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THE RELATIONSHIP BETWEEN NON-NUTRITIVE SUCKING AND RESPIRATION

IN 6- TO 8-WEEK-OLD INFANTS

by

Kimberly Gail Fisher

B.A.(Hon.), Simon Fraser University, 1986

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The Relationship between Non-nutritive Sucking

and Respiration in 6 - to 8 - week-old Infants

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ABSTRACT

Sucking, both nutritive and non-nutritive, is a potent soothing technique. Although the temporal characteristics of these two types of sucking have been documented, little research has focussed on the effects sucking has on the infant's physiological systems, especially the effects elicited by non-nutritive sucking. The temporal relationship between respiration and nutritive sucking rates has been reported to be 1:1, or completely entrained. The coordination of these rhythms may be necessary to facilitate swallowing. However, entrainment of respiration has also been reported for rocking, another soothing technique. These findings are in keeping with Lester's hypothesis which suggests that endogenous rhythms can be organized by external rhythms, thereby soothing the infant. The purpose of this investigation was to examine the effects of non-nutritive sucking on respiration rate, respiration variability, and behavioural state, and to explore Lester's hypothesis by documenting the temporal relationship between respiration and non-nutritive sucking rates. Each of 20 infants was placed in a stationary carriage. Data were recorded for a 60 second baseline period. Following the 60 seconds, once two observers agreed that the infant had fussed/cried for 30 consecutive seconds, the infant was given the opportunity to suck on a pacifier for 4 minutes, followed by a 2-minute period of no sucking. Respiration was measured by a strain gauge transducer. State was rated continuously on an 8-point scale by

two independent observers. As hypothesized, analyses of variance on the respiration data indicated that infants breathed more regularly during the Suck than during the Post-suck period. In addition, all subjects showed evidence of breathing being entrained to the speed of the sucking. However, infants showed very little 'pseudoentrainment' i.e., they did not maintain the sucking-induced respiration rhythm when sucking stopped. The hypothesized behavioural state differences were supported, with infants spending a greater percentage of time awake non-crying and a smaller percentage of time fussing/crying during the Suck period than during the Post-suck period. The results are discussed in terms of their comparison to previous findings on the relationship between respiration and nutritive sucking and the relationship between respiration and rocking.

DEDICATION

This work is dedicated to my daughter, Megan, whose expected
arrival sparked my interest in infancy research.

ACKNOWLEDGEMENTS

This work represents not only my effort, but the work of a number of individuals to whom I am most grateful.

I would like to thank the members of my committee for their advice and support over the past year. I owe a special thanks to Dr. Elinor Ames who spent countless hours editing and revising the many drafts of this thesis.

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Finally, I thank all the infants and parents who took the time to volunteer for this project.

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CHAPTER I

INTRODUCTION

It has long been recognized that most infants relax completely while being nursed or when sucking their fingers, and that even following the trauma of circumcision, young infants will relax and remain quiet when sucking on a nipple. This calming effect of sucking has been shown to be independent of the relationship to food.

Although the calming effects of soothers, such as non-nutritive sucking, rocking, and swaddling are well documented, there is as yet no adequate explanation as to how these soothers calm distressed infants. Research has begun to look to physiological changes in the infant for an explanation of the soothing phenomenon.

The purpose of the present research is to determine the effects of non-nutritive sucking, NNS, on infants' behavioural state and on the rate and variability of their respiration, and to examine the temporal relationship between NNS rate and respiration rate in order to better understand the relationship between soothing and NNS.

Characteristics of Sucking

When an infant sucks on an object, negative pressure is exerted on the object as the infant enlarges the mouth cavity through lowering the jaw while not allowing air to enter from the naso-pharyngeal cavity (Weber, Woolridge, & Baum, 1986). Electrophysiologically, the waveform produced by a suck can be defined by four characteristics: (1) overall base to peak amplitude, (2) rate of pressure decrease to peak, (3) rate of pressure recovery to base, and (4) response time or length of cycle (Kaye, 1964). The added temporal variable of interresponse time is needed to describe a sucking burst.

Various researchers use slightly different criteria for defining what thresholds a suck must meet or exceed in order to be called a suck. Kaye (1964) used the following four criteria or thresholds relating to the four characteristics of a suck respectively: (1) amplitude must exceed -7 mm of mercury (Hg), (2) change of -7 mm Hg must occur in 0.5 sec or less, (3) return from peak negative pressure must be at least 3.5 mm Hg in 1 sec, and (4) a total response cycle from base to base (or from base to beginning of next suck) must not exceed 1.5 sec.

Nutritive sucking occurs as a continuous series of slow sucks (Wolff, 1968; Hack, Estabrook, & Robertson, 1985). This pattern of slow, consistent sucking does not change across the feeding session, even towards the end of a feeding when the infant becomes satiated (Wolff, 1968).

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Non-nutritive sucking occurs as a pattern of short bursts of
-fast sucking with pauses between the bursts. The mean rate of
sucks per second is quite consistent from burst to burst.
However, within a burst, the duration of individual sucks varies
systematically, with the first sucks in a burst being shorter in
duration than the later ones (Wolff, 1968). The number of
bursts per minute increases between 26 and 37 gestational weeks,
while the duration of each burst is stable across these ages
(Hack et al., 1985). This temporal organization of NNS is very
similar to the spontaneous mouthing movements observed during
sleep when an infant has no nipple (Wolff, 1987). The
characteristic NNS sucking burst pattern cannot be produced by
adults unless decorticate or anesthetized (Wolff, 1987).

Individual consistencies in burst length and pause durations
have been found in non-nutritive sucking patterns. Kaye (1967)
noted that although individual subjects showed small minute-to
minute fluctuations, the part-whole rank-order correlations
between cumulative rates within the first minute of the first 3
minute segment of sucking and totals for either the first 3
minutes or for all 9 minutes quickly asymptoted at about r=.90,
indicating a consistent intersubject ranking.

Effects of Non-nutritive sucking

NNS affects several aspects of infant behaviour and
physiology. Following are summaries of the effects of NNS on

behavioural state and respiration.

Effects on State

Effects on behavioural state and activity level (others call it 'arousal') are well established in the literature on NNS. Several studies have demonstrated that sucking reduces and stops crying (Cohen, 1967; Gunnar, Fisch, & Malone, 1984; Levine & Bell, 1950); decreases amount of time spent in active states (Woodson, Drinkwin, & Hamilton, 1985); reduces the frequency of state transitions (Woodson et al., 1985); and increases response thresholds to external stimulation (Wolff & Simmons, 1967). Such results have been found in studies both on term (Woodson et al., 1985; Kessen, Leutzendorff & Stoutsenberger, 1967) and pre-term infants (Paludetto, Robertson, Hack, Shivpuri, & Martin, 1984; Woodson et al., 1985), and in newborn infants undergoing circumcision (Gunnar et al., 1984). In addition, NNS reduces general movement, independent of the effects attributable to the influence of NNS on behavioural state, as demonstrated by within state analyses (Cohen, 1967; Kaye, 1964; Paludetto et al., 1984; Wolff & Simmons, 1967; Woodson et al., 1985).

The extent of reduction in motor function elicited by NNS has been found to be a function of the infant's prestimulus state. The more active an infant is before intervention, the greater the resulting decrease in activity level (Woodson et al., 1985). Because of the reported effects NNS has on

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behavioural state, many of the studies have controlled for prestimulus state by requiring the infant to be in a specific state before NNS commences. This method will be used in the present study.

Effects on Respiration

A number of studies have examined the effect of NNS on respiration rate. Paludetto et al. (1984) found no change in respiration rate from 5 minutes of pre-NNS to 5 minutes NNS; however, these researchers failed to examine separately the suck versus non-suck time during the NNS period. Similarly, Mathew, Clarke, and Pronske (1985) found the overall pattern during the NNS period (suck and pause combined) not to be significantly different from respiration in a control period with respect to frequency, duration of inspiration, duration of expiration, and inspired tidal volume. However, when the sucking part of the NNS period was compared to the pause, respiration was significantly faster during sucking. There was a concurrent reduction in all other respiration measures, with the reductions in duration of expiration and inspired tidal volume reaching statistical significance. Thus, it is clear from these further results and later research by Paludetto, Robertson, and Martin (1986) that the lack of significant findings, or changes in respiration during NNS, resulted from a failure to look within the time the infant was actually sucking. Moreover, it appears that changes in respiration rate may be dependent on the length of the sucking burst. Paludetto et al. (1986) found that

respiratory rate increased significantly during NNS bursts of less than 6 s, but not in those of greater than 6 s duration. However, it is possible that there were too few samples of sucking bursts of greater than 6 s for the increased respiration during these sucking bursts to reach statistical significance.

On a more microscopic level, Dreier, Wolff, Cross, and Cochran (1979) examined the pattern of breath intervals within NNS bursts for a group of full-term infants. These researchers classified breath intervals as occuring during one of four periods: (1) non-sucking, (2) sucking onset, (3) sucking, and (4) sucking offset. The results were that infants breathed faster during sucking than non-sucking. A sex difference was noted, with females' showing greater changes in breathing rate overall. However, for both sexes, respiration for sucking offset was slower than during non-sucking, and respiration at sucking onset was not significantly different from that of non-sucking. The finding that respiration at sucking onset was not significantly different from that of non-sucking does not concur with the finding of Sameroff (1971) who found that respiration rate was significantly faster at the beginning of a burst than before sucking. This discrepancy may be a function of the definitions of 'beginning' or 'onset' of suck used in the two studies. Sameroff (1971) used a 4 second segment, while Dreier et al. (1979) used only those respirations that overlapped or spanned the first complete suck in a burst; the respiration samples in the Dreier et al. study were thus of

varying duration with a mean duration of 1.3 seconds. Although
only a mean breath duration was reported for sucking onset, it
is possible that all of Dreier et al.'s respiration samples were
less than the 4 seconds duration used by Sameroff (1971). The
short samples by Dreier et al. may, therefore, account for the
lack of significant results. Another possible explanation for
the discrepancy comes from the infants' behavioural states.
Infants in Sameroff's (1971) study were awake, while in Dreier
et al.'s (1979) study only regular sleep (state 1) episodes were
analyzed.

