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The Organization of Human Newborn Sucking and Movement During Auditory Stimulation*

JANET E. FISCHEL
State University of New York at Stony Brook 11794

Many of the newborn human's earliest interactions occur during episodes of sucking, but there is little understanding of how sucking may interact with responsiveness to other social and physical stimuli. In the present study, levels of body movement, or activity, and characteristics of nonnutritive sucking were evaluated for two groups of newborns; one receiving brief presentations of a complex sound as they initiated sucking bursts, and a second group receiving the same sound during pauses between their sucking bursts. A control group for comparison received no sound stimulation. Infants stimulated during pausing showed significantly higher activity levels and more rapid habituation of movement than those stimulated during bursting. Sound during bursting was less likely to cause a shift to pausing than sound during pausing was to cause a shift to sucking. These differences suggested that bursting and pausing were not similar contexts for responding to sound stimulation. Potential mechanisms underlying differential responsiveness during sucking are suggested.

Many of the human infant's earliest interactions with the social and physical environments occur during episodes of feeding. Since several hours of the in-

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Correspondence and reprints should be addressed to: Janet E. Fischel, Department of Pediatrics, Health Sciences Center, T-11, Rm 020, State University of New York at Stony Brook, Stony Brook, NY 11794.

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fant's waking time are spent in feeding-related behavior each day, it is important to map more fully the interaction of feeding with other aspects of reactivity. Sucking may provide a complex setting for the baby's interaction with other components of the environment, a setting which influences the infant's organization of behavior at several levels. Support for this proposition can be gathered from several studies of infant stimulation during ongoing sucking.

In the 1950s, Soviet research indicated that the newborn would cease sucking when exposed to a moderately intense tone, with habituation to repeated presentation of that sound (Bronshtein & Petrova, 1952; Bronshtein, Antonova, Kamenetskaya, Luppova, & Sytova, 1958). Although the criteria for cessation of sucking were not clear in the Soviet reports, the phenomenon was nonetheless an intriguing one, relating to questions of attentional shift and recognition processes in the infant. American researchers have subsequently shown that discrete visual (Bruner, 1969; Haith, 1966), tactile (Wolff & Simmons, 1967), kinesthetic (K. Kaye, 1977, 1980), and auditory (Crook, Burke, & Kittner, 1977; Kaye, 1966; Keen, 1964; Sameroff, 1967, 1970; Semb & Lipsitt, 1968) events can modify aspects of the suckle response.

The current body of research on the modification of sucking during stimulation provides no clear indication of the directionality or scope of influence of exteroceptive effects on the infant's behavior. Keen (1964) and Semb & Lipsitt (1968), for example, presented newborns with relatively loud, brief, pure tones and found that if the baby was actively engaged in nonnutritive sucking when stimulation occurred, an immediate, qualitative cessation of sucking was probable. However, Kaye and Levin (1963), using a measure of response rate per unit time rather than immediate cessation, were not able to obtain differential suppression of sucking across experimental and control groups. Kaye (1966) eventually obtained suppressed response rates, but only for infants exposed to the very loudest tones (104 dB) under study. Sameroff (1970) found that the *onset or offset* of stimulation during nonnutritive sucking effectively shortened the burst of sucks, and stimulation change during pauses between bursts of sucks shortened the ongoing pause. Finally, Semb and Lipsitt (1968) found that tonal stimulation during pauses between sucking bursts increased the probability that infants would initiate sucking within a few seconds after stimulation. Crook et al. (1977) reported a similar initiation effect for nutritive sucking.

While there is evidence to support both a cessation and an initiation phenomenon in sucking as a function of exteroceptive stimulation, a coherent framework for interpreting these responses is elusive. Consider, for example, the following possibility: sucking cessation or suppression reflects an attentional shift toward the novel event and away from ongoing behavior; sucking initiation reflects motoric activation, or exteroceptive stimulus-induced arousal. If cessation indicates a shift in attention to the exteroceptive event, then initiation of sucking when the same event is presented during pauses should not occur. But it does (Semb & Lipsitt, 1968). If sucking *initiation* reflects a motoric activation of the infant (leading to the activation of sucking, a reasonably high probability response), then *cessation* should not reliably occur. But it does (Keen, 1964; Semb & Lipsitt, 1968). It would seem best, at this point, to limit the interpretive framework to the descriptive: stimulation apparently causes the baby with a nipple in its mouth to "do something else". Thus, if engaged in sucking, the infant will stop sucking and pause; if engaged in pausing, the infant will stop pausing and suck.

