

The Behavioral Effects of Nonnutritive Sucking
on Infants of Differential Fetal Growth

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Masters Thesis submitted to the Faculty of
Virginia Polytechnic Institute and State University
in fulfillment of the requirements for the degree of
Masters of Science

in

Psychology

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(ABSTRACT)

Newborn infants with differential patterns of fetal growth, as determined by their weight-for-length, typically display behaviors which have been conceptualized as reflecting the integrity of the infant's behavioral organization. The newborn infant's sucking is one behavior that has been hypothesized to both reflect the effects of previous experiences on behavioral organization and affect the infant's future behavioral development. In particular, the infant's pattern of sucking activity may not only reflect the integrity of the infant's nervous system, it may also alter the temporal organization of the infant's behavioral state and motor activity by increasing behavioral quiescence. The purpose of this study was to compare the sucking activity of underweight-for-length (N = 30) and average-weight-for-length (N = 30) infants and its effects on behavioral state and motor activity. Fifteen low-PI and 15 average-PI infants were randomly assigned to each of two

experimental conditions. Infants in an experimental condition were given access to a pacifier for the first 30 minutes of a 60-minute observation period. Infants in the control condition were observed undisturbed for the entire observation period. Behavioral state, and motor and sucking activity were recorded every 30-seconds throughout the 60-minute observation. Results showed that when given access to a pacifier, underweight-for-length infants sucked for less time than average weight-for-length infants.

Underweight-for-length infants also displayed higher levels of motor activity during and immediately following periods of increased sucking activity. During periods of sucking activity, underweight-for-length infants changed state more frequently than average weight-for-length infants.

Following sucking activity, underweight-for-length infants changed state less frequently than average weight-for-length infants. These data were discussed in the context of the newborn's behavioral organization and its impact on future behavioral development.

ACKNOWLEDGMENTS

I would like to thank my family and friends whose help and support continues to make my graduate saga possible. Special thanks to the nursing staff and the physicians at Roanoke Memorial Hospital, to _____ and

Without their help and consideration this project would have been immensely more difficult. I would also like to thank _____ and

whose humor, interest and dedication helped make the data collection one of the more memorable aspects of this project.

Many friends provided the social support necessary for completion of this project and my degree. Thank you

and all the others who shared the heights and depths of this experience with me. A special thanks to

for his technical expertise and friendship.

I owe many thanks to _____ who despite my occasional protest, taught me the value of a disciplined mind and clear effective communication. As a result of my encounter with his sharp wit and intellect, I have gained a greater appreciation for scholarship and his friendship.

Finally, and most importantly, I wish to thank my family; to my wife who continues to love and believe in me, to "the baby", who though not yet born has already brightened my life. I also wish to my parents my sister and brother for always being there when I needed them.

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Introduction

Sucking is one of the first behaviors the newborn infant demonstrates following birth (Anderson, Burroughs, & Measel, 1983) and occurs spontaneously during and between feeding situations (Measel & Anderson, 1979). The newborn infant's sucking may reflect the integrity of the infant's behavioral organization and affect the infant's future developmental processes (Wolff, 1966, 1967). The healthy neonate's well-developed rooting, sucking and swallowing complex promotes early nutrient intake. However, infants also appear to derive other benefits from sucking even in the absence of nutritional intake. For example, parents and researchers have long recognized that sucking on a pacifier quiets distressed or crying infants (Wolff, 1967). These observations have been supported by studies in which nonnutritive sucking (NNS), such as that provided by sucking on a pacifier, has been shown to increase behavioral quiescence in both term and preterm neonates (e.g., Kessen & Leutzendorff, 1963; Woodson, Drinkwin & Hamilton, 1985). These quieting effects may be particularly important during the human neonate's first few days of life when up to 40% of

the infant's daily available energy is expended in behavioral activity alone (Mestyan, 1978).

Most studies have focused on the concurrent effects of NNS both during and after invasive procedures that disrupt the quiescent state of the infant. Field and Goldson (1984) observed that infants provided with opportunities for NNS during a routine blood drawing procedure (heelstick) remained in alert and quiescent states for significantly longer periods than did infants in the control group who spent more time in fussy and crying states both during and after the procedure. Campos (1988) found that two-week-old full term infants allowed to suck on a pacifier during and after heelstick procedures spent significantly more time in an alert state than did infants in a swaddled group. Crying was also approximately 40% less in fullterm infants who sucked on a pacifier during and after circumcision (Gunnar, Fisch, & Malone, 1984). In addition to these concurrent behavioral effects, the quieting effects of NNS may extend beyond the immediate sucking bout. Neely (1979) reported that infants allowed to suck nonnutritively to satiety at 1, 4, and 8 hours of age spent more time in alert, wakeful states and less time in sleep or irritable states during

their first feeding at 12 hours of age than infants in control groups (Neely, 1979). These results show that the effects of NNS may not only quiet infants who are crying, but may also, in some cases, bring infants who are sleeping to an alert state.

While many studies have examined the effects of NNS among full term, full birthweight newborn infants, other research has focused on preterm and low birthweight infants. Because an infant's suck-swallow reflex is rarely fully developed or coordinated before 34 weeks of gestational age, preterm infants characteristically display poorly coordinated sucking activity such as fewer sucks per burst and greater frequency of sucks (Bernbaum, Pereira, Watkins & Peckham, 1983). Prenatal malnourishment and subsequent low birth-weight have also been shown to diminish the frequency and amplitude of sucking activity in newborns (Engen, Lipsitt, & Robinson, 1978; Pollitt, Gilmore & Valcarcel, 1978). The diminished amplitude and frequency of sucking found among preterm and low birthweight infants may reflect the compromised integrity of these infants behavioral organization.

A separate program of studies has indicated that the

behaviors associated with low birthweight and preterm infants may also be found among the seemingly "healthy" infants in the normal newborn nursery. Among the full term, full birthweight infants in the newborn nursery are infants who are underweight-for-length, as assessed by a ratio of the infant's ponderal index (PI) (Miller & Hassenein, 1971) evidence a wide range of behaviors indicative of poor autonomic regulation (Lester & Zeskind, 1982; Zeskind, 1983). They typically display poorer state regulation, less quality of tone and alertness, and a greater difficulty in sustaining attention than average-PI infants (Als, Tronick, Adamson, & Brazelton, 1976; Lester, 1979). Underweight-for-length neonates also exhibited poor use of available stimulation and showed deficiencies in social interactive behaviors as assessed by the administration of the Neonatal Behavior Assessment Scale (NBAS) (Lester & Zeskind, 1978). Recent work has suggested that the nonoptimal behavioral characteristics of underweight-for-length infants are associated with less rhythmic behavioral systems and organization (Zeskind & Marshall, in press). Infants who are underweight-for-length are also at high risk for nonoptimal social and intellectual development in non-

supportive caregiving environments (Zeskind & Ramey, 1978; 1981).

As Wolff (1967) suggested, sucking is a rhythmic behavior that reflects the effects of previous experiences on behavioral organization. The behavioral organization of underweight-for-length infants has been shown to differ from that of average weight-for-length infants (Zeskind, 1981). The purpose of the present study was to examine the sucking activity of underweight-for-length infants when offered access to a pacifier. Additionally, our study sought to assess the effects of NNS on the behavioral state and motor activity of underweight-and average-weight-for-length neonates. It was expected that underweight-for-length infants would suck less frequently than average weight-for-length infants. Additionally, it was expected that regardless of the infant's ponderal index, increased sucking activity would result in an increase in behavioral quiescence.