Dreier et al. (1979) stated that the "coupling effects
between sucking and breathing were non-linear" (p. 197), that is
to say that sucking rate and breathing rate increases and
decreases were not always concurrent. However, these
researchers noted only changes in respiration rate and failed to
indicate if there was any change in the sucking rate during a
sucking burst. Thus, the interaction between NNS rate and
respiration rate was left unclear.

As yet, no one has examined the effect of NNS on respiratory
regularity, or the temporal relationship between sucking and
breathing during bursts of sucking. However, the temporal
relationship between sucking and breathing has been examined
with respect to nutritive sucking. Peiper (1963) examined
respiration and sucking movements and stated that "if the infant
has breathed and sucked regularly at all, a definite rule can
always be deduced: One or two complete sucking movements

correspond to each respiration.... As long as the respiratory
and sucking centers function regularly, their activity is
closely coupled." (p. 421-422). It was also noted that the
transition from the original respiratory rate to the respiratory
rate during sucking was established suddenly (Peiper, 1963).
However, the data referred to were not presented.

More recently, Weber, Woolridge, & Baum (1986), using
ultrasonic equipment, found that the breathing pattern, as
measured by a breath sensor fixed to the baby's abdomen, seemed
to be uncoordinated with the nutritive sucking rhythm in 2- and
3-day-old infants; however, breathing was fully entrained to the
sucking rhythm in 4- and 5-day-old infants. The procedure for
analyzing entrainment of respiration by sucking was not clearly
stated in this study. It appears that a visual examination was
made of the respiration trace, with markers indicating nipple
indentation super-imposed, to assess entrainment.

It is possible that the entrainment of sucking and
respiration in nutritive sucking is a function of the effects of
a third variable, swallowing. Alternatively, as Peiper (1963)
suggested, sucking might organize respiration. This hypothesis
posits that since ontogenetically and phylogenetically
respiration and sucking are closely linked, intense sucking
might overpower the respiratory center and force its own rhythm
on it. NNS provides an opportunity to dissociate the three
variables, to examine the temporal relationship between sucking
and respiration independent of the effects of swallowing, and to

assess whether the alteration of breathing during sucking is predominantly due to the-sucking act.

Unfortunately, the picture of the relationship between respiration and sucking may not easily be uncovered. Sucking is not the only variable that influences respiration. Age influences respiration parameters. Both Adamson et al. (1981) and Hoppenbrouwers, Harper, Hodgman, Sternman, & McGinty (1978) have claimed that respiration shows a definite maturational pattern with rate greatest in the first postnatal week, declining thereafter, and leveling off between the third and sixth months. In the Adamson et al. (1981) study, however, the tendency for rate to decrease with increasing age was not statistically significant. Indeed, of the 4 infants examined, one showed no change and another showed a significant increase in rate with increasing age. Hoppenbrouwers et al. (1978) recorded the respiration of infants during the first postnatal week and at 1, 2, 3, 4, and 6 months of age. Although these researchers claimed that "respiration rate and variability decreased across the agespan studied" (p. 122), the data presented are not unequivocal. Respiration rates were highest during the first week of life. At months 1 and 2 the respiration rates were similar, and lower than the rate for the first week. The lowest group of similar rates were for 3, 4, and 6 months. A similar initial decline in respiration with a levelling off at 3 months was reported for respiration variability; however, the summary of variability data shows a

less obvious pattern of decline than for respiration rate. The cross-sectional findings of Curzi-Dascalova, Lebrun, & Korn (1983) also failed to support a simple linear decline in respiratory rate with increasing age. These researchers reported no significant differences among mean respiratory frequencies of three groups of infants--31-34 weeks gestational age (GA), 35-36 week GA and 37-38 weeks GA--while respiratory frequency was significantly faster for the 39-41 week GA full-term newborns than for the younger infants. Interestingly, respiratory frequency was also a function of GA at birth with those prematurely born infants reaching 37-38 weeks GA having significantly greater respiratory frequency across sleep states than that of full-term newborns of the same GA (Curzi-Dascalova et al., 1983). As noted, the infants in this study were not past the normal GA at birth; therefore, the findings do not necessarily conflict with the earlier findings of Adamson et al. (1981) and Hoppenbrouwers et al. (1978). Nonetheless, it is unclear whether or not infants' respiration rate and/or respiration variability decreases in a linear fashion during the first 3 months of life.

Respiration parameters are not independent of behavioural state. In fact, rate and variability of respiration are often used to define behavioural state. Wolff (1959), the first infant researcher to provide a descriptive categorization of states in infants, distinguished these states by differences in respiration and in type and amount of movements engaged in by

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the infants as well as by vocalizations and opening and closing of the eyes. Curzi-Dascalova et al. (1983) found respiratory frequency to be significantly greater in Active Sleep (AS) than in Quiet Sleep (QS) independent of GA or conceptional age (CA) in 35-41 week old infants. The difference in respiratory frequency between AS and QS for 30-34 week GA and 31-34 week CA was in the same direction but failed to reach statistical significance. In a study of eight infants examined repeatedly at 1 week and 1, 2, 3, 4, and 6 months of age, Hoppenbrouwers et al. (1978) reported that respiratory rate and variability were greatest when the infant was awake (except at one week of age when variability was the highest for the awake state, as for the other ages, but when the difference between respiration rate for the awake state and active sleep was virtually naught), lowest during quiet sleep, and intermediate during active sleep. It should be noted, however, that respiration variability was one of the variables used to define state in this study; the conclusion that respiration varies as a function of state is therefore not suprising, nor particularly valuable. Moreover, it is important to note that when respiration variability was examined with respiration rate held constant at 25-30 breaths per minute, variability decreased independent of respiratory rate between birth and 3 months of age in active sleep, while in quiet sleep variability remained the same once rate was controlled. This finding may be the result of changing activity levels during the active sleep state across the ages.

Authors of the studies above have made broad generalizations about the effect of age and behavioural state on respiration rate and variability, stating that infants' respiration rate decreases and regularity increases in postnatal weeks and that respiration is slower and more regular during QS than during AS. However, a thorough analysis of their results reveals numerous limitations on these generalizations that should not be overlooked. It is apparent that many variables may modulate respiration parameters. These findings nonetheless point out the necessity of considering infant behavioural state and age when attempting to accurately assess respiratory changes resulting from stimulation such as NNS.

Why does NNS soothe?

Wolff and Simmons (1967) put forward four hypotheses to account for the effectiveness of non-nutritive sucking as a soothing technique:

1. NNS reduces psychological energy. This is a formulation of the tension-reduction hypothesis; sucking serves as an outlet for stored 'negative' psychological energy.

2. NNS is associated with the satisfaction of feeding. This hypothesis has been refuted by the findings reported by Koepke and Barnes (1982) which pointed out that newborn infants offered a pacifier spent an average of 28 minutes per hour sucking. The mean rate of spontaneous finger

sucking in the control group, not offered pacifiers, ranged from 1.9 to 21.0 minutes per hour. All the infants in the experimental (pacifier) group in this study sucked on pacifiers during the first observation when they were only a few hours old and had never received nourishment via sucking, suggesting that sucking need not have been associated with previous food intake. An earlier study by Kessen et al. (1967) differentiated the pacifying effects of sucking from the association with food by studying infants prior to their first feeding. Sucking on a nipple reduced bodily movement in infants who had never been fed. Kessen et al. (1967) concluded from this work that the tendency of infants to quiet when sucking is congenitally organized and independent of the need for nutrients.

3. NNS is organized at birth in a hierarchy of dominant and subordinate motor functions, and pacifier (or nipple) sucking inhibits subordinate diffuse motility. Any intervention which blocks the self-stimulation of random diffuse motility, whether it be pacifier sucking, swaddling, or other monotonous nonpainful stimulation, reduces the infant's excitement and eventually promotes sleep.

4. Lip stimulation is a specific inhibitor of diffuse motility. This hypothesis can be viewed as a sub-hypothesis of the previous hypothesis. In this case, lip stimulation is seen as a dominant activity which blocks random motility of the fussing infant.

Another possible explanation of the soothing effect of NNS is drawn from Lester's (1985) hypothesis that external rhythms organize the infant's internal rhythms, which in turn lowers arousal and leads to more organized behaviour. More specifically, Lester (1985) hypothesized that the infant's internal rhythms, such as respiration, could be entrained, i.e., show one-to-one temporal correspondence, to external rhythms. In addition, he suggested that the infant should exhibit the greatest degree of entrainment to frequencies of oscillation that match or are multiples of his or her endogenous rhythmic timing. One way in which this hypothesis differs from hypotheses 3 and 4 above is that NNS serves to organize rather than to block or inhibit infants' activity. This hypothesis is compatible with Peiper's (1963) notion of intense sucking overpowering the respiratory center and forcing its own rhythm on it.

The present study is designed to investigate the relationship between NNS and the respiration parameters of rate and variability, as well as to examine the entrainment hypothesis. The dependent variables are behavioural state, respiratory rate, respiratory variability, and entrainment of respiration by NNS. Entrainment of respiration is defined as breathing at a rate of 1:1, 2:1, 3:1, or 4:1 compared to sucking. Respiration and behavioural state before, during, and after NNS are examined.

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The research previously reviewed regarding the relationship between respiration and NNS established that respiratory rate increases during NNS bursts of 6 seconds or less (Paludetto et al., 1986) and that respiration is faster during sucking than during non-sucking (Dreier et al., 1979). Little is known about the effect of NNS on respiratory variability, although the effects that another soother, rocking, has on this respiration variable have been examined. Ambrose (1969) reported that rocking decreased irregular respiration, but he presented no supporting data. More recently, other researchers have found that respiration is both faster and more regular during fast rocking than either before or after the rocking session (MacKinnon et al., 1986; Fisher, 1986; Elliott, Fisher, & Ames, 1988). Substantial entrainment of respiration to the speed of rocking has also been noted for most infants, suggesting, in line with Lester's (1985) hypothesis, that entrainment or organization of internal rhythms may in part account for the soothing effect of rocking (Fisher, 1986; Elliott et al., 1988).