It is also not yet clear whether the period of active sucking (the sucking burst) should be viewed as equivalent to the period of no sucking (the pause) as events for reception of other stimulus inputs. Differential reactivity to stimulus events presented during the burst and the pause components of sucking would support the notion that the sucking pattern does not provide a uniform context for reaction. The burst-pause pattern might then be considered as a contextual factor in the sense discussed by Gewirtz (1972). Preliminary evidence supporting this notion exists in the work of Wolff and Simmons (1967). They obtained increased bodily movement and sucking initiation from infants receiving light cheek stimulation during pauses when compared to the same stimulation presented during active sucking. Furthermore, Nelson, Clifton, Dowd, and Field (1978) found that both the direction and intensity of cardiac shift during tonal presentations was closely related to the burst-pause cycling of ongoing sucking. Such data from studies of auditory and tactile sources offer preliminary support for the concept that bursting and pausing are non-uniform contexts for reactivity. It should be noted however, that Mendelson and Haith (1975) found no relation between the burst-pause pattern of sucking and visual scanning in the neonate, though subsequent research (Mendelson, 1979) suggested a coordination of sucking and oculomotor control in the newborn. With slightly older infants, Bruner (1973) reported that the amount of scanning, whether looking at or looking away from the visual events, was highest with no pacifier, somewhat reduced with a pacifier but no sucking, and even more reduced with active sucking on the pacifier. Although modality differences may exist, it appears that a shift in reactivity of one response system may be directly, indirectly, or at least probabilistically tied to the status of another response system.

In the present study, characteristics of (a) general body movement, (b) the sucking profile, and (c) the more specific components of active sucking and pausing were monitored both prior to, and during a period of brief and repetitive exposure to sound stimulation. Different response intensities, profiles, or habituation curves for infants exposed to sound during bursting and infants exposed to sound during pausing would support the notion that these two components of the suckle pattern do not provide a homogeneous context for reactivity.

METHOD

Subjects

Eighteen male and 18 female, healthy, full-term newborns served as subjects. All infants were between 36 and 100 hours of age (mean age = 56.5 hours) and weighed above 6.0 pounds at birth and at the time of testing (mean weight = 7.7 pounds). Maternal permission for testing was secured for each child participating in the study. All babies were bottle-fed and had completed their last feeding at least 60 min prior to testing. Testing was carried out between 11:30 A.M. and 1:30 P.M. Infants were randomly assigned to one of three groups, with the restriction that there were 6 males and 6 females in each group.

An additional 23 infants were sampled, but did not complete testing. Sixteen of these babies failed to meet the criteria of the wake-up procedure or the minimal sucking rate described below. Other infants were disqualified for procedural or equipment problems, or hiccoughing developed during the session.

Apparatus

The testing location consisted of a sound controlled experimental chamber (Industrial Acoustics, 104970) with internal dimensions of 1.2 m length and 1.0 m width, equipped with an infant crib and stabilimeter bed (Lipsitt & DeLucia, 1960).

Body movement on the stabilimeter bed was monitored in analog and cumulative form on a polygraph recorder (Beckman, Type RB dynograph). With a sensitivity of 2 mv per cm pen deflection for the integration of activity, the bed's sensitivity approximately equaled 1.7 mv per lb force. Thus, a weight of 0.2 pounds dropped on the bed from 6 inches yielded an integrated activity reading of 2 mm deflection.

The sound system included a cassette tape recorder with a continuous recording of a shaking rattle fed through a Bogen (CHB-50) amplifier to a Bozak (B800A) speaker located at the foot of the infant's crib, approximately 15 inches from the the child's head. The taped rattle ranged in frequency from 75 to 10,100 Hz, with the main body of sound spanning 350 to 6,000 Hz. The tape was played at 78–79 dB SPL (re:0.0002 dynes/cm^2), as measured at the head of the bed by a General Radio sound level meter, channel B, with ambient noise level in the chamber ranging from 40 to 55 dB. Sound presentation was controlled manually by the initiation of a timer (Hunter, Model 127S), which in turn lit a dim cue light on the chamber wall beyond the infant's view, and controlled demarcation of sound onset and offset on the analog record.

