kessen & Leutzendorff, 1963). The short lived effects of pacifier use were also evident in the current study. Infants who received a pacifier during the Pretreatment or Treatment Periods were more likely to display epochs in the Fuss-Cry State during the Posttreatment Period compared with infants who did not receive a pacifier in the Pretreatment or Treatment Periods. In contrast, although there were no reliable difference in the amount of time infants in the Control and Experimental Groups were in the Fuss-Cry State during the Posttreatment Period, during the Posttreatment Period nominally fewer infants in the Experimental Group cried for at least 2 continuous minutes compared with infants in the Control Group.

Thus another effect of picking-up, holding and rocking infants was to increase the number of infants in the Experimental Group who responded like the infants in the Control Group who did not cry for at least 2 continuous minutes. The only differences that can be identified in the dependent variables of this study between the infants in the Control Group who did not cry for at least 2 continuous minutes and the infants in the Experimental Group were the tentatively differences in Mean Heart Rate Within States.

Providing infants with tactile and vestibular-proprioceptive stimulation has generally been associated with benefits for the stimulated infant. These benefits have been shown to include more mature functioning, despite marked variability in type of stimulus given infants (Field, 1986; Barnard & Bee, 1983). An argument could be made that since the holding and rocking procedure increased the number of infants who responded like the infants in the control Group who did not cry for 2 continuous minutes, then these non-crying control infants might have been more mature or healthier than the infants in the Control Group who did cry. Inspection of the demographic and obstetric information collected in this study did not show reliable differences between the two subgroups of infants in the Control Group. This may have been partially attributable to the selection criteria that excluded most of the infants who might be considered less healthy. However, if the measures used in this study do reflect more mature functioning, as others have predicted, then, except for the decreased time infants spent in the Quiet Alert state, the current findings suggest that the infants

in the Control Group, who did not cry for at least 2 continuous minutes, were healthier or functioning at a more mature level than the infants in the Control Group who did cry. Interestingly, crying infants are the infants who nursing staff, and parents try to calm through interventions such as picking-up holding and rocking the infant.

Models of early infant development

Barnard (1987) argued that for full-term neonates effective stimulation programs modulate the behavioral states by increasing the length of time in the Quiet Alert State, increasing the Smoothness of Transitions Between States, and increasing the coherence of the physiological or biological systems within states. While Horowitz (1987) suggested that effective stimulation programs would effect full-term infants by aiding the infant in organizing their behavioral states, specifically, by increasing the state variability (Range of States), the Stability of States, and the Smoothness Transitions Between States. To the extent that the measures used in the current study measure the changes Barnard and Horowitz have referred to, the holding and rocking procedure used in the current study did result in Smoother Transitions Between States, and greater Stability of States. State variability, as defined by the Range of States, however, was not reliably different, and there was a decrease instead of an increase in the time amount of time infants in the Experimental Group were observed in the Quiet Alert State.

During the Posttreatment Period the Infants in the Experimental and Control Groups were not reliably different in the Smoothness of Transitions Between States nor the Stability of States. Only the increased number of infants in the Experimental Group who were observed in Quiet Sleep, and the fewer infants in the Experimental group who cried for at least 2 continuous minutes reliably differentiated infants in the Experimental and the Control Groups during the Posttreatment Period. Therefore, the behavioral state measures of infants during the holding and rocking stimulation seemed in line with the proposal that stimulation increases organization of the behavioral states. However, the lack of behavioral state measures differentiating infants in the Experimental and Control Groups during the Posttreatment Period did not provide support for the proposal that organization behavioral states is a residual effect of the stimulation. Instead, both of the differences noted above during the Posttreatment Period could be interpreted as a reduction in the infants' arousal level rather than an organization of the infants' behavioral states.

The perspective presented by Mason (1970) and Levine and Stanton (1984) stipulates that stimulation in the form of tactile, vestibular-proprioceptive or body heat aids the infants' in regulating their physiological arousal and maintaining their autonomic homeostasis. This regulation has been measured in infant animals through decreased motoric activity or more quiescent states, fewer calls or cries, decreased heart rates and heart rate variabilities, lower cortisol levels and lower body temperatures. The current study did find evidence of reduced arousal

for infants in the Experimental Group during the Treatment Period as expressed through less time in the Fuss-Cry State, lower Mean Heart Rates, lower Heart Rate Standard Deviations, and lower Heart Rate Within the Active Sleep State. However, the suggested difference in Mean Heart Rate Within the other states, and the differences in spectral measures of heart rate organization were not found. During the Posttreatment Period infants in the Experimental Group displayed a lower Mean Heart Rate Within the Quiet Alert State, and a lower overall Mean Heart Rate. However, during the Posttreatment Period differences between infants in the Experimental and Control Groups were not found in Heart Rate Standard Deviations, Heart Rate Within Active Sleep, Mean Heart Rate Within the other states, nor the differences in spectral measures of heart rate organization.

The lower Mean Heart Rate Within the Quiet Alert State for the infants in the Experimental Group during the Posttreatment Period compared with the infants in the Control Group was interesting, but one that was difficult to evaluate. If a Bonferroni correction was made to control experimentwise error, neither the Mean Heart Rate Within the Active Sleep State during the Treatment Period, nor the Mean Heart Rate Within the Quiet Alert State during the Posttreatment Period were significant. Then also, differences in the Mean Heart Rate Within the Quiet Alert State were not predicted based on previous research. Thus, until this finding is replicated it is difficult to interpret the meaning of this finding.