The present study extends the work on the relationship between rocking and respiration, hypothesizing that the same relationships found between rocking and respiration will be found between NNS and respiration, namely, that respiration will be faster and less variable during NNS than either before or after the NNS period and that respiration will show evidence of entrainment to the rate of sucking.

Hypotheses

1. Infants will cry less and spend less time in active states during the period that includes NNS than during the periods that do not include NNS.

2. Respiration rate will be faster during the NNS period than during the periods that do not include NNS.

3. Respiration variability will be less during the period that includes NNS than during the periods that do not include NNS.

4. Infants will exhibit entrainment of respiration to the rate of sucking during the NNS session, both during sucking bursts and between sucking bursts.

CHAPTER II

METHOD

Subjects

The subjects were 25 6- to 8-week-old infants. All were
full-term and healthy. Three male subjects were excluded from
all analyses; two due to recording problems and one as a result
of mother intervention. In addition, two female subjects were
excluded from all analyses because a computer analysis program
repeatedly failed and was unable to retrieve sufficient data
from their respiration records. The median age at testing of
the remaining 20 subjects, 10 males and 10 females, was 49.5
days with a range of 42 to 56 days. The mean weight at birth
for the 20 subjects was 3630 g with a range of 2500 g to 4400 g.

Mothers' ages ranged from 23 to 37 (M = 29.8) and fathers'
age ranged from 24 to 42 (M = 31.6). Mothers' education ranged
from 10 to 17 years (M = 14.0 years) and fathers' education
ranged from 8 to 23 years (M = 13.9 years). These couples were
recruited from volunteer families who had returned subject
request forms distributed to four greater Vancouver hospitals.
Mothers were contacted by telephone when their infants were the
appropriate age and were given a brief outline of the
experimental procedure. Sixty-four percent of the 47 parents
contacted agreed to have their infants participate. Three data
collection sessions were cancelled, two by the experimenter and

one by a parent. Two subjects failed to arrive for scheduled data collection sessions.

Apparatus

Subjects were placed in an electrically shielded, acoustically insulated 3m x 3m room, from which the continuously collected data were transmitted to the control room. Two channels of data were collected: one channel of respiration, and a channel that recorded the infant's sucking. A digital button press was also cabled to the control room recording console.

The respiration signal was obtained from a strain gauge respiratory transducer designed at Simon Fraser by Howard F. Gabert, P.Eng., Engineering Supervisor, Psychology Department.

Equipment to measure sucking consisted of a commercially available rubber nipple (Tommee Tippee Model TT186) attached to a 3.1 m length of plastic tubing with a diameter of .5 cm and connected to a Grass Model PT5 Volumetric Pressure transducer. The air pressure changes associated with sucking were transformed into electrical signals by the pressure transducer.

Data collection and information storage were handled by a NOVA computer 3/D 96kw with a RDOS operation system and a 10 megabyte disc. To observe the data off line it could be displayed on an oscilloscope, or the digits could be printed on a line printer or plotted on an X,Y plotter. Data were

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collected at a sampling rate of .05 seconds, with a resulting Nyquist frequency of 10 Hz.

An Apple IIE computer was employed for the collection and analysis of the observers' state ratings.

Procedure

Subjects participated after being fed and changed. The parent, or parents, were briefed in the subject room. Parents then read a research information sheet (Appendix A), signed a consent form (Appendix B), and were made fully aware that they could withdraw their child at any point. Parents remained in the subject room with their infant but were requested not to make visual, auditory, or physical contact with their infant during the session.

During the data collection session each mother was asked to complete a questionnaire (Appendix C) which included questions on her infant's crying and sleeping behaviour and demographic variables.

The strain gauge belt was fastened around the infant's abdomen before the infant was placed on his or her back in the carriage. During the entire experimental session, the infant's behavioural state was rated by two independent observers who were positioned on either side of the carriage. The infant's states were continuously rated on an 8-point scale modified from

the work of Prechtl (1974):

State 1 (Quiet Sleep):

eyes closed, no body movement.

State 2 (Active Sleep):

eyes closed, body movement.

State 3 (Drowsy):

eyelids slowly opening and closing.

State 4 (Quiet Awake):

eyes open, no movement.

State 5 (Active awake):

eyes open, movement.

State 6 (Fussing):

intermittent cries and/or whimpers.

State 7 (Moderate crying):

steady moderate crying.

State 8 (Vigorous crying):

continuous uninterrupted crying, with colour change and body tension.

The infant was required to remain in each new state for a period of five seconds before the observers rated a change into that state. The rating was carried out via hand-held switch boxes containing toggle switches and connected to the Apple IIE computer.

Infant states and respiration were recorded during a Baseline period, the length of which was dependent on infant behaviour. The first 60 s of Baseline was recorded independent

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of infant state, but after that time, the first time the infant completed 30 consecutive seconds in one of state 6 or 7, he or she was judged to have met criterion and the sucking pacifier was introduced. If the infant alternated between states 6 and 7 during the baseline, the 30 seconds were counted from the beginning of the final state change, e.g., if the infant changed from state 6 to state 7, the 30 consecutive seconds were counted from the beginning of state 7. This requirement was to ensure that the criterion states were comparable across subjects and to allow grouping by criterion state (6 or 7).

Once the two observers agreed that the infant had completed 30 consecutive seconds in state 6 or 7, a computer tone sounded and the pacifier was introduced by the experimenter, who sat beside the carriage within sight of the infant. The Suck period lasted 4 minutes. If the pacifier fell out of the infant's mouth at any time during the sucking period, it was replaced by the experimenter who also indicated, via a button press linked to the main computer, when the pacifier had fallen out. The Suck period was followed immediately by a 2 minute Post-suck period during which respiration was recorded and behavioural state was coded.

CHAPTER III

RESULTS

Baseline data

Subjects spent an average of 11 minutes 41 seconds before the start of the 30 s criterion period, with a range of 60 seconds ($\underline{n}$ = 4) to 40 minutes 2 seconds.

Baseline data used for analysis included the 5 minutes prior to the start of the 30 s criterion period, or whatever portion of that 5 minutes an individual infant had completed. Because of the 60 s initial period all infants had at least one minute of baseline data. The criterion 30 s was not included in any analyses. Initially, it had been planned that subjects would be grouped by state (6 or 7) maintained during the 30 s; however, only 4 of the 20 subjects spent the 30 s criterion in state 7 and all four had less than 2 minutes of Baseline.

State

Inter-observer agreement

An ABC computer software program locally designed by H. Gabert (1982) represented data as time spent in each of the 8 states for observer 1 and observer 2 separately. For the purposes of analysis, the eight states recorded by observers were grouped into three groups:

Sleep (quiet sleep, active sleep, drowsy)

Awake non-crying (quiet awake, active awake)

Fussing/crying (fussing, moderate crying, vigorous

crying).

Inter-observer agreement was calculated with two measures: Kappa

(Cohen, 1960) and proportion of inter-rater agreement. For each

subject the three periods were combined to create an overall

Kappa and Percent Agreement. Kappas ranged from .21 to .98.

Percent agreement ranged from 71.8 to 99.5. Table 1 shows

Kappas and proportion of agreement for all subjects across all

conditions of the study.

Table 1

Overall Kappa and Percent Agreement for each subject

Males

Subject number	Kappa	Percent Agreement
1	.97	98.8
2	.50	97.2
3	.29	81.9
4	.84	92.8
5	.99	99.5
6	.95	98.3
7	.82	98.0
8	.95	96.9
9	.87	99.1
10	.98	99.5

Females

Subject number	Kappa	Percent Agreement
11	.57	78.1
12	.95	99.0
13	.85	92.7
14	.83	93.9
15	.69	90.6
16	.76	93.6
17	.21	71.8
18	.79	96.2
19	.87	99.2
20	.79	93.1

Baseline

For the purpose of describing behavioural state during the Baseline period, Baseline was divided into one-minute segments for the 5 minutes immediately preceding the 30 s criterion.

For the first minute of Baseline (n = 12), over 90% of the time was spent in the awake non-crying state-group (92.9% of which was state 5). For the second, third, and fourth Baseline minutes (n = 14 for each minute), the great majority of time was spent in the awake non-crying state-group (all of which was state 5, active awake).

During the last minute of Baseline (N = 20), the minute immediately preceding the 30 s criterion, the following state breakdowns were observed: approximately 2/3 awake non-crying (4.4% state 4 and 60.9% state 5) and 1/3 fuss/cry (25.1% state 6 and 9.6% state 7). Figure 1 shows the percentage of time in each of the three state-groups across the three periods.