Method

Subjects

Seventy infants were selected from the normal newborn nursery of a small urban hospital. All infants were from a low-socioeconomic status (SES) population as defined by their mothers' participation in a prenatal care program for the indigent. Infants showing any congenital or gross abnormal neurological anomalies on physician administered routine physical and neurological examinations were excluded from the study. Measurement of the infants' birth weight was obtained from the hospital's records; birth length was determined by the experimenter and a research assistant who elicited a tonic neck reflex and measured crown-heel length. The measures of birthweight and birth length were used to determine the infant's ponderal index (PI) according to the ratio of birth weight (in grams) X 100/the cube of crown-heel birth length (in centimeters) (Miller and Hassanein, 1971). Of the seventy infants observed, 10 of these infants were not included in the analysis on the basis of their PI classification. Five infants were excluded because their ponderal indices were greater than 2.82, placing them in the high-PI category. The remaining five infants were excluded

due to the borderline status of their PI values (e.g., 2.29 or 2.81). By omitting the data from these infants we hoped to minimize the possibility of misclassification of infants due to possible measurement error by the examiners who determined the infant's length.

Thirty low-PI infants ($PI \leq 2.28$) and 30 average-PI infants ($PI > 2.28 \leq 2.82$) were selected for the study. Fifteen low-PI and 15 average-PI infants were randomly assigned to each of two experimental conditions: one in which access to a pacifier was provided during the first 30 minutes of a one-hour observation period (Experimental condition); the other in which no access to a pacifier was provided during the one-hour observation period (Control condition).

Table 1 lists the means and standard deviations of the infants' demographic characteristics by Experimental condition. No differences were found between infants in the Experimental and Control conditions with regard to sex, race and type of feeding (bottle vs breast). Infants in the Control condition had a lower Apgar score at 1 minute than did infants in the Experimental condition.

Insert Table 1 about here

Chi-square analyses showed that the distributions of race (Experimental, blacks = 9, whites = 21; Control, blacks = 6, whites = 23, asians = 1, χ^2 (2) = .34, $p < .56$), sex (Experimental, Females = 15, Males = 15; Control, Females = 20, Males = 10, χ^2 (1) = 1.7, $p < .19$), and type of feeding (Experimental, bottle = 27, breast = 3; Control, bottle = 27, breast = 3, χ^2 (1) = 0.0, $p < 1.0$) for the two conditions did not differ significantly from that which would be expected by chance.

Procedure

All infants were observed for 60 minutes approximately midway between scheduled feedings. During that period, infants rested unswaddled in their isolettes in a quiet, temperature controlled environment (82 degrees F.). All infants' diapers were changed before the procedure began. A rolled linen diaper was used to brace each infant in a right lateral position in order to facilitate observation. Each infant in the experimental condition was given ad-libitum access to his or her regular pacifier for the first 30

minutes of the 60-minute observation period. The pacifier was supported so that the tip of the nipple touched the infant's lips mid-way of both the horizontal and vertical planes. The infant was able to take the pacifier completely into the mouth or to suck on the tip of the nipple. During the second 30 minute period, the infant in the Experimental condition received no pacifier access. No contact was provided. Each infant in the control group did not have access to a pacifier and was observed for 60 minutes undisturbed. Behavioral state, motor activity and sucking activity were assessed by two observers every 30 seconds during the entire 60-minute observation period. Behavioral state was determined using a 6 point nominal scale including (1) Quiet and (2) Active Sleep, (3) a Drowsy, Semi-dozing state, (4) Quiet Alert, (5) Active/Fussy Awake and (6) Continuous Crying States (Brazelton, 1984) (see Appendix B). The level of motor activity was also determined using a 6-point scale (Woodson, Drinkwin, & Hamilton, 1985) (see Table 2).

Insert Table 2 about here

Inter-observer reliability was assessed on approximately one of every seven infants. During reliability checks, two trained research assistants, who were unaware of the hypotheses of the study, independently considered the last 10-second epoch in each 30-second interval to evaluate the state and motor activity of the infant. Mean reliability for behavioral state was 96% (range = 84-100%); and 84.4% for level of motor activity (range = 68.4-91%). Sucking activity was also observed and recorded throughout each 30-second interval using both a frequency (number of 30-second intervals in which sucking occurred) and a continuous measure (number of seconds infants sucked). Spontaneous sucking of the lips, tongue or hands was also noted for all infants. Reliability was calculated for the number of intervals infants were observed sucking only. Mean reliability for sucking activity was 96.4% (range = 90.9-98.3%). The observer positioned closest to the infant's head recorded the continuous measure of sucking activity using a Micronta LCD quartz stopwatch. The following summary measures were derived separately for each 30-minute observation period: (1) the number of intervals in which infants were observed sucking, (2) the number of seconds

each infant was observed sucking, (3) the number of intervals in which infants were observed in each behavioral state, (4) the total number of changes in behavioral state and, (5) the number of intervals infants were observed in each level of motor activity. Individual infant's data were combined within PI groups and Experimental conditions for each 30-minute observation period. These variables were examined in 4 separate repeated measures multivariate analyses of variance (MANOVAs). Newman-Keuls post-hoc analyses and t -tests were conducted to determine the location of differences among cell means. Pearson product-moment correlations were employed to further describe the relations between variables.

Results

A 2 (Low- vs Average-PI) X 2 (Experimental vs Control) X 2 (Time 1 vs Time 2) repeated measures MANOVA, including 1) the number of 30-second intervals and 2) the number of seconds infants sucked, showed a reliable two-way interaction for Condition by Time, $F(2,55) = 5.37, p < .005$. The univariate tests indicated that the two-way interaction for Condition by Time was reliable for the number of seconds, $F(1,56) = 10.32, p < .005$, and the number of intervals in which sucking was observed, $F(1, 56) = 6.94, p < .01$ (see Table 3).

Insert Table 3 about here

Newman-Keuls post-hoc comparisons showed that infants in the Experimental condition sucked for a significantly greater number of seconds and intervals in Time 1 than in Time 2. The difference between experimental and control infants at Time 1 on both the interval and continuous measures of sucking activity was also significant. No differences were found for either measure of sucking activity for control infants between Time 1 and Time 2 or

between experimental and control infants at Time 2. These findings show that the access to the pacifier increased the infants sucking activity as measured by both the number of intervals in which infants were observed to be sucking and the actual number of seconds infants sucked.

The MANOVA for sucking activity also showed a reliable main-effect for PI group, $F(2,55) = 3.49$, $p < .05$. The univariate tests indicated that the main-effects for PI group were reliable for the number of intervals infants were observed to be sucking, $F(1,56) = 6.27$, $p < .05$. Average-PI infants were observed to suck in a significantly greater number of intervals than low-PI infants. The univariate test for the amount of time (in seconds) infants in each PI group actually sucked was marginally reliable, $F(1,56) = 3.15$, $p < .08$. These results show that low-PI infants were observed to suck less frequently than average-PI infants.

A 2 (Low- vs Average-PI) X 2 (Experimental vs Control) X 2 (Time 1 vs Time 2) X 2 (State 1 vs State 2) repeated measures MANOVA including the number of intervals infants were observed in each behavioral state showed a reliable two-way interaction for State by Time, $F(1,56) = 10.1$, $p < .005$. Newman-keuls post-hoc analyses showed that during

Time 1, infants were observed in State 2 ($M = 41.0$, $SD = 20.0$) for a significantly greater number of intervals than in State 1 ($M = 6.9$, $SD = 11.9$). During Time 2, infants were observed to be in State 2 ($M = 34.1$, $SD = 17.9$) for a significantly greater number of intervals than State 1 ($M = 17.7$, $SD = 16.6$). Infants were observed in State 1 for a greater number of intervals during Time 2 ($M = 17.7$, $SD = 16.6$) than during Time 1 ($M = 6.9$, $SD = 11.9$). The number of intervals infants were observed in State 2 between Time 1 and Time 2 did not differ significantly (see Table 4).