The apparatus for eliciting and recording sucking consisted of a standard nipple (Davol) attached via flexible tygon tubing to a volumetric pressure transducer (National Semiconductor, LX1601D, ± 5 PSID). Air pressure changes in sucking were channeled through the transducer to the polygraph recorder, where an analog record of sucking was obtained.

All recording and electrical equipment was located outside and adjacent to the chamber.

Procedure

Wake-Up Period. Prior to testing, infants were brought to the experimental area in their individual cribs and received a brief wake-up procedure consisting of: (1) blanket removal and undershirt adjustment; (2) lifting the infant to the experimenter's shoulder, attempting to burp the child; (3) holding the baby away from the shoulder, in an elbow cuddling and/or partial sitting position. Each baby was continually spoken to and often moved into the dimmer light of the chamber to aid in obtaining eye-opening and increased motor/muscle tone, indicative of awakening. The infant was then loosely swaddled with arms free, and brought into the experimental chamber for study.

One experimenter remained with the child to offer and hold the pacifier throughout testing. Earphones providing continuous white noise at 80–82 dB to this experimenter muffled sound presentations.

Experimental Procedure. Each baby initially received a 5-min period of continuous sucking with no auditory stimulation (prestimulation period). Following the 5-min prestimulation period was a 3-min stimulation period. With the initiation of the first burst of sucks after the 5-min prestimulation period, infants in one group *(burst group)* received three min of auditory stimulation. The rattle sound was presented for three sec at the start of the third suck in each burst, thus assuring that the infant was actively sucking and not simply producing a single suck followed by pausing. A second group of infants *(pause group)* received the presentation of sound after two sec of pausing between sucking bursts. The sound was produced by the same tape as that for the burst group, and was identical in duration and intensity. Infants in a third group *(silent group)* also continued sucking for the 3-min period beyond the prestimulation time zone, but the tape recorder was not active and no rattle sound was produced with the initiation of the timer, event marker, and signal light. For half the babies in this group, "silent" 3-sec trials were presented at the start of each burst. For the remaining babies in the silent group, "silent" trials were presented during pausing.

The mean number of trials presented to infants in the burst group was 16 (range = 11 to 22). For pause group infants, the mean number of trials presented was 14 (range = 6 to 21), and for silent group infants, the mean number of trials was 15 (range = 7 to 24). On a few occasions, sound trials were presented when they should not have been, or were omitted when they should have been presented. The proportion of trials for either of these errors was less than 4 %. Only correctly presented trials were used in reported analyses, except where the basic measures of sucking (defined below) were analyzed for general profile changes per unit time.

Infants who did not produce at least 20 sucks in the first minute of responding and at least 15 sucks in each remaining minute were not continued in the experimental procedure. If a baby failed to meet criterion prior to the sixth minute, he was removed from the chamber, handled briefly and examined again if circumstances permitted.

Response Measures

The recording of a "suck" on the analog record allowed the use of objective criteria of response occurrence. The criteria used were similar to those provided by Kaye (1967), and Brown (1972). A response was counted as a *suck* if the negative pressure response produced at least a 4 mm monotonic pen deflection within 0.5 sec, followed by a 2 mm return within 0.5 sec. The total event had to occur within 1.5 sec. The 4 mm deflection, at 500 mv polygraph sensitivity was equivalent to a negative pressure of 10.3 mm Hg. A series of at least 2 sucks that were separated from one another by less than 1.5 sec between the end of one suck and the start of the next was defined as a sucking *burst*. A pause between bursts of sucks was defined on the analog record as an *interburst interval* (IBI) when the duration of no sucking bursts, i.e., from the end of a burst to the start of a burst, was at least 1.5 sec.

The following basic measures served as dependent variables: (1) responses per minute (or rate per unit time); (2) mean burst length defined as the average number of sucks per burst in each minute; (3) average IBI duration in each minute; and (4) frequency of bursts per minute. In addition, an index of variability (the standard deviation), and an index of shift in parameter levels over time (the linear trend component) for rate, burst length, and IBI duration were used as response measures.

The cumulative record of body movement provided a scoring of activity by measuring the number of mm pen deflection per unit time. Two measures were derived for assessing body movement. The first was a score of total movement per minute, starting with the third minute of the prestimulation period. The second was a score of activity only in response to sound trial presentation. A time zone defined by the initiation of sound and lasting for a duration of 5 sec (2 sec after sound offset)was used to delineate a "trial" of local activity in response to auditory presentation.