Figure 1

Percent of time in Sleep, Awake non-crying, and Fussing/crying
during each of the Baseline minutes
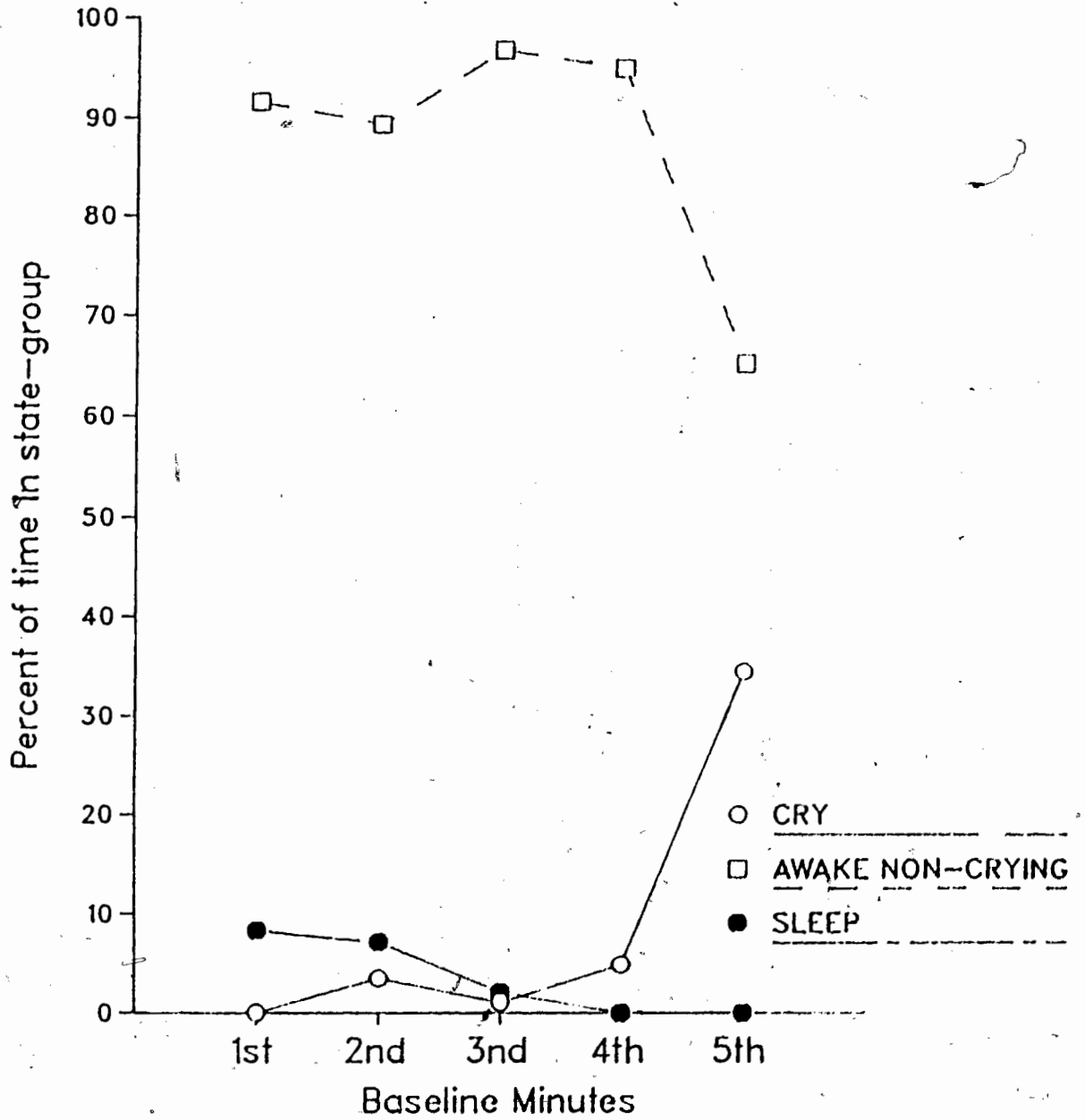
Total time (in seconds) spent in each of the three
state-groups during the Suck and Post-suck periods was
calculated for each subject. State was analyzed using a 3
factor repeated measures design. Period (Suck and Post-suck)
and States (Awake non-cry, and Fuss/Cry) were within-subject
factors and Sex was the between-subject factor (Table D-1 of
Appendix D). The Baseline period could not be included in
overall state analyses as too many subjects had zeros for
particular state groups. For the same reason, sleep was not
included in the Suck versus Post-suck analysis of state. There
was a significant main effect of State, $p < .00001$ and a
significant Period x State interaction, $p < .00001$. There was no
effect of sex. The state data for both observers showed an
identical pattern of statistically significant results;
therefore, only the results for observer 1 are reported here.
For observer 2's results see table D-2.

Figure 2 shows the percent of time awake non-crying and
crying/fussing during the Suck and Post-suck periods. Matched
t-tests were performed on the awake non-crying and cry states.
The percent of time spent fussing or crying was significantly
lower during Suck than during Post-suck, $t(19) = 4.42$, $p < .0003$.
The percent of time spent awake non-crying was significantly
higher during Suck than during Post-suck, $t(19) = 4.42$ $p < .0003$.

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Figure 2

Percent of time in Awake non-crying and Fussing/crying States during Suck and Post-suck
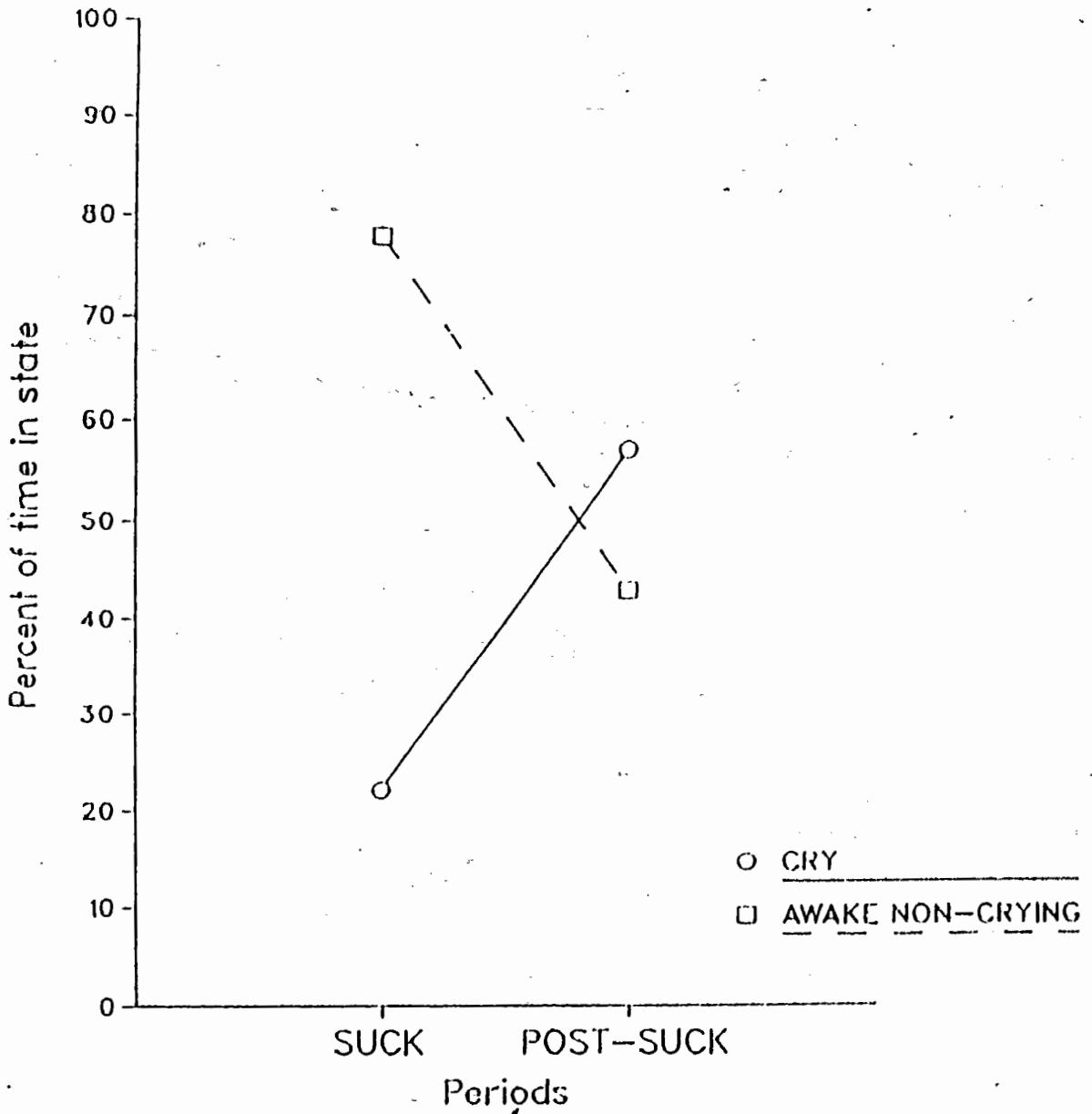
Respiration

Respiration data were analyzed using a computer peak detection algorithm designed by H.F. Gabert, P. Eng., Engineering Supervisor, Psychology Department, Simon Fraser University. The program computed mean inter-peak intervals (MIPI) and standard deviations of distributions of IPIs (SDIPI) from a sample initially consisting of the first 25 positive and first 25 negative peaks within a one-minute window of data. These peaks were then filtered to remove double peaks. The remaining portion of the peaks were used to calculate MIPIs and SDIPIs. For Suck and Post-suck periods, the first window was positioned at the start of the period and later windows started every 60 seconds thereafter for a total of four windows for the Sucking period and two windows for the Post-suck period. If there was an algorithm failure due to triple peaks being detected, the sample window was moved ahead by 5 seconds, up to a maximum of 30 seconds (6 moves), into the sample window in order to obtain a MIPI and SDIPI for that sample. Two female subjects were excluded from analyses due to repeated algorithm failure. No MIPIs and SDIPIs could be obtained for one subject, while for the second subject only one MIPI and SDIPI could be retrieved for each of the Suck and Post-suck periods. For the remaining 20 subjects, the algorithm failed on a total of 20 windows. MIPIs and SDIPIs were able to be retrieved by advancing the sample window in all but 5 cases. There was never more than one missing MIPI-SDIPI pair for any one subject.

Baseline data summary statistics were calculated in the same manner but were obtained by beginning the window backwards from the onset of the 30 second fuss/cry behavioural criterion and including only complete one-minute segments of data to a maximum of 5 Baseline minutes.

Within each of the three periods (Baseline, Suck, and Post-suck) MIPIs and SDIPIs were visually examined for trends over time. No consistent trends over time were found for any of the three periods. Therefore, mean SDIPI and mean MIPI were calculated for each subject within each period. For those subjects with missing values, the mean SDIPI and MIPI for that period were based on one less sample value.

Respiration rate

The mean inter-peak intervals provided by the computer algorithm for each minute of the experiment were converted to breaths per minute (BPM = 60/MIPI). BPMs were analyzed by a 2 factor repeated measures analysis of variance. The between-subject factor was Sex and the within-subject factor was Period. The three periods were Baseline (mean based on a maximum of five 1-minute samples), Suck (four 1-minute samples), and Post-suck (two 1-minute samples). A summary table of the analysis appears in Table D-3. The analysis of variance yielded no significant main effects or interactions. Infants' rates of breathing did not differ significantly across periods. The mean respiratory rate across all periods was 61.7 BPM and 57.5 BPM

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for males and females respectively. Although there was a tendency for males to breathe faster over all conditions, this difference failed to reach a conventional level of significance (p = .16).