Insert Table 4 about here

Throughout the 60-minute observation period, all infants regardless of condition were observed in State 2 more frequently than State 1. Infants were observed in State 1 for a greater number of intervals in Time 2 than Time 1.

The MANOVA for Behavioral States 1 and 2 also showed a marginal 3-way interaction for Condition by State by Time, $F(1,56) = 3.66$, $p < .06$ (see Table 5). Infants in the Experimental condition were observed in State 2 for a

greater number of intervals during Time 1 (\underline{M} = 44.6, \underline{SD} = 18.4) than during Time 2 (\underline{M} = 31.1, \underline{SD} = 17.9). These same infants were observed in State 1 for a greater number of intervals in Time 2 (\underline{M} = 18.4, \underline{SD} = 16.9) than in Time 1 (\underline{M} = 3.6, \underline{SD} = 5.8). During sucking activity infants in the Experimental condition were more likely to be in State 2 than in State 1. However, immediately following sucking activity, the incidence of State 1 increased for these same infants. For infants in the Control condition, the mean number of intervals infants were observed in State 1 increased from Time 1 (\underline{M} = 10.3, \underline{SD} = 15.1) to Time 2 (\underline{M} = 17.0, \underline{SD} = 16.7). There was minimal change in the number of intervals infants were observed to be in State 2 from Time 1 (\underline{M} = 37.4, \underline{SD} = 21.2) to Time 2 (\underline{M} = 37.1, \underline{SD} = 17.9).

A 2 (Low- vs Average-PI) X 2 (Experimental vs Control) X 2 (Time 1 vs Time 2) repeated measures MANOVA on the measures of modal state and the number of times infants changed behavioral state showed a reliable 3-way interaction for Condition by PI Group by Time, $\underline{F}(2,55) = 4.97$, $\underline{p} < .01$. The univariate tests indicated that the 3-way interaction was reliable for the measures of modal state, $\underline{F}(1,56) = 7.8$, $\underline{p} < .05$, and total number of state changes, $\underline{F}(1,56) = 7.01$,

$p < .01$ (see Table 5). Post-hoc analyses using the Newman-Keuls and the less conservative Duncan's multiple range test showed no differences between cell means for modal state. However, t -tests showed significant decreases between Time 1 and Time 2 for low-PI infants in the Experimental condition, $t(14) = 3.05$, $p < .05$, and for average-PI infants in the Control condition, $t(14) = 3.21$, $p < .05$, but not for average-PI Experimental and low-PI Control infants. Newman-Keuls post-hoc analyses of the total number of state transitions showed that within the Experimental condition, average-PI infants showed greater frequency of state changes at Time 2 than did low-PI infants. No other significant differences were found.

Insert Table 5 about here

A 2 (Low- vs Average-PI) X 2 (Experimental vs Control) X 2 (Time 1 vs Time 2) repeated measures MANOVA on modal and mean levels of motor activity showed a reliable main-effect for Time, $F(4,53) = 3.12$, $p < .05$. The univariate tests indicated that the effects for Time were reliable for modal motor activity, $F(1,56) = 10.07$, $p < .005$, and mean motor

activity, $F(1,56) = 12.05$, $p < .001$ (see Table 6). The modal motor activity level for Time 1 ($M = 2.1$, $SD = .54$)

Insert Table 6 about here

was significantly greater than for Time 2 ($M = 1.3$, $SD = .65$). Similarly, the mean motor activity level for Time 1 ($M = 2.2$, $SD = .22$) was significantly greater than for Time 2 ($M = 1.8$, $SD = .38$). This shows that all infants were more active during the first 30 minutes of the observation than during the second 30 minutes of the observation.

Pearson product-moment correlations were conducted to describe the relations between the duration, in seconds, infants sucked and 1) the number of intervals in which infants were observed in each behavioral State 2) the total number of changes in behavioral State 3) the mean level of motor activity and 4) the modal level of motor activity (see Table 7). The amount of time both low- and average-PI infants in the experimental condition spent sucking in Time 2 was negatively correlated with the number of intervals spent in State 1. Consequently, the more these infants sucked during Time 2, the less time they spent in State 1

during that time. Table 7 also shows a significant positive correlation between sucking time and the total number of state changes for low-PI infants in both conditions. As sucking increased, so did the number of state changes. There was also a significant positive correlation, for low-PI infants, regardless of condition, between the amount of sucking activity and concurrent mean and modal levels of motor activity. That is, increases in the sucking activity of low-PI infants were accompanied by increases in motor activity.

Insert Table 7 about here

Significant correlations were found between sucking in Time 1 and modal motor activity levels in Time 2 for low-PI infants in the Experimental condition (see Table 8). Significant positive correlations between the amount of sucking and the mean level of motor activity in Time 2 were found for low-PI infants in the Experimental condition.

Insert Table 8 about here

Discussion

This study shows that low- and average-PI infants behave differently when given opportunities to suck on a pacifier. Overall, low-PI infants in our sample sucked less than average-PI infants. This was evidenced in the frequency and the continuous measures of sucking activity. All infants in the Experimental condition sucked with greater frequency when given access to the pacifier (Time 1) than when denied access (Time 2). Infants in the Experimental condition also sucked more often than infants in the Control condition. Within the Experimental condition, low-PI infants changed state more frequently than average-PI infants during periods of sucking activity. However, following periods of sucking activity, low-PI infants in the Experimental condition changed state less frequently than average-PI infants. When left undisturbed for the entire 1-hour observation period, low-PI infants in our sample were observed in State 1 more often than average-PI infants. Lastly, in comparison to average-PI infants, low-PI infants displayed higher levels of motor activity both during and immediately following sucking activity.

The finding that low-PI infants sucked less than

average-PI infants when given access to a pacifier is consistent with previous research showing that the birthweight of the infant is positively correlated with the sucking frequency, amplitude and nutrient intake in newborns (Engen, Lipsitt, & Robinson, 1978; Pollitt, Gilmore, & Valcarcel, 1978). Low birthweight infants and infants who are underweight-for-length are similar in that both populations display signs of intrauterine growth retardation related to prenatal malnutrition. The ponderal index is sensitive to subtle patterns of differential fetal growth reflecting late gestational nutritional insult (Miller & Hassenein, 1971). This implies that subtle differences in the weight-for-length ratio can affect behavioral functioning in ways which may indirectly alter the infant's development. For example, the sucking behavior of low-PI infants may not be sufficient to derive some of the quieting effects commonly associated with NNS. In terms of nutritive sucking (Pollitt, et al., 1978), the diminished sucking response of low-PI infants may also make it more difficult for the infant to take in the nutrients necessary to support catch-up growth.

The finding that infants in the Experimental condition

sucked more often as assessed by the frequency and the continuous measures of sucking confirms that newborns respond to the pacifier as a sucking stimulus. Future study could determine the relation between the frequency and the length of sucking bouts during exposure to a pacifier. This finding serves as a manipulation check and suggests that the newborns in our study who were offered a pacifier, did suck more often.

For infants in the Experimental condition, we found that sucking activity led to greater concurrent state lability for low-PI infants than average-PI infants, but less state lability immediately following sucking activity.

Previous research has suggested that the frequency of state transitions may reflect the integrity of autonomic (Anderson, et al., 1983; Zeskind, 1981) and behavioral organization (Neely, 1979; Woodson, et al., 1985).