In order to view the levels of activity occurring during trials in relation to levels of activity in the remaining seconds of each minute during the stimulation period, a measure reflecting the ratio of trial activity to remaining non-trial activity was derived. The summed activity for trials in each minute and the activity level of the remaining seconds in the minute were each prorated to a base of 60 sec, in order to calculate an activity discrimination index. The discrimination index was the ratio of activity during trials to the sum of activity during trial and non-trial periods. In this ratio, an index of 0.50 reflected equal levels of activity during trial and non-trial periods. An index below 0.50 and approaching 0.00 represented lower activity during trial periods than during the remaining time in the minute.

Reliability on Data Scoring

The sucking and activity data were scored from the polygraph records independently by two judges. Reliability obtained from one third of the 36 records, was 0.90 for scoring activity per minute (in mm deflection) and 0.93 for activity in trial zones, according to the equation:

$$\text{Reliability} = \frac{\text{Number of Agreements on mm count}}{\text{Number of Agreements} + \text{Number of Disagreements}}$$

Reliability on the sucking data was taken from a randomly selected minute in the prestimulation period and a minute in the stimulation period for each of 12 infants' records. The index of reliability, computed as the Pearson product-moment correlation between the two judges' scores, for the measures: number of sucks per minute and number of bursts per minute, was 0.99 in each case. Given agreement on the occurrence of a burst, reliability on burst length, according to the equation used previously for sets of activity scores, was 0.90. Within the disagreements on burst length, 80 % of the discrepancies were scores of only one suck apart.

RESULTS

Prestimulation Period

General body movement in the prestimulation period was examined for potential activity differences among groups, between sexes, and over time, prior to the differential treatment of groups. Preliminary analysis of activity levels in the final three min of the prestimulation period revealed marked heterogeneity of variance on Cochran's test for homogeneity ($C(18, 5) = 0.38, p < 0.01$). These data clearly fit Winer's case i (Winer, 1971, p. 399), in which means and variances are correlated and many data points fall below a value of 10. The data were transformed according to the equation: $X' = \sqrt{X} + \sqrt{X + 1}$, thus drastically reducing heterogeneity of cell variance.

Analysis of variance (group x sex x time) on the transformed data set revealed no difference in activity levels across groups or between the sexes.

However, a significant shift in activity level over time was obtained ($F(2, 60) = 3.38, p = .04$). General activity increased in the fourth minute of study when compared with minutes 3 and 5.

For the four basic measures of sucking, there were no differences among groups, and no differences between male and female infants. For all groups, the response rate declined over the 5-min time zone ($F(4, 120) = 12.69, p < .001$), and burst lengths decreased significantly ($F(4, 120) = 7.12, p < .001$). Average IBI duration did not shift significantly, but the number of bursts occurring in each minute (burst frequency) increased over the prestimulation period ($F(4, 120) = 6.96, p < .001$).

Stimulation Period

Bodily movement levels of the three groups during the stimulation period were compared in order to evaluate the influence of sound presentation on activity. To assess the amount of activity occurring during sound trials in relation to activity occurring in the remaining seconds of each minute, an activity discrimination index for each child in each minute was obtained after prorating trial and non-trial activity to a base of 60 sec. Analysis of variance (group x time) revealed a significant main effect for group $F(2,33) = 6.78, p = .003$), and a significant main effect for time ($F(2, 66) = 3.34, p < .05$). Infants in the groups exposed to sound demonstrated higher activity levels during trial presentations than during the remainder of each minute, while subjects in the silent group showed an approximately equal distribution of activity in trial and non-trial zones. In addition, infants exposed to auditory stimulation apparently localized their activity to trial zones most strongly in the initial minute of sound presentation.

Each infant's activity during the 5-sec trial zones of sound for each minute of the stimulation period was divided by the number of sound presentations occurring in that minute, in order to examine group differences in reactivity to sound stimulation. The resulting scores reflected average activity per trial for each minute of the stimulation period for each child. Preliminary analysis revealed heterogeneity of cell variance in these data ($C(9, 11) = .39, p < .01$). The scores were therefore transformed according to the equation: $X' = \sqrt{X} + \sqrt{X + 1}$. The assumption of homogeneity of variance was not violated using the transformed data set ($C(