The same analysis was performed on only those subjects with at least one minute of non-crying time prior to the 30 s criterion (n=15; 7 males and 8 females) and a similar pattern of results was found (Table D-4). There was no significant main effect of Periods and no Period x Sex interaction. The trend for male subjects to breathe faster across all periods was not apparent in this analysis.

Respiration rate for the Suck period was analyzed separately for bursts and interbursts, and compared using a matched t-test. For the purpose of analyses, a sucking burst was defined as two or more consecutive sucks separated by less than .3125 s at their adjacent bases. The .3125 criterion was employed as it was the shortest period of time that could be accurately measured on the subject records and it was apparent from the records that .3125 seconds of no pressure change was not characteristic of sucks within a burst. The beginning and end time of each sucking burst was indicated on the plot record of each subject. All the burst periods and all the interburst periods were then concatenated for the respiration data using a concatentation program written by Malcolm P. Toms, Programmer/Analyst at Simon Fraser University. A computer program designed locally by Malcolm P. Toms was used to give a

SDIPI and MIPI for all respirations during the burst times and all the respirations during the interburst times. The program calculated interpeak intervals on burst files entered and combined them over all the bursts to give an overall SDIPI and MIPI for bursts and for interbursts for each subject.

Total time spent in sucking bursts for the 20 subjects ranged from 45.6 seconds to 216.3 seconds of the possible 240 seconds. The mean total burst time for females was 115.5 seconds, while the mean for males was 130.0 seconds; this difference was not statistically significant ($t(18) = 0.81$, $p = 0.43$). The mean number of bursts for the Suck period was 18 with a mean length of 6.6 s for individual bursts. The mean rates of respiration were 57.1 and 58.1 breaths per minute for the burst and interburst times respectively ($t(19) = .04$, $p = .97$).

Respiration variability

The standard deviation of the distribution of inter-peak intervals (SDIPI) was computed as a measure of respiratory variability for each one minute window of data. Each SDIPI was divided by its own mean interpeak interval (SDIPI/MIPI) in order to account for the fact that the magnitude of the standard deviation is dependent upon the mean of the distribution from which it is derived, and to allow for comparison across subjects.

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A Sex x Period (Baseline, Suck, Post-suck) analysis of variance of SDIPI/MIPI (Table D-5) yielded a significant main effect of Period, p =.0036.

Figure 3 shows mean SDIPI/MIPI during Baseline, Suck, and Post-suck.

Figure 3

Mean respiration variability (Mean (SDIPI/MIPI)) during

Baseline, Suck, and Post-suck
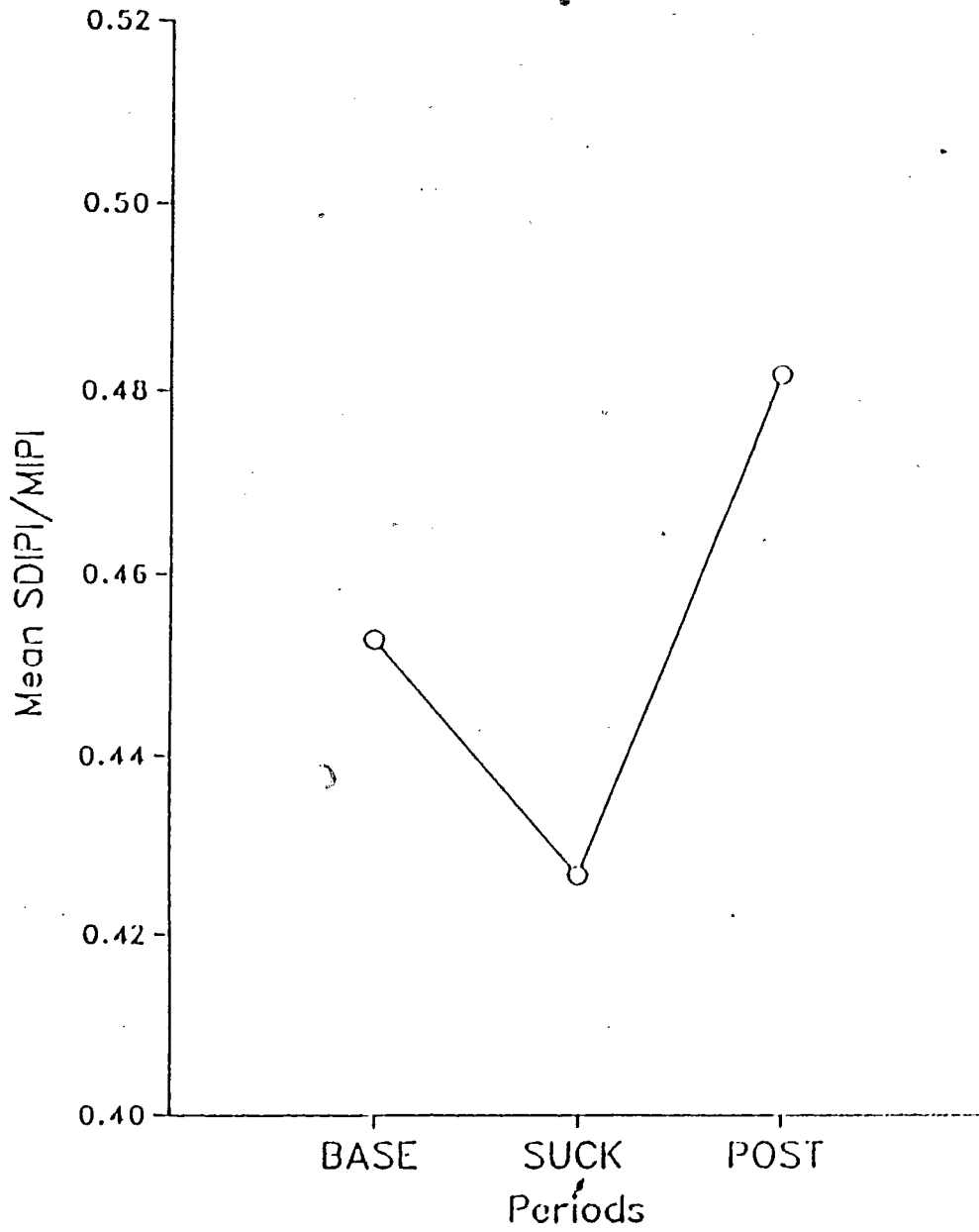
The significant main effect of Periods reflects the fact that infants' breathing variability was different across periods.. Separate analyses for pairs of conditions (Tables D-6, D-7, and D-8) were carried out. Three tests were performed yielding a required probability level per test of .05/3 or p =.016. Results indicated that infants had less variable respiration during Suck than during Post-suck (t(19) = 3.59, p = .002), while the Baseline vs Suck comparison and the Baseline versus Post-suck comparison failed to reach significance (t(19) = 1.52, p = .14 and t = 2.17, p = .04 respectively).

Once again, the overall analysis was performed on only those infants with at least one minute of non-crying time prior to the 30 s criterion (n = 15) (Table D-9) and the same general pattern of results was found, with the main effect of Period having a p =.0006. Variability comparision was significantly different during Suck and Post-suck (t(14) = 4.71, p = .003), while the Baseline vs Suck comparison failed to reach significance (t(14) = 1.52, p = 0.15). The Baseline vs Post-suck comparison did reach statistical significance for this analysis (t(14) = 2.97, p = 0.01).

In order to assess whether the lower variability in respiration during the Sucking period was due largely or exclusively to changes in respiration during the burst times, a matched t-test was performed on the respiration SDIPIs/MIPIs for the burst versus the interburst times. The t-test indicated no significant difference between the variability of respiration

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during the burst and interburst times. The mean SDIPI/MIPIs were .39 and .42 for the burst and interburst times respectively, $t(19) = .94$, $p = .36$.

A within state analysis was conducted to examine respiration variability for the 3 periods (Baseline, Suck, and Post-suck). Active awake (state 5) was chosen for within state analysis as 13 of the 20 subjects had some portion of state 5 in each period. All other states would have yielded fewer subjects with state samples in each period. SDIPIs and MIPIs were calculated on combined times in state 5 for each period. Only those times that both observers agreed the subject was in state 5 were included in the analysis. A one-way repeated measures ANOVA (Table D-10) indicated no significant main effect of Periods for SDIPI/MIPI ($p = .4$) However, for 10 of the 13 subjects, the variability was less during Suck than during Post-suck. If both periods are assumed to be equally likely to contain the lowest variability value, the binominal probability of ten or more of 13 subjects having lower variability for the suck period would be $p = .046$. For 8 of the 13 subjects, the variability was less during Suck than during both Baseline and Post-suck.

Entrainment of respiration by sucking

Entrainment of respiration by sucking is indicated by the infant breathing at the same rate as sucking or at some multiple of that rate. The concatenated sucking burst times and corresponding respiration files were analyzed for entrainment by a computer program written by Malcolm P. Toms, Programmer/Analyst at Simon Fraser University. The program counted both the number of breaths (0 - 20) that fell within each inter-peak interval of sucking, and the number of sucks (0 - 20) that fell within each inter-peak interval of respiration. For each infant the number of inter-peak intervals of sucking containing one respiration was divided by the total number of inter-peak intervals during the four minute sucking period. Similar percentage measures for intervals of n respirations per suck and n sucks per respiration were computed for each infant.

Only two of these measures yielded high percentages: % one breath per suck; and % two breaths per suck. The higher of these two percentages for each infant was taken as the infant's percent entrainment. All but one infant had the greatest percentage of entrainment for one breath per suck. (For that subject, the 1:1 entrainment percentage was 39.5 and the 2:1 entrainment was 44.2 percent). Table 2 presents entrainment measures for the 20 infants. Percent entrainment ranged from 38.2 to 78.7 with a mean of 53.4%.