Typically, frequent changes in state signal that the infant may have difficulty maintaining a homeostatic balance in autonomic function (Zeskind, 1981). Greater stability of state organization may reflect the infant's emerging capacity to regulate autonomic and behavioral organization. In the absence of well developed endogenous regulatory

capacities, an infant may use sucking activity as an exogenous source of regulation (Goff, 1985). The increased state lability found among low-PI infants during sucking activity may reflect these infants' diminished capacity for self-quieting during exposure to the rhythmic stimulus of sucking (Zeskind, Goff & Marshall, 1985).

The finding that low-PI infants showed less state lability than average-PI infants after sucking activity seems contrary to expectations. First, this may be explained by the tendency for frequent sucking opportunities in the first hours of life to increase the amount of time full-term newborns were observed in quiet alert states during first feeding interactions (Neely, 1979). The greater state lability observed among average-PI infants immediately following sucking activity suggests that over time, increased opportunities to suck may facilitate quiet alertness among average- but not low-PI infants. The diminished state lability observed among low-PI infants immediately following sucking activity may reflect in part the tendency of low-PI infants to suck less than average-PI infants when exposed to a pacifier. Second, this finding may reflect the relative ineffectiveness of sucking activity

to alter the infant's state organization beyond the sucking bout.

Third, the lack of state lability found among low-PI infants following sucking activity may reflect these infants' altered behavioral organization and autonomic functioning. This hypothesis is further supported by our observation that among infants in the Control condition, low-PI infants were observed in State 1 more often than average-PI infants. This observation is consistent with the view that the behavior of low-PI infant's (e.g., low muscle tonus and diminished behavioral responsivity) may reflect parasympathetic dominance in these infants' autonomic functioning.

Low-PI infants in the Control condition were observed in State 1 for a greater number of intervals than were average-PI infants. Ordinarily, the newborn will alternate between quiet (State 1) and active sleep (State 2) on a 15 minute cycle (Hofer, 1981). Rapid or delayed cycling between states may reflect poor behavioral organization. Our finding may suggest that low-PI infants cycle less frequently than average-PI infants. This is consistent with previous literature which documents the unique behaviors of

the low-PI infant which are also thought to reflect poor behavioral organization and less stable patterns of autonomic functioning (Zeskind, 1981).

Low-PI infants, regardless of condition, displayed a significant positive correlation between the continuous measure of sucking activity and concurrent modal levels of motor activity. This suggests that low-PI infants are more motorically active when sucking than average-PI infants. The increase in motor activity found among low-PI infants subsequent to sucking activity may suggest that sucking does not facilitate behavioral quiescence in these infants. This suggestion is supported by the finding that sucking activity in low-PI infants was accompanied by an increase in the number of state changes. These two findings suggest the diminished capacity of low-PI infants to use the rhythmic sucking stimulus as a source of exogenous regulation. These findings also suggest differences in the overall relation between sucking activity and concurrent and subsequent levels of motor activity among infants of differential fetal growth categories.

Low-PI infants in the Experimental condition also showed significant positive correlations between the

continuous measure of sucking activity in Time 1 motor activity in Time 2. Previous literature suggests that the behavioral characteristics of the low-PI infant differ from those of average-PI infants (Als, et al., 1976). Typically, low-PI infants display less orientation to social (Lester & Zeskind, 1978) and nonsocial, visual and auditory stimulation (Zeskind, 1981). The characteristics of the cry sounds also differentiate these infants from average-PI infants (Zeskind & Lester, 1981). These differences have been conceptualized as reflecting the integrity of the infant's behavioral and autonomic organization (Lester & Zeskind, 1978; Zeskind & Lester, 1981).

The present study suggests that low- and average-PI infants also differ in regards to sucking activity and its behavioral consequences. For example, the positive correlations found among low-PI infants between sucking activity and concurrent and subsequent motor activity suggests that unlike average-PI infants, low-PI infants may expend more, rather than less, energy in the presence of sucking opportunities. This may be of particular importance during the infant's first few days of life when under the best of conditions motor activity consumes up to 40% of a

newborn's total energy budget (Mestyan, 1978). To the extent that low-PI infants suck less frequently than average-PI infants, they may develop and subsequently display different patterns of behavioral organization than average-PI infants.

Further experimental study is necessary to determine causality and the degree to which this finding extends beyond the newborn period.

The finding that, within the Control condition, low-PI infants, left undisturbed, were observed in State 1 more often than average-PI infants may reflect increased parasympathetic activity among these infants. This may be adaptive for the low-PI infant as valuable energy is conserved in the first hours and days of life (Mestyan, 1978) enabling the infant to support catch-up growth. However, to the extent that this distribution of sleep states may be generalized over time, this finding may have negative implications for the infant's developing nervous system. The full term newborn spends approximately 50% of its time in rapid eye movement (REM) activity (State 2) at birth, though REM sleep declines quickly throughout the first postnatal year (approximately 30% at 6 months

postnatal age) (Hofer, 1981). The amount of time newborn infants engage in REM activity may suggest its importance in the developing organism. For example, REM activity stimulates the release of growth hormone and increases the rate of protein synthesis thought to be necessary for consolidation of learning (Carlson, 1986). REM activity also provides diffuse stimulation from the brain stem to upper brain centers providing stimulation for the eye, ear and heart muscle and to other vital systems (Hofer, 1981). To the extent that low-PI infants engage in less REM activity, they experience less of the physiological and biochemical stimulation triggered by REM sleep.

The findings of this study are consistent with previous research documenting the behavioral differences among infants of differential fetal growth categories. The diminished sucking activity, increased motor activity and unique patterns of state organization found among low-PI infants in this study may reflect poorly regulated autonomic functioning among low-PI infants (Lester & Zeskind, 1978; Zeskind & Lester, 1981). These behaviors are important for the developing infant to the extent that they provide experiences which effect future development and contribute

to the quality of the caregiving environment. For example, regarding the behavior of infants who are given pacifiers while undergoing a variety of stressful medical procedures (Campos, 1988; Field & Goldson, 1984; Gunnar, et al., 1984) our findings suggest that low-PI infants may not quiet as easily as average-PI infants either during or after the procedure.

Additionally, the tendency of low-PI infants to suck less during the first hours of life may diminish their ability to maintain levels of alertness which facilitate successful initial feeding interactions with caregivers (Neely, 1979). Over time, the apathetic, unresponsive and irritable behavior commonly associated with low-PI newborns (Als, et al., 1976; Beeghley, 1988) may negatively impact the functional relationship between the infant and the caregiving environment (Als, et al., 1976; Blackburn & Barnard, 1985). In non-supportive caregiving environments, the behavioral characteristics of the low-PI infant may contribute to impoverished intellectual, behavioral and social-intellectual development (Zeskind & Ramey, 1978; 1981).

These results have important methodological implications for the study of sucking activity in newborns. Prior research examining the sucking activity (nutritive and nonnutritive) of newborn infants may contain within their full term, full birthweight sample, infants who have experienced differential fetal growth. The results of the present study suggest that within presumably homogeneous samples are infants who show the same behavioral capacities as infants, such as low birthweight or preterm infants, who were purposely excluded from the study. As such, ponderal index status, if not controlled, may confound other variables resulting in threats to internal validity and limiting generalizability of results.

In summary, the results of this study provide support for the differential effects of sucking on infants of differing PI status. It was suggested that low-PI infants may have a diminished capacity to effectively use the rhythmic sucking stimulus as a source of exogenous regulation. Differential sucking activity may also reflect current behavioral organization and feed back to impact future developmental processes. These results may have important implications for studies involving sucking

activity in newborns, the infant's energy utilization and for the development of infant-caregiver interactions.

Future research may be directed at determining the presence and extent of differences between infants of differing PI status under more stressful conditions. "If differences exist, do they extend beyond the actual stressful event?" Answers to these questions would provide the information necessary to more accurately assess the impact of these differences upon subsequent development.

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Table 1.