Regardless of the differences in the Mean Heart Rate Within the Quiet Alert State, the lower overall Mean Heart Rate for infants in the Experimental Group during the Posttreatment Period could reflect a residual effect of the stimulation indicating lower infant arousal levels. Alternatively, the lower mean heart rate could reflect a subtle alteration in the state system, that is more infants who displayed epochs of quiet sleep and nominally fewer infants who cried for 2 continuous minutes. Nevertheless, the lower mean heart rates, the decreased number of infants who cried continuously, and the increased number of infants who displayed epoch of the Quiet Sleep State during the 30 minutes following rocking added support to the perspective that reduced arousal is a residual effect of the rocking stimulus.

Obviously the infant's behavioral state and the infant's arousal levels are intimately interrelated. Most of the indices of altered arousal can also be interpreted as an altered of behavioral state, as can most of the indices of an altered behavioral state be interpreted as altered arousal. Because of the interrelationship of these systems, an attempt to reduce the infant's response into measures reflecting either an independent behavioral state system or an independent arousal system may not be possible. Evidence was found to support both the perspective that hold and rocking infants alters the behavioral state and the arousal level. During the follow-up period support for these perspectives was less clear. This might be seen as support for Hofer's (1987) premise that the immediate and the residual responses to stimulation reflect related but independent systems being affected.

The strongest support for this hypothesis was generated by differences not observed during the presentation of rocking, but then emerged during the Posttreatment Period. Of course, in the current study this was found in the increased number of infants displaying at least one epoch of the Quiet Sleep State and the lower Mean Heart Rate Within the Quiet Alert State. Although, these differences seemed to reflect a slightly different expression of reduced arousal rather than an independent system being affected.

Conclusions

This project is a first step in exploring how stimulation programs, and specifically holding and rocking infants, translate into the long term benefits previously reported, such as, more mature motor skills, fewer, abnormal reflexes, improved state organization, improved orienting abilities, higher mental development scores and improved mother-infant interactions. Accordingly, the current study identified measures of behavioral state and heart rate that reflect the both the effect of the stimulation and residual effects from the stimulation during the 30 minutes immediately following the cessation of the stimulus. Evidence was found to support previous proposals that both the infants' behavioral state and arousal were affected by holding and rocking infants. The clearest residual effect of holding and rocking infants appears to have been a reduction in arousal. During the newborn period when infants are still adjusting to life outside the womb, the residual reduction in arousal may be expressed through lower Mean Heart

Rates, a reduction in continuous crying, and more infants reaching quiet sleep.

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Appendix 1.

Spectral analysis is a technique that decomposes the variance of the time series into its constituent frequencies; that is, spectral analysis estimates the amount of variance in the time series that can be accounted for by sinusoidal waves of various frequencies (Bloomfield, 1976). The frequencies that this technique uses are such that the length of the series contains a whole number of cycles at each frequency. For example, the lowest frequency is zero, representing a cycle that does not vary. The next lowest frequency is one cycle per series, followed by 2 cycles per series. The frequencies that were of interest in this study were between 2 cycles per hour (a period length of 30 minutes) to 60 cycles per hour (a period length of 1 minute). For each frequency, a discrete and independent estimate, often referred to as either a spectral density estimate or a spectral power estimate, is produced. The sum of the spectral power estimates for all the frequencies is proportional to the total variance of the time series (Chatfield, 1984). The larger the spectral density estimate, the better the sinusoidal wave describes the data and the greater the percentage of variance can be accounted for by an oscillation at that particular frequency. When all the frequencies are presented together they are called the spectral density function. When a spectral power estimate of a particular frequency has a higher value than the spectral power estimate of the next highest and next lowest frequencies then this frequency is often called a peak in the spectral density function.

Appendix 2.

LETTER OF INFORMED CONSENT

Dear Parent:

Even at birth newborn infants have a temperament that makes each individual special and unique. For example, some infants sleep for most of the day and within a month start sleeping through the night. Other children appear to have more difficulty falling asleep. Many of these children will quickly fall asleep if their parents pick them up and gently rock them for several minutes; although, no one is sure why rocking a newborn helps them fall asleep.

Several infant assessment scales use a child's sleep and wake patterns to assess a child's health. In order to obtain more information on infants' sleep and wake patterns and patterns in infant heart rate, we are asking mothers' of healthy infants if they would allow us to watch their infants' heart rate and sleep and wake patterns. We would like your help by giving us permission to watch you baby.

First, we will record some of the important facts surrounding your baby's birth from the medical records. Then we will move your child to a quiet area next to the nursery and watch your baby for about one and a half hours. We will also watch the rate of your baby's heart beat and breathing as determined by a hospital heart rate and respiration monitor. During the 1 1/2 hour period some infants will be gently rocked for about 30 minutes.

We are willing answer any questions you have about this examination. Later if you think of any questions you might have about this examination, you can get in touch with either Dr. Zeskind at 231-6598, or Timothy R. Marshall at 231-6581.

I hereby agree to voluntarily participate in and allow my child to participate in the examination described above. I understand that I may withdraw from this examination at any time and prevent my baby from taking part.

(Mother's Signature) (Date)

Timothy R. Marshall (Date)

Dr. Philip Sanford Zeskind

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