Table 2

Entrainment of Breathing to Sucking

% sucks entrained

	MALES		FEMALES
S#	% ENTRAINED	S#	% ENTRAINED
1	58.9	11	56.8
2	67.9	12	38.2
3	78.7	13	59.8
4	54.4	14	59.6
5	48.8	15	50.3
6	52.7	16	60.7
7	49.3	17	63.5
8	39.8	18	44.2*
9	49.4	19	45.2
10	41.4	20	47.8

* entrained with 2 breaths/rock

Visual examination of a scatter plot of mean sucking rate during bursts against mean percent of entrainment for the 20 subjects revealed an inverted-U relationship. Of the 9 data points with less than 50 percent mean entrainment, 5 were the lowest extreme scores of the mean sucking rates and 3 were the uppermost extreme values of mean sucking rate.

Persistence of entrainment during interburst intervals

In order to determine whether or not the entrained respiration rhythm persisted during the interburst periods, respiration during each interburst period was compared to sucking during the immediately preceding burst. The shorter of the two periods, sucking burst or interburst, was used for analysis. Therefore, if the interburst period was shorter than the sucking burst, only the last portion of the sucking burst, equal in length to the interburst time, was used for analysis. Conversely, if the interburst time was longer than the burst time, only the first portion of the interburst, equal in length to the immediately preceding sucking burst, was used. Combined interburst periods ranged from 25.9 to 79.7 sec with a mean of 57.8 seconds. The mean number of interbursts per subject was 17 and of these, 6 on average equalled the entire preceding burst.

Respiration during interburst times were concatenated in the same manner as the burst times, and 'pseudo-entrainment' was calculated by running the computer entrainment program on concatenated interburst respiration and concatenated sucking

during immediately previous bursts. The term 'pseudo-entrainment' was used to indicate percentage of time for which respiration during the interburst times was occurring in rhythm with the sucking of the previous burst. The amount of pseudo-entrainment for the interburst times was significantly less than entrainment during the bursts, $\underline{t}(19) = 10.79$, $\underline{p} <$ .00001. Only one subject showed an amount of pseudo-entrainment that was high enough to be within the range of entrainments found. The highest percentage of pseudo-entraiment for 1, 2, 3, or 4 breaths per suck for each subject is listed in Table 3.

Table 3

Pseudo-entrainment for Total Interburst Time

% entrained

MALES			FEMALES	
S#	%		S#	%
1	12.8*		11	7.8*
2	9.0*		12	10.7*
3	9.4*		13	15.2*
4	13.8*		14	5.4*
5	52.9*		15	6.0***
6	10.0**		16	7.2***
7	7.0*		17	7.0*
8	21.4*		18	12.5****
9	9.4** and ***		19	11.9*
10	25.0** and ****		20	8.8*

* 1 breath/suck

** 2 breaths/suck

*** 3 breaths/suck

**** 4 breaths/suck

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The small percentage of interburst pseudo-entrainment that was found seemed incongruent with the failure to find statistically significant differences in respiration rate and respiration variability for the burst versus the interburst times. In an effort to understand this discrepancy, sucking rate and sucking variability were calculated by the peak detection program and for each of these sucking measures a comparison was made between the entire burst times and those portions of the burst times to which interburst respiration had been compared. The mean sucking rate during entire bursts was 66.5 sucks per minute; for the partial burst times to which interburst respiration had been compared, it was 61.9 sucks per minute. A paired t-test indicated no significant difference, $t(19) = .43$, $p = .67$. For the variability measure, SDIPI/MIPI, there was a non-significant trend for greater variability for the sucking times to which interburst respiration was compared than for entire burst times, $t(19) = 1.52$, $p = .15$.

Since no significant differences were found for sucking bursts and those portions of sucking bursts that were compared to interburst respiration, a within burst analysis was conducted to see if there was any consistent pattern of changes for sucking rate and variability. The longest burst for each subject, greater than or equal in duration to the cutoff for the uppermost one-third of the group distribution of burst durations (7.5 s), was analyzed. Each burst was divided into 3 segments equal in duration (early tail of the burst, middle, and late

tail of the burst). The burst of 3 subjects were excluded from analyses; one because the subject had no sucking burst greater than or equal to 7.5 s in duration, and the other two because one segment the burst contained fewer than 3 peaks. MIPIs and SDIPI/MIPIs were examined for trends over the three time segments within the bursts. No consistent pattern was noted for SDIPI/MIPI over time. When sucking rate was examined, it was observed that sucking rate for the early tail (first one-third of the burst) was faster than both of the other segments for 12 of the 17 subjects. However, a one-way repeated measures ANOVA (Table D-11), with Segment (early, middle, and late) as the factor, revealed no significant effect of Segments ($\underline{F}(2,32)$ = 1.15, $\underline{p}$ = 0.33). A similar analysis of short bursts (the burst closest in duration to the cut-off for the lowest one-third of the group distribution of bursts) was attempted; however, there were too few peaks within the short bursts to obtain reasonable summary statistics when the bursts were divided into three segments. The majority of short bursts contained six or less peaks of sucking.

CHAPTER IV

DISCUSSION

The present study was designed to explore the relationship between non-nutritive sucking and respiration and between non-nutritive sucking and behavioural state. Although the study was conducted on a limited number of subjects the results are generally encouraging, as all but the hypothesis concerning changes in respiration rate during NNS (hypothesis 2) received some support.

Respiration rate was hypothesized to be faster during the Suck period than during either the Baseline or Post-suck period, but this hypothesis received no support. This finding is in keeping with the reports of no significant difference in respiration rates for a period containing NNS and a control period reported by Paludetto et al. (1984) and Mathew et al. (1985) but their results were shown to be due to failure to consider burst and interburst times separately. In the present study, when respiration rate for combined burst times was compared to combined interburst times, no significant difference was found. It is possible that differences between the ages of the subjects used in the present study (6-8 weeks) and the ages of subjects used in the previous studies (newborns) of NNS may account for the discrepant results. Perhaps older subjects' respiration rate is less easily influenced by the NNS stimulus. The finding is also incongruent, however, with the respiration

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rate difference for bursts of less than or equal to 6 s duration as compared to respiration during non-sucking time reported by Paludetto et al. (1986). Perhaps in the present study many bursts were too long to find significant differences in respiration between sucking and non-sucking time. The mean burst length for the present study was 6.6 s. Paludetto et al. (1986) found no signficant differences between respiration rate during a control period and rate during bursts of greater than 6 s duration. This possibility could be examined by looking separately at respiration during long bursts of sucking and short bursts of sucking.

Analysis of results on respiration variability revealed a significant main effect of period, thus lending support to hypothesis 3, that respiration would be less variable during sucking than during non-sucking. Individual comparisons between the periods revealed a significant difference for only the Suck versus Post-suck comparison. One possible explanation for the lack of Baseline vs Suck difference for variability is the small amount of baseline data for some subjects. Even with few data, there was a trend for greater variability for the Baseline period than for the Suck period (p =.14). With a larger sample of subjects, or alternately, longer Baseline for subjects (possibly obtained by commencing the study during a sleep period), a conventional level of statistical significance might well be reached. The difference between respiration variability for the combined bursts and the combined interbursts was not

statistically significant, suggesting that what influence NNS has on respiration is present to some degree throughout the entire NNS period.

As yet, there is no literature on the effect of NNS on respiratory variability with which to compare the present findings. However, the rocking literature reports similar changes in respiration variability with intervention. MacKinnon et al. (1986), Fisher (1986), and Elliott et al. (1988), all working in the same laboratory in which the present study was done, have found statistically significant differences in variability between a period of rocking and a post-rocking period.

Changes in behavioural state cannot be ruled out as a possible explanation for the difference between respiration variability during Suck and Post-suck, as significant state differences were noted between these two periods. A within state analysis also did not conclusively rule out state dependent changes in respiration. Although within state 5 (active awake) there was a trend for less variability during Suck than during Post-suck, with 10 out of the 13 subjects exhibiting this pattern; however, the difference was not statistically significant. Again, more subjects may be required to determine whether significant respiration variability changes can be obtained within a state. It should be noted that Hoppenbrouwers et al. (1978) found respiration to be most variable during the awake state. Thus, active awake may have

been a poor choice for within-state analysis. However, none of the other states would have yielded enough subjects with state samples in each period to find any statistically significant within-state differences in respiration variability.

Subjects in the present study showed a mean of 53.4% respiration entrainment to the rate of sucking during bursts, and all 20 subjects were entrained during more than one-third of their sucks. Thus, it is apparent that entrainment is not dependent on swallowing, as one might conclude from the literature on nutritive sucking. The findings of entrainment in the present study and in the rocking studies (MacKinnon et al., 1986; Fisher, 1986; Elliott et al., 1988) are congruent with Lester's (1985) hypothesis concerning the effects of exogenous rhythms on endogenous rhythms. The main tenet of Lester's proposition is that if endogenous timing mechanisms maintain the infant's homeostasis, then exogenous rhythms that entrain these endogenous mechanisms would help to organize infant behaviour and calm the infant.

The degree of entrainment of respiration during bursts of sucking may be compared to the 66.5% entrainment reported by Elliott et al. (1988) in their study of the relationship between rocking and respiration. The lower limit of entrainment was similar in the rocking study and the present study; however, the mean percentage entrainment was higher in the rocking study. This discrepancy may be partially accounted for by the different rates of sucking of different infants. In the rocking study all

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infants were rocked at either 40 or 57 rocks per minute, while in the present study individual infants' mean sucking rates during bursts ranged from 37.4 to 101.4 sucks per minute. Visual examination of a scatter plot of mean respiration rate against mean percent entrainment for concatentated bursts suggested that there may be a curvilinear relationship between respiration rate and entrainment, such that it is difficult to entrain respiration to the extremes of these rates.