Means and Standard Deviations of Infant Demographic Characteristics

by Experimental Condition

	Experimental		Control		t(1,58)	p<
	n = 30		n = 30			
	Mean	SD	Mean	SD		

Gestational Age	39.5	1.5	39.5	1.4	-4.5	.98
Birthweight (grams)	3184.5	520.4	3003.8	351.2	1.6*	.12
Birthlength (centimeters)	51.2	2.6	50.5	2.2	1.0	.32
Apgar 1	7.8	1.6	6.7	2.3	2.1**	.04
Apgar 5	8.9	.3	8.9	.3	0.0	1.0
Infant Age (hours)	36.1	23.4	34.7	21.7	.24	.81
Maternal Age	25.3	4.6	24.4	4.8	.71	.48

*df = (7, 52)

**df = (5, 54)

Table 2.

Observable Signs Corresponding to each Motor Scale Rating

- | | |
|---|---|
| 0 | No motor activity other than respiratory movements. |
| 1 | Activity restricted to face or head. |
| 2 | Activity involving neck or limited to one limb. |
| 3 | Simultaneous activity in two limbs. |
| 4 | Simultaneous activity in three or more limbs. |
| 5 | Crying with generalized activity. |

Table 3.

Means and Standard Deviations of Frequency and Continuous Measures of Sucking Activity by Low- and Average-PI Infants in Experimental and Control Conditions, In Time 1 and Time 2

	Experimental		Control	
	Mean	SD	Mean	SD
Low-PI/Time 1				
Seconds	219.6	258.2	91.3	89.1
Intervals	26.3	14.4	14.9	10.2
Low-PI/Time 2				
Seconds	84.3	98.6	70.2	114.3
Intervals	17.9	15.4	14.2	10.7
Average-PI/Time 1				
Seconds	405.1	341.0	152.5	237.0
Intervals	39.5	14.0	22.1	10.7
Average-PI/Time 2				
Seconds	99.3	68.0	94.2	122.4
Intervals	21.2	9.4	15.6	10.7

Table 4.

Means and Standard Deviations of the Number of Intervals During Time 1 and 2 in Which Low- and Average-PI Infants From Experimental and Control Conditions Were Observed in State 1 and State 2

	Experimental		Control	
	Mean	SD	Mean	SD
Low-PI/Time 1				
State 1	4.3	7.3	14.3	17.1
State 2	46.0	16.9	35.4	18.9
Low-PI/Time 2				
State 1	20.5	15.2	13.6	15.1
State 2	33.8	15.8	39.1	19.8
Average-PI/Time 1				
State 1	2.9	3.9	6.3	12.2
State 2	43.2	20.3	39.5	23.8
Average-PI/Time 2				
State 1	16.4	18.7	20.4	17.9
State 2	28.5	19.9	35.1	16.1

*using number of intervals in each state

Table 5.
 Means and Standard Deviations of Modal State and State Transitions of Low-and Average-PI
 Infants in Experimental and Control Conditions at Time 1
 and 2

	Experimental		Control	
	Mean	SD	Mean	SD
Low-PI/Time 1				
Modal State	2.2	0.6	1.9	0.7
Transitions	4.5	6.2	4.8	4.3
Low-PI/Time 2				
Modal State	1.8	0.8	2.2	1.3
Transitions	2.6	2.1	5.3	6.4
Average-PI/Time 1				
Modal State	2.3	0.7	2.4	0.9
Transitions	2.9	1.6	5.5	6.8
Average-PI/Time 2				
Modal State	2.3	1.4	1.7	0.5
Transitions	8.7	11.1	3.5	2.1

Table 6.
Means and Standard Deviations of Modal and Mean Motor Activity Levels for Low- and Average-PI Infants in Experimental and Control Condition, at Time 1 and 2

	Experimental		Control	
	Mean	SD	Mean	SD
Low-PI/Time 1				
Modal	2.1	1.9	1.5	1.9
Mean	2.2	.96	1.9	1.1
Low-PI/Time 2				
Modal	.73	1.4	1.1	1.9
Mean	1.5	1.1	1.7	.99
Average-PI/Time 1				
Modal	2.8	1.5	1.9	1.8
Mean	2.4	.70	2.3	1.1
Average-PI/Time 2				
Modal	2.2	2.0	1.0	1.7
Mean	2.3	1.3	1.5	.93

Table 7.

Correlation Between the Duration of Sucking and Concurrent State Behavior
of Low- and Average-PI Infants as a Function of Time

	State 1		State 2		Total State Bouts	
	Time 1	Time 2	Time 1	Time 2	Time 1	Time 2
Low-PI Experimental	-.33	-.80**	-.73**	-.31	.90**	.27
Low-PI Control	-.29	-.31	-.24	.02	.73**	.14
Average-PI Experimental	-.44	-.68*	-.62*	.09	.59	.47
Average-PI Control	-.29	-.51	-.47	.28	.35	.47

** - .001 level of significance

* - .01 level of significance

Table 7 cont.

Correlation between the Duration of Sucking and Concurrent Motor Activity of Low- and Average-PI Infants as a Function of Time.

	Mean Motor Level		Modal Motor Level	
	Time 1	Time 2	Time 1	Time 2
Low-PI Experimental	.84**	.87**	.44	.86**
Low-PI Control	.57	.59	.68*	.74*
Average-PI Experimental	.40	.62	.43	.43
Average-PI Control	.55	.64	.54	.59

** - .001 level of significance

* - .01 level of significance

Table 8.
 Correlation Between the Duration of Sucking and Subsequent
 State Behavior of Low- and Average-PI Infants as a Function
 of Time.

	State 1	State 2	Total
	Time 2	Time 2	Transitions
			Time 2
Low-PI Experimental	-.45	-.49	.41
Low-PI Control	.46	-.21	.13
Average-PI Experimental	-.43	-.25	.48
Average-PI Control	-.21	-.13	.40

** - .001 level of significance

* - .01 level of significance

Table 8 cont.

Correlation Between the Duration of Sucking and Subsequent
Motor Activity of Low- and Average-PI Infants as a Function
of Time.

	Mean Motor Level Time 2	Modal Motor Level Time 2
Low-PI Experimental	.77**	.75**
Low-PI Control	.16	.16
Average-PI Experimental	.59	.45
Average-PI Control	.46	.41

** - .001 level of significance

Appendix A

Introduction

Development is a probabilistic process. The likelihood that any particular developmental pathway or outcome will occur depends upon the specific experiences the developing organism encounters (Gottlieb, 1976). In a probabilistic model of development, experience may be provided through a variety of stimuli in the environmental surround as well as self-generated through the function and/or behavior of the developing organism. Even subtle changes in experience may alter the pathways by which an organism develops. For example, subtle forms of prenatal malnutrition may alter central and autonomic nervous system functioning resulting in less optimal behavioral responsiveness as determined by the Neonatal Behavioral Assessment Scale (NBAS) and high-pitched cry sounds (Zeskind, 1981). These altered behaviors and cry sounds may negatively influence the quality of care and thereby the subsequent development of the infant (Zeskind & Ramey, 1978, 1981). Experience plays a continuous and important role in shaping the infant's development.