The amplitude of sucking may also have been a factor in the mean percentage of entrainment being somewhat lower for NNS than for rocking. The amplitude and rate of sucking was under the infant's control, while in Elliott's study, the amplitude and rate of rocking remained constant within a rocking period and were controlled by the experimenter; subjects were rocked over an amplitude of 12.7 cm at either 40 or 57 rocks per minute. In Elliott et al.'s (1988) study more entrainment was found for the group of infants rocked at 57 rocks per minute than for the group rocked at 40 rocks per minute. Pederson and Ter Vrugt (1973) proposed that linear acceleration, a function of both amplitude and frequency, was the parameter determining the effectiveness of rocking. In Elliott et al.'s study, the effects of linear acceleration and rate were completely confounded as the amplitude of the rocker was held constant. A parameter analogous to linear acceleration, pressure change over time, may be the parameter accounting for entrainment for NNS. Peiper (1963) suggested that 'intensity' would be needed to

entrain respiration. However, what was meant by the term intensity was left unclear. It is possible that Peiper was referring only to rate; however, a function including both amplitude and rate may be compatible with the term 'intensity' (Peiper, 1963). The importance of total pressure change (both amplitude and rate) over time in calming infants and entraining respiration has not been investigated. The relative importance of amplitude and rate has as yet not been outlined, nor have the limits to the relationship between amplitude and rate been delineated. One could examine amplitude of sucking independent of rate in order to see if this parameter of the stimulus is an important factor in entrainment. However, it is possible that there are rates of sucking, probably the extremes, to which respiration will not entrain in a 1:1 fashion even with great amplitude of each suck.

Lester (1985) suggested that individuals' endogenous rhythms would be most likely to entrain to rhythms that are closest to, or multiples of, their endogenous rhythms. However, in the present study, there was only one subject who exhibited substantial entrainment of respiration during sucking bursts to a multiple of the sucking rate. Why subjects failed to entrain to any great degree to multiples of their sucking rates is unclear.

A second finding with respect to entrainment of respiration was the low percentages of pseudo-entrainment during the interburst times. As there was no significant difference in

either respiration rate or variability for the burst vs the interburst times, the possibility that the portion of the sucking bursts to which interburst respiration was compared was not representative of the overall suck and was therefore a poor template to which to compare the respiration was explored. Although the t-tests for sucking variability for the burst vs the interburst times was not significant, it was thought possible that the trend for greater variability of sucking for times used for interburst respiration comparison would reach significance if shorter portions of the sucks were used. The mean number of interbursts per subject was 17 and of these, 6 on average equalled the entire preceding burst (range of 0 to 15). If the tails of the bursts are more variable with respect to rate, as suggested by Wolff (1968), it could be that the middle portion of bursts have entrained respiration while the tails show little entrainment of respiration to rate of sucking. However, a preliminary analysis of the longest respiration burst for each subject did not reveal any consistent pattern of variability for the early, middle, and late thirds of a burst. It is possible that the one-third portions used for analysis were not the best choice to reveal differences that might exist at the extreme tails.

As hypothesized, infants fussed/cried less and were awake non-crying more during the Suck period than during the Post-suck. These state findings are not surprising as it is difficult to fuss/cry with an object in the mouth. The state

results are instructive in the light of the findings on changes in respiration variability. It is possible that the significant difference in respiration variability between the Suck and the Post-suck period was due to a concurrent change in behavioural state; however, this finding appears inadequate as a complete explanation in light of the amount of entrainment found. While a change in behavioural state might automatically imply a change in respiration variability, it is difficult to see why it would necessarily lead to a change in the amount of entrainment of respiration by sucking.

Future research might include other types of soothing techniques, such as auditory stimulation and swaddling, to determine whether they have similar effects on respiration. If so, it may be that respiration regularity is one of the mechanisms underlying infant soothing. Perhaps soothing interventions help the infant organize his or her respiration by decreasing the variability, resulting in a more contented infant. Entrainment may be involved in organization of behaviour and soothing (Lester, 1985).

Finally, future research may be extended to include infants with respiratory problems, such as pre-term infants and those with central nervous system disorders. It is possible that some groups of infants may need more intense stimulation in order to entrain repiration. It would also be interesting to examine whether entrainment is beneficial to the infant in other ways, e.g., by promoting sleep (perhaps dependent on the rate of the

stimulus to which respiration is entrained), aiding metabolism, or reducing apnea in premature infants.

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Appendix A

Information Sheet for Subjects

INFORMATION SHEET FOR SUBJECTS

PSYCHOPHYSIOLOGICAL RESEARCH ON INFANTS: SOOTHING STUDY

Pacifiers are frequently used by parents to soothe their babies. In this research we are interested in what happens to infants' breathing when they are sucking and when they are not sucking.

During the study the baby lies in a baby buggy. A belt is placed around the baby's abdomen to allow us to record his or her breathing.

The baby's breathing and the sucking are recorded on computer by the equipment in Dr. Davis' psychophysiology lab next door. In addition, the baby's state (i.e., whether the baby is alert, asleep, crying, etc.) is observed and recorded on the Apple microcomputer in the same room as the baby.

The parent is free at any time to terminate any part of this procedure, and will make all decisions regarding the baby's wellbeing and care (feeding, changing, dressing, comforting, etc.) throughout the entire session.

YOUR INITIALS ON THE BACK OF THIS SHEET INDICATE THAT YOU HAVE READ IT.

Appendix B

Consent Form

CONSENT FORM

As parent/guardian of ----------------------------------I consent to my baby engaging in the procedures specified in the document entitled PSYCHOPHYSIOLOGICAL RESEARCH ON INFANTS: SOOTHING STUDY, to be carried out in the human psychophysiological research laboratory, CC4205, Simon Fraser University, at the following time:
-------------------------------- in a research project supervised by Dr. Elinor W. Ames of Simon Fraser University.

I certify that I understand the procedures to be used and the risks involved in taking part. I know that I have the right to withdraw ------------------------------------ from the project at any time. I further understand that I will be the one to make all the decisions regarding my baby's wellbeing and care (feeding, changing, dressing, comforting, etc.) throughout the entire procedure. I realize that any complaint about the research may be brought to the chief researchers named above, or to Dr. Vito Modigliani, Chairman of the Psychology Department, Simon Fraser University.

I understand that I will receive from Dr. Elinor Ames a copy of the result of this study, upon its completion.

Date:--------------

Name (please print):----------------------

Signature:----------------------------

Address:-------------------------------

Signature of witness:------------------

Appendix C

Questionnaire

Questionnaire

Date:————————————————

1. Baby's sex: Boy   Girl

2. Baby's birthdate:_____

3. Baby's birthweight:_____gm or _____lb _____oz

4. Was the pregnancy normal?   Yes   No

   If there were problems during the pregnancy, what were they?

   _____

   _____

5. During the mother's pregnancy, how many cigarettes did she smoke?

   _____ None

   _____ Less than 1 per day

   _____ 1-2 per day

   _____ 3-5 per day

   _____ 6-12 per day

   _____ 13-20 per day

   _____ More than 20 per day

6. During the mother's pregnancy, how much cola, coffee and tea did she drink? (Do not include herbal teas or decaffeinated coffee.)

_____ None

_____ 1-3 cups per month

_____ 1-6 cups per week

_____ 1-2 cups per day

_____ 3-5 cups per day

_____ More than 5 cups per day

7. Was your baby's activity level before birth:

___ Less than average ___ Average ___ More than average

8. Delivery was: (Check as many as apply)

_____ vaginal

_____ caesarean section

_____ with problems. What problems? ————————————————

——

9. Has the baby had any illnesses?   Yes   No

If yes, please specify what illness(es):————————————

10. Has your baby been:

_____ breastfed?

_____ bottlefed?

11. does the baby feed well?   Yes   No

12. Has the baby been introduced to solid food yet?   Yes   No

13. Does the baby burp
spontaneously?   Often   Sometimes   Seldom or never

14. Does the baby
regurgitate?   Often   Sometimes   Seldom or never

15. Does the baby vomit?   Often   Sometimes   Seldom or never

16. Following a feeding, is your baby:

    _____ easy to burp?

    _____ difficult to burp?

17. During a 24 hour period, approximately how many hours is
    your baby awake?

    _____ hours.

18. At what time of day is the baby most content (i.e., awake
    and alert but not fussing or crying)?

    _____ Morning

    _____ Afternoon

    _____ Evening

    _____ Night

    Is this a fairly regular pattern?   Yes   No

19. How long is the longest stretch of time that the baby is
    continuously awake?

        _____ hours.

    When does this longest awake time usually occur?

    _____ Morning

    _____ Afternoon

    _____ Evening

    _____ Night

20. While awake, how much of the time does your baby move his/her arms and legs?

_____ Almost all of the time

_____ Most of the time

_____ Some of the time

_____ Very little of the time

21. Approximately how many hours per day does the baby spend in the following situations? (Note: the times given in A, B, and C. should total 24 hours).

A. Being touched by someone (include feeding, _____ hours changing, and bath times as well as times carried, rocked, or held)

B. In a stationary apparatus (include time _____ hours spendt in a crib, cuddle seat, stationary buggy or stroller, or on a bed, floor, or table)

C. In a moving apparatus (such as rocking _____ hours cradle, stroller or buggy or car seat in motion, or an infant swing)

22. During the day, what do you most often do after the baby has finished feeding?

_____ Soothe and try to settle him/her

_____ Play and talk with him/her

_____ Have the baby sit and watch household activity

_____ Other (please specify) ——————————————————

23. During the day, after a feeding the baby is usually:

_____ Drowsy or asleep

_____ Alert and content

_____ Ready for play

_____ Crying and/or fussing

_____ Other (please specify) ——————————————————

24. How would you describe your baby?

_____ Easy-going

_____ Average temperament

_____ High strung

25. Does your baby enjoy cuddling?

_____ Always

_____ Sometimes

_____ Hardly ever

26. How does your baby sleep?

_____ Restlessly

_____ Quietly

27. Do you believe that babies should be picked up when they cry?

_____ Always

_____ Sometimes (When? ———————————————————————)

_____ Seldom

28. During the day, if you think that the baby is going to start crying, what do you **usually** do?

_____ Do something to try to prevent the crying before it starts.

_____ Wait for the crying to begin, and then attempt to soothe the baby immediately.

_____ Let the baby cry for a while before trying to soothe him/her.

29. Overall, when your baby cries, what proportion of the time are you able to stop his/her crying with your soothing techniques?

_____ % of the time

30. Approximately how many times per day does your baby cry?

_____ Less than 5 times per day

_____ Between 5 and 9 times per day

_____ Between 10 and 15 times per day

_____ More than 15 times per day

31. Is there a particular time of day that your baby is most likely to fuss and cry?

_____ Morning

_____ Afternoon

_____ Evening

_____ Night

Is this a fairly regular pattern?   Yes   No

If you can name specific hours when your baby usually fusses or cries please do.