The development of infants "at risk" can also be seen as probabilistic (Zeskind, 1985). The term "at risk" is commonly used to refer to the infant's increased probability of atypical or nonoptimal cognitive, motoric or social development. A variety of developmentally relevant experiences may occur during pre-, peri- or early postnatal periods which place an infant at varying degrees of risk for nonoptimal development. Some experiences that may place the infant at risk are organismic, such as brain damage due to prenatal exposure to teratogenic agents or perinatal anoxia (Knobloch & Pasamanick, 1966), while others may be environmental. For example, due to lack of resources, infants born into economically stressed families are likely to receive poor health care, inadequate nutrition and deficient amounts of stimulation. Because an exclusive focus upon organismic risk factors proved inadequate to account for the variety of outcome among infants of similar biological risk status, Sameroff and Chandler (1975) proposed that both organismic and environmental risk factors must be assessed in order to accurately estimate the probability of nonoptimal development. Specifically, these authors examined the ways in which the unique

characteristics of the infant and caregiver interact and shape one another. This bidirectional interaction provides the context in which the probabilities for subsequent developmental processes and outcomes are determined. The quality of infant-caregiver interaction may significantly alter the probabilities of developmental outcome for biologically at-risk infants.

A number of behavioral measures have been used to assess the status and progress of development. Of these, the organization of behavioral state may have particular relevance for the quality of the infant-caregiver relationship and as a reflection of the infant's current functioning. Behavioral state is a descriptive term referring to the regular co-occurrence of a cluster of behavioral and physiological parameters observed during the various stages of sleep and waking behavior (Prechtl & O'Brien, 1982). As development proceeds, these clusters or states normally develop into a predictable, recurring pattern. The pattern of behavioral organization is perhaps most apparent in the sleep-wake cycle which contains discrete and largely predictable patterns of behavioral states. Infants at-risk show great variability in their

degree of behavioral organization. Infants characterized by atypical patterns of fetal growth, for example, evidence less stable behavioral organization than infants with more typical fetal growth patterns (Zeskind, 1981).

Specifically, the behavioral states of infants with atypical patterns of fetal growth are likely to be less well defined and transitions from one state to another are uneven and irregular. Variability may reflect the infant's diminished capacity for autonomic regulation (Zeskind, 1981).

One experience which may alter behavioral state and its organization is a subtle form of malnutrition resulting in subtle patterns of atypical fetal growth. These fetal growth patterns are assessed by a ratio of the infant's birth weight and birth length known as the ponderal index (PI). Rohrer used the PI to calculate the amount of soft tissue mass present in an infant (in Miller & Hassenein, 1971). This index is thought to reflect third trimester nutritional insult leading to atypical patterns of fetal growth. Studies show that full birthweight, full-term infants who are underweight-for-length (low-PI) evidence a wide range of behaviors indicative of poor autonomic regulation (Lester & Zeskind, 1978; Zeskind, 1981). In

addition to more variable state organization, low-PI infants have higher pitched cries than infants with average PI's. These higher pitched cries have been associated with altered functioning of the autonomic nervous system (Zeskind & Lester, 1981; Zeskind, 1981).

A variety of sensory experiences have been demonstrated to facilitate and support development in at-risk infants (Blackburn, 1983; Leib, Benfield, & Guidubaldi, 1980; Ulrich, 1984). Sucking on a pacifier, in particular, has been shown to increase behavioral organization both in preterm infants (Anderson, Burroughs, & Measel, 1983; Bernbaum, Pereira, Watkins, & Peckham, 1983; Field & Goldson, 1984; Field, Ignatoff, Stringer, Brennan, Greenberg, Widmayer, & Anderson, 1982; Woodson, Drinkwin, & Hamilton, 1985) and in healthy term infants undergoing stressful medical procedures (Campos, 1988; Field, & Goldson, 1984; Gunnar, Fisch, & Malone, 1984). Infants who are at risk due to processes associated with atypical fetal growth may also benefit from nonnutritive sucking (NNS). Infants who are underweight-for-length, as indicated by a low-PI, may be likely to benefit from the behavioral effects associated with NNS. Specifically, NNS may serve as an

exogenous regulator which facilitates greater autonomic regulation and subsequent behavioral organization (Goff, 1985). The improved organization of behavioral states associated with NNS may have important implications for behavioral development and subsequent quality of the infant-caregiver relationship.

The purpose of this study is to examine the behavioral effects of NNS on infants of differential fetal growth. The study will focus on sucking activity and its subsequent effects of NNS on behavioral state and motor activity in infants with low and average ponderal indices. It is hypothesized that low-PI neonates will evidence less motor activity and spend more time in quiescent states during periods of NNS. Results will be discussed in the context of autonomic functioning and energy expenditure explanations of behavioral development and the indirect impact of NNS on subsequent infant-caregiver interaction.

Hypotheses

1. Access to a pacifier will increase the frequency of NNS in both average- and low-PI infants.
2. Low-PI infants would suck less often than average-PI infants when given access to a pacifier

3. Increased frequency of NNS will result in an increase in quiescent states during exposure to the pacifier in low- and average-PI infants.
4. Opportunity to suck nonnutritively on the pacifier will decrease the frequency of state transitions for low- and average-PI infants during exposure to the pacifier.
5. Opportunity to suck nonnutritively on the pacifier will decrease overall motor activity during exposure to sucking in average- and low-PI infants.

Nonnutritive Sucking

Sucking is one of the first experiences following natural childbirth (Anderson, Burroughs, & Measel, 1983) and occurs spontaneously both during and between feeding situations (Measel & Anderson, 1979). The well-developed rooting response of the healthy neonate promotes early nutrient intake in the newborn. Infants also appear to derive other benefits from sucking nonnutritively. Parents and other infant caretakers have long recognized the quieting effects of a pacifier on a distressed or irritable infant. These observations have generated research

providing documentation of the behavioral and physiological consequences of nonnutritive sucking (NNS) and the possible mechanisms mediating these effects.

Biobehavioral Effects of NNS on Full Term Infants

Nonnutritive sucking is a reflexive behavioral pattern which is easily elicited in the newborn. This sucking response may occur in response to any stimulation in or around the infant's mouth. Placing a pacifier in the infant's mouth results in a reflexive sucking pattern composed of vigorous, rhythmic mouthing movements interspersed with swallowing. This reflexive sucking/swallowing pattern is common to all mammals at birth and it serves at least two important functions. The sucking reflex allows the infant to acquire available nutrients from its mother's teat and it induces the infant into a more quiescent behavioral state (Hall & Williams, 1983). Though this second function is not essential for successful feeding, quiescence allows the neonate to conserve valuable energy. The postulated effect of NNS on energy savings may be particularly important during the human neonate's first few days of life when up to 40% of the infant's daily

available energy is expended in activity alone (Mestyan, 1978).

Using a nipple placed over the experimenter's finger, Kessen and Leutzendorff (1963) demonstrated a marked reduction in general motor activity in highly aroused infants within 5 seconds of receiving intra-oral stimulation. Though the quieting effect was robust, the duration of these effects on highly aroused infants were short lived. Infants typically returned to baseline levels of activity within 25 seconds of nipple removal. Field and Goldson (1984) noted that NNS appears incompatible with crying and excessive motoric activity. They sought to determine the effects of NNS on the infant's behavioral state, heart rate and respiration rate during invasive medical procedures. One common invasive medical procedure is the heelstick procedure used to obtain blood samples from newborns. Infants who were provided opportunities for NNS during the heelstick procedure "spent more time in an alert/quiescent state while control infants spent more time in fussy/crying states both during and following the procedure" (p. 1013). More recently, Campos (1988) found that two-week-old fullterm infants allowed to suck on a

pacifier during and after heelstick procedures had significant reductions in heart rate (an average of 26 beats per minute). Additionally, infants in the pacifier group spent significantly more time in an alert state than infants in the comparison (swaddled) group. Crying was also reduced approximately 40% in healthy fullterm infants who sucked on a pacifier during and after circumcision (Gunnar, Fisch, & Malone, 1984). Similar benefits have been documented for preterm infants undergoing stressful medical procedures (Field & Goldson, 1984; Gunnar et al., 1984).

Despite some evidence of an inverse relation between the degree of quieting due to NNS and prestimulus activity levels (Rovee & Levin, 1966), other studies (Wolff, 1966; Wolff, 1967) suggest that NNS has an equally quieting effect upon infants during low levels of activity. Neely (1979) found that in addition to the short term effects cited above, fullterm infants also experienced long term effects from NNS. In her study, infants allowed to suck to satiety at 1, 4, 8 and 12 hours of age spent more time in alert, wakeful states and less time in sleep states or periods of irritability during the first feeding than did controls. Additionally, infants in the sucking condition required less

time to burp after feeding than did control infants. NNS has been shown to affect behavioral state in both term and preterm infants. In addition to an overall reduction in motor activity and frequency of state transitions, NNS significantly decreased the amount of time spent in active states and, at the same time, increased both quiescent states and length of longest state bout (Woodson, Drinkwin & Hamilton, 1985).

NNS and Infants At Risk

A variety of patterned sensory experiences have been shown to foster behavioral development in high risk infant populations (Ulrich, 1984; Cornell & Gottfried, 1976; Blackburn, 1983). Due to the many risk factors associated with preterm birth, preterm infants have been the subject of numerous developmental and intervention studies. In particular, the role of sucking in fostering the behavioral development of the preterm has received much attention.

Due to the immature status of the preterm infant's gastrointestinal system, preterm infants are often unable to feed orally at birth. Instead, these infants are fed through a gavage tube inserted directly into the stomach. One consequence of this type of feeding is that the preterm

infant is offered little natural opportunity to suck. This lack of sucking experience, though nonobvious, may have important implications for the behavioral development of the preterm infant. For example, the relatively immature status of the preterm infant's central nervous system diminishes its capacity to regulate heart and respiration rates, body temperature and other vital autonomic functions necessary for successful adaptation to the extra-uterine environment (Als, 1982). This difficulty is exacerbated by frequent exposure of the preterm to a variety of disquieting and often painful medical procedures. The experience of sucking may support the infant's regulatory capacity and consequently may foster the infant's behavioral development.

Significant increases in transcutaneous oxygen tension (TcPO₂), a non-invasive measure enabling the study of the impact of various stimulation upon tissue oxygenation, were found both during and after (up to 8 minutes) NNS (Paludetto, Robertson, Hack, Shivpuri, & Martin, 1984). Nonnutritive sucking has also been shown to result in significant reductions in heart rate (Woodson, et al., 1985) and motor activity (Woodson & Hamilton, 1986) both during and following sucking exposure in term and preterm infants.

In each of these studies the effects of NNS appear to extend beyond the actual sucking bout thus enhancing any benefit which may be derived from the sucking experience.

Sucking during gavage tube feedings was shown to "accelerate the organization and efficiency of the sucking pattern" in preterm infants, to facilitate a more rapid transition from gavage to oral feedings and to facilitate more rapid weight gain among preterms (Bernbaum, Pereira, Watkins, & Peckham, 1983; Ignatoff & Field, 1982; Measel & Anderson, 1979). In another study (Anderson, et al., 1983) treatment (NNS) infants received an average of 27 fewer tube feedings than control infants and were ready for bottle feedings a mean of 3.4 days before control infants. This resulted in hospital discharge for the treatment infants an average of 4 days earlier than control infants. Although it is clear that sucking nonnutritively facilitates the behavioral development and growth of the preterm infant, the processes which may mediate these effects are not well understood. The increased growth seen in preterms exposed to NNS may be secondary to the maturation and coordination of the sucking-swallowing reflexes. Simply, more sucking experience may facilitate the development and coordination

of the suck-swallow reflex enhancing the preterm's feeding skills. Alternatively, Bernbaum et al., (1983) suggest that the greater weight gain among treatment (NNS) infants may be due either to "decreased energy expenditure or to more efficient nutrient absorption stimulated by NNS" (p. 44). One mechanism which may account for these effects, as well as a variety of other effects associated with NNS, is an increase in parasympathetic activity (Anderson, et al., 1983; Anderson & Vidyasagar, 1979; Measel & Anderson, 1979). Increases in quiescent states (Campos, 1988; Goff, 1985; Gunnar et al., 1984; Wolff & Simmons, 1967), decreases in motor activity (Kessen & Leutzendorff, 1963), and heart rate (Campos, 1988; Woodson & Hamilton, 1986) and more efficient oxygenation (Paludetto et al., 1984) are all consistent with the hypothesis that NNS acts upon the autonomic nervous system to facilitate the regulation of both behavioral and autonomic activity (Goff, 1985).

Role of NNS on Autonomic Functioning in Low-PI Infants

While most healthy neonates are able to achieve autonomic regulation on their own, those infants born preterm and/or term infants at increased risk may evidence altered patterns of autonomic regulation (Anderson, et al.,

1983; Zeskind, 1981). These infants often have difficulty adapting to and interacting with the environment due to nonoptimal states of arousal and behavioral disorganization. Whereas the infant with a properly functioning autonomic nervous system is predominantly in more quiescent states, infants at risk are unable to maintain a homeostatic balance between over and underarousal. It is hypothesized that sensory experiences which quiet the infant may do so by stimulating the parasympathetic branch of the ANS which acts to reduce arousal. For infants at increased risk, NNS may serve as an exogenous regulator of autonomic activity, enabling the infant to achieve states of arousal and behavioral organization optimal for interaction with the environment.

Atypical Fetal Growth

Infants who have experienced stressful circumstances during the pre- or perinatal periods and yet evidence no obvious anomaly are not easily assessed. Due to the nonobvious nature of the insult, the importance of these stressful experiences may be minimized if not overlooked entirely. Consequently, timely identification and treatment are unlikely to occur, thus increasing the infant's risk for

further developmental problems. Fetal malnutrition is one such experience. Although fetal malnutrition often results in subtle patterns of atypical fetal growth, many of these infants are unlikely to be detected (Miller & Hassenein, 1971). The unique behavioral repertoire of these infants places them at greater risk for nonoptimal development (Beeghley, Barrett, Burrows, Nugent, Sepkoski, Vo, & Brazelton, 1988). Zeskind and Ramey (1978) demonstrated that compared to average-PI infants, low-PI infants were at greater risk for delayed cognitive development as early as 3 months of age and more likely to experience nonsupportive caregiving as early as 18 months of age. In a follow-up study, detrimental effects on intellectual, behavioral and social-interactional development were shown to persist at 36 months of age (Zeskind & Ramey, 1981).

There are three general sources of fetal malnutrition and subsequent atypical fetal growth. Insufficient maternal diet is the most implicated factor contributing to fetal malnutrition. Additionally, the mother may be adequately nourished, but due to inadequate placental transport of nutrients and or the inability of the fetus to metabolize available nutrients, the fetus may experience nutritional

insult (Miller & Hassenein, 1971).

Traditionally, atypical fetal growth in the newborn has been determined by comparing the birth weight and calculated gestational age to derive the appropriate weight for gestational age (AGA) (Lubchenco, Hansman, Dresler, & Boyd, 1963). Using this measure, infants are categorized as either large (overweight) for gestational age or small (underweight) for gestational age. More recently, the ponderal index (PI), a ratio of birth weight (in grams) X 100/the cube of crown-heel birth length (in centimeters), has been used to identify more subtle patterns of differential fetal growth and compromised nutritional status (Miller & Hassenein, 1971). Typically, a weight-length ratio below the 10th percentile (2.28) or above the 90th percentile (2.82) for infants of 38 weeks or greater gestation signifies a late gestational nutritional deficiency (Brazelton, Parker, & Zuckerman, 1976).