My baby regularly cries and fusses from ___ a.m. p.m. to ___ a.m. p.m.

32. Please indicate the soothing techniques you have used to try to stop your baby from crying when you knew he/she was not hungry.

	HAVE YOU DONE THIS?		HOW EFFECTIVE WAS IT?			WHAT DID THE BABY DO?				
	Yes	No	Very	Some what	Not at all	slept	stopped crying	cried/ fussed but less	no change	other (specify)
Talked to the baby	Y	N	V	S	N	Sleep	Stop	Less	No	
Rocked the baby	Y	N	V	S	N	Sleep	Stop	Less	No	
Walked the baby	Y	N	V	S	N	Sleep	Stop	Less	No	
Sung to the baby	Y	N	V	S	N	Sleep	Stop	Less	No	
Played music or other sounds	Y	N	V	S	N	Sleep	Stop	Less	No	
Given the baby a pacifier	Y	N	V	S	N	Sleep	Stop	Less	No	
Fed the baby	Y	N	V	S	N	Sleep	Stop	Less	No	
Given the baby a heating pad or hot water bottle	Y	N	V	S	N	Sleep	Stop	Less	No	
Patted the baby's back	Y	N	V	S	N	Sleep	Stop	Less	No	
Changed the baby's position	Y	N	V	S	N	Sleep	Stop	Less	No	
Wrapped the baby in a blanket	Y	N	V	S	N	Sleep	Stop	Less	No	
Bathed the baby	Y	N	V	S	N	Sleep	Stop	Less	No	
Taken the baby for a car ride	Y	N	V	S	N	Sleep	Stop	Less	No	
Walked the baby in a buggy or stroller	Y	N	V	S	N	Sleep	Stop	Less	No	
Placed the baby by or on a machine	Y	N	V	S	N	Sleep	Stop	Less	No	
Given the baby medicine (what?)	Y	N	V	S	N	Sleep	Stop	Less	No	
Other (Specify)	Y	N	V	S	N	Sleep	Stop	Less	No	

33. Please indicate how often your baby does each of the following, and whether or not it is ever accompanied by crying.

How often?

Accompanied by crying?

	Often	Sometimes	Seldom or Never		Usually	Sometimes	Seldom or never
a. Stomach rumbling							
b. Noisy sucking							
c. Sucking on fists, fingers, pacifier							
d. Passing of gas							
e. Abdomen hard to touch							
f. Legs stiffened out							
g. Legs drawn up to abdomen							
h. Diarrhea							
i. Constipation							

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34. How long does the single longest crying episode last each day? (Do not count periods when baby is fussing but never actually cries)

_____ Less than 2 minutes

_____ 2 to 5 minutes

_____ 5 to 10 minutes

_____ 10 to 30 minutes

_____ Longer than 30 minutes

During this single longest crying period, do you try to stop the baby's crying?

_____ Always

_____ Sometimes

_____ Seldom or never

35. How long does an average crying episode last?

_____ Less than 2 minutes

_____ 2 to 5 minutes

_____ 5 to 10 minutes

_____ 10 to 30 minutes

_____ Longer than 30 minutes

36. Has the amount of time the baby spends crying:

_____ increased?

_____ not changed?

_____ decreased?

37. Have there been any periods of dramatic change in the amount of crying?

    Yes   No

    If yes, please give details about the change. Was it an increase or a decrease? How old was the baby when this happened?

    _____

    _____

38. When the baby starts to cry, does the crying usually:

    _____ start suddenly?

    _____ start with fussing, and build to crying?

39. Was the baby's mother a difficult or colicky baby?

    Yes   No   Don't know

40. Was the baby's father a difficult or colicky baby?

    Yes   No   Don't know

40a. What is the total amount of time your baby spends crying each day?

    _____ 1 hour or less?

    _____ more than 1 hour, but not more than 3 hours?

    _____ more than 3 hours, but not more than 5 hours?

    _____ more than 5 hours?

40b. How many days a week does your infant cry for a total of 3 hours or more?

    _____

41. Before pregnancy, did the baby's mother drink milk?

    _____ Regularly

    _____ Occasionally ·

    _____ Never

42. Does the baby's mother like the taste of milk?

        Yes   No

43. Does the baby's mother have any allergies?

        Yes   No

If yes, allergic to what?——————————————————————————

44. Does the baby's father have any allergies?

        Yes   No

If yes, allergic to what?——————————————————————————

45. During the mother's pregnancy, on the average how much beer, wine, or other alcoholic beverage did she drink?

_____ None

_____ Less than 1 drink per week

_____ 1 drink per week

_____ 2 drinks per week

_____ 3 drinks per week

_____ 4 drinks per week

_____ 5 or more drinks per week

46. Has any ever said that your baby has colic?

        Yes   No

If yes, who? (Check as many as apply.)

_____ The baby's mother

_____ The baby's father

_____ A doctor or nurse

_____ A relative

_____ A friend

47. How many years of education has the baby's mother completed? (Starting at Grade One, count the number of years of formal education completed, including elementary, secondary, and post secondary education --e.g., college, university, technical school, apprentice training.)

    _____years

48. How many years of education has the baby's father completed? (Count as in previous question)

    _____years

49. How old is the baby's mother? _____

50. How old is the baby's father? _____

THANK YOU for your help in our research on crying. If you
would like to find out what we learn from these questionnaires,
please fill in the information below, and we will send you a
copy of our results when they are ready.

Baby's name —————————————————————

Parent's name —————————————————————

Address —————————————————————

—————————————————————

Are you interested in participating in any future research on
children? If so, please indicate below. Your signature indicates
that you are willing to be contacted by us about research in the
future; it does not indicate your willingness to take part. At
the time we contact you, we would explain the particular
research project, and then you could decide whether or not you
or your children wish to participate in it.

I would be interested in being invited to participate in
future research projects on children or parenting.

—————————————   —————————————
        signature   phone #

Again, THANK YOU VERY MUCH for helping us to learn more
about children.

Appendix D

Analyses of Variance Summaries

Sex x Period x State ANOVA for Observer 1

source	df	MS	F	p
Mean	1	13333.295	557.08	
Sex	1	0.000	0.20	0.66
Error	18	0.000		
Periods	1	0.000	0.00	1.00
S x P	1	0.000	0.00	1.00
Error	18	0.000	0.00	
State	2	37632.518	24.32	0.000
St x S	2	37.230	0.02	0.98
Error	36	1547.446		
P x St	2	12248.946	18.54	0.000
P x St x S	2	19.670	0.03	.971
Error	36	660.593		

Sex x Period x State ANOVA for Observer 2

source	df	MS	F	p
Mean	1	133369.967	55094848.00	
Sex	1	0.003	1.04	0.32
Error	18	0.002		
Periods	1	0.002	0.96	0.34
S x P	1	0.002	0.96	0.34
Error	18	0.002		
State	2	27684.718	18.28	0.000
St x S	2	26.961	0.02	0.98
Error	36	1514.126		
P x St	2	7876.675	7.01	0.003
P x St x S	2	24.526	0.02	0.98
Error	36	1123.574		

Appendix D-3

Sex x Period (Baseline, Suck, and Post-suck) ANOVA for BPM

source	df	MS	F	p
Mean	1	147734.571	1194.54	
Sex	1	264.852	2.14	0.1606
Error	18	123.675		
Periods	2	9.584	0.44	0.6481
P x S	2	24.270	1.11	0.3400
Error	36	21.831		

Sex x Period (Baseline, Suck, and Post-suck) ANOVA of BPM for

Subjects with Non-cry Baseline

source	df	MS	F	p
Mean	1	106889.500	1121.65	
Sex	1	26.974	0.28	0.6037
Error	13	95.297		
Periods	2	13.160	0.80	0.4616
P x S	2	18.400	1.11	0.3435
Error	26	16.521		

Sex x Period (Baseline, Suck, and Post-suck) ANOVA for Mean

SDIPI/MIPI

source	df	MS	F	p
Mean	1	12.367	3586.68	
Sex	1	0.003	0.94	0.3449
Error	18	0.003		
Periods	2	0.015	6.59	0.0036
P x S	2	0.003	1.50	0.2369
Error	36	0.002		

Sex x Period ANOVA of Mean SDIPI/MIPI for Suck vs Post-suck

Periods

source	df	MS	F	p
Mean	1	8.254	2188.92	
Sex	1	0.000	0.10	0.7570
Error	18	0.004		
Periods	1	0.030	13.62	0.0017
P x S	1	0.005	2.10	0.1644
Error	18	0.002		

Sex x Period ANOVA for Mean SDIPI/MIPI Baseline vs Post-suck

source	df	MS	F	p
Mean	1	7.739	2938.34	
Sex	1	0.000	0.26	0.6195
Error	18	0.003		
Periods	1	0.007	2.24	0.1354
P x S	1	0.006	2.00	0.1744
Error	18	0.003		

Sex x Period ANOVA of mean SDIPI/MIPI Baseline vs Suck

source	df	MS	F	p
Mean	1	8.737	3140.12	
Sex	1	0.009	3.19	0.0909
Error	18	0.003		
Periods	1	0.008	4.46	0.0489
P x S	1	0.000	0.02	0.8793
Error	18	0.002		

Sex x Period ANOVA of mean SDIPI/MIPI for subject with non-cry

Baseline

source	df	MS	F	p
Mean	1	9.428	2069.07	
Sex	1	0.002	0.41	0.5329
Error	13	0.005		
Periods	2	0.019	10.12	0.0006
P x S	2	0.002	1.05	0.3631
Error	26	0.002		

Period ANOVA for within State 5

source	df	MS		F	p
Mean	1	6.923	1281.73	0.000	
Error	12	0.005			
Periods	1	0.007	0.003	0.401	
Error	24	0.004			

Segment ANOVA for mean SDIPI/MIPI within Longest Sucking Burst

source	df	MS	F	p
Mean	1	73.796	49.26	0.000
Error	16	1.498		
Segments	2	1.250	1.15	0.328
Error	32	1.083		