Although weight-for-length and weight-for-age measures have both been used to diagnose atypical patterns of fetal growth, they may identify different infants. For example, the small for gestational age category as defined by appropriate weight for gestational age (AGA) may exclude

infants who are full birth weight for their gestational age but are underweight relative to their own length (Zeskind & Lester, 1981). Conversely, infants who are overweight for their length (high-PI) are often excluded from the large for gestational age category as defined by weight-for-age as they are not considered heavy for their gestational age. The difference between weight-for-age and PI is especially apparent at the extremes of the distribution of the PI (Zeskind & Lester, 1981).

Additionally, the PI may be more sensitive to the timing and the extent of the intrauterine nutritional insult (Brazelton, et al., 1976). This specificity has become increasingly important as various subgroups within this heterogeneous population of atypical fetal growth infants have been identified. In particular, two patterns of atypical fetal growth are thought to differ in the timing of the nutritional insult in-utero (Beeghley et al., 1988). Symmetrical patterns of atypical fetal growth appear to result from a chronic malnutrition throughout the gestational period. Consequently, both the skeletal structure (length) and degree of tissue and body fat (weight) are compromised leaving the infant both underweight

and underlength. These "small-for-date" infants are typically identified during routine newborn examinations. Infants with asymmetrical patterns of fetal growth are thought to have experienced chronic malnutrition only after skeletal growth has peaked, around the 27th through 30th week of gestation, resulting in their being underweight-for-length or low-PI (Beeghley, et al., 1988).

In summary, the PI is able to identify a pattern of atypical fetal growth not identified by the AGA measure currently used in the routine hospital newborn examination. Additionally, the PI appears to be sensitive to late gestational nutritional insult. Because of the inadequacy of other measures in identifying these often subtle weight-for-length disparities, these infants often go undetected and so are placed at even greater risk for nonoptimal development.

Low-PI and Behavioral State

There is considerable variability in the degree of behavioral organization among newborns. This variability is particularly evident in infant populations at increased risk. Changes in the organization of behavioral state are commonly associated with atypical patterns of fetal growth.

Specifically, the infant's ability to organize its behavioral rhythms after birth is critical for enabling the infant to respond optimally to his or her environment and for providing caregivers with clearer, more consistent cues (Blackburn & Barnard, 1985).

Behavioral state is a descriptive term referring to the regular co-occurrence of a cluster of behavioral and physiological parameters observed during the various stages of sleep and waking behavior (Precht1 & O'Brien, 1982). As development proceeds, these clusters or states normally develop into a predictable, recurring pattern. Compared with average-PI neonates, both low- and high-PI neonates evidence less stable behavioral organization (Zeskind, 1981). That is, their behavioral states are less likely to be well defined and transitions from one state to another are characteristically uneven and irregular. Given this difficulty in regulating behavioral state, these infants are likely to experience greater difficulty than average-PI infants in adapting to the demands of extrauterine life.

Other studies have demonstrated an association of a wide range of nonoptimal behavior associated with atypical fetal growth (Beeghley, et al., 1988, Zeskind & Ramey, 1978;

1981). Behaviorally, both low- and high-PI infants have been shown to perform less optimally than average-PI infants on the Brazelton Neonatal Behavioral Assessment Scale (Lester & Zeskind, 1978; Zeskind, 1981). Beeghley, et al., (1988) found that infants with both symmetrical and asymmetrical patterns of fetal growth performed poorer on motor and orientation clusters on the NBAS than did infants with more typical patterns of fetal growth. However, unlike their symmetrical counterparts, infants evidencing asymmetrical growth patterns (low-PI) continued to perform poorly on these measures throughout their first month. These infants were also shown to have significantly lower Mental Development Indices (MDI) and Psychomotor Developmental Indices (PDI) on the Bayley Scales of Infant Development (BSID) at 4 months than did average-PI infants (Beeghley, et al., 1988). Additionally, infants at the extremes of the PI distribution show poorer state regulation, less quality of tone and alertness, and a greater difficulty sustaining attention than average-PI infants (Als, Tronick, Adamson, & Brazelton, 1976; Lester, 1979). Low-PI newborns also made poor use of available stimulation, showed deficient social interactive behaviors

during the NBAS and had higher pitched cries than average-PI

infants. In a longitudinal study by Zeskind and Ramey (1978; 1981), low-PI infants displayed signs of delayed cognitive development in as few as three months after birth and continuation of detrimental effects on intellectual, behavioral and social-interactional development through 36 months of age.

Overall, the behavioral characteristics of the infant with atypical patterns of fetal growth have led to the description of these infants as apathetic, unresponsive to environmental stimuli and irritable when aroused (Als et al., 1976; Beeghley, 1988). Long-term sequelae associated with atypical patterns of fetal growth include poor performance on standardized tests of intellectual and motor development (Zeskind & Ramey, 1978; 1981), special education needs (Rubin, Rosenblatt, & Barlow, 1973) and subsequent educational failure (Birch & Gussow, 1970). Those infants on the extremes of the PI distribution (low- and high-PI) may comprise a particularly vulnerable subgroup among infants showing signs of atypical fetal growth.

Summary and Hypotheses

The poor behavioral organization and responsiveness commonly associated with infants evidencing signs of atypical fetal growth are highly associated with nonoptimal development (Beeghley, 1988) in nonsupportive caregiving environments (Zeskind & Ramey, 1978; 1981) and may reflect an altered functioning of the infant's autonomic nervous system (Zeskind, Goff & Marshall, 1985; Zeskind & Lester, 1981). The inability of these infants to achieve and sustain levels of arousal facilitative of optimal receptiveness and responsiveness to environmental stimuli may also have significant consequences for cognitive, social, and emotional development (Neely, 1979; Zeskind & Ramey, 1978; 1981). Nonnutritive sucking is one experience which has been shown to ameliorate the suboptimal behavioral sequelae associated with infants of varying degrees of risk. NNS may facilitate behavioral development by serving as an exogenous regulator of autonomic activity and behavioral organization in infants with behavioral profiles similar to that of the infant with atypical patterns of fetal growth. In particular, NNS facilitates the organization of behavioral state which may have important implications for

infant-caregiver interaction and subsequent probabilities for development.

The purpose of the present study is to determine the immediate and delayed effects of NNS on the behavioral organization of the newborn low-PI infant. Specifically, this study seeks to quantify the sucking activity and the temporal organization of behavioral state and motor activity during exposure to NNS. All infants engaged in sucking activity during sleep, are expected to spend more time in quiet sleep. When awake, all infants engaged in sucking activity are expected to spend more time in the less active, quiet alert state. Additionally, this study should provide information regarding presence and extent of differences in sucking activity and its subsequent affects on the behavioral organization of low- and average-PI neonates.

Appendix B

Observable Signs of Behavioral States

- 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 A 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 may or may not be present.

State 6 Continuous crying is present.

APPENDIX C

ID# _____

LETTER OF INFORMED CONSENT

Dear Parent:

Parents often use pacifiers to sooth and quiet fussy or crying infants. We are interested in watching healthy full term infants when they are given pacifiers. In particular, we want to see the effects that sucking on a pacifier has on the infant's sleep patterns during and immediately after sucking on a pacifier.

We would like your consent to watch your baby for about one hour. During the one hour period, your baby may be given a pacifier for 30 minutes. The remaining 30 minutes, your baby will not have a pacifier and will be watched while she or he sleeps undisturbed. If your baby is not given a pacifier for the first 30 minutes, she or he will be watched for the entire hour undisturbed. While this examination will not directly benefit your baby, we will learn important lessons for treating babies in the future.

We will be willing to answer any questions you have about this project. If later, you think of any question you might have about this project, you can get in touch with Dr. Philip S. Zeskind, at (703) 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)

(Philip S. Zeskind, Ph.D.)

(Date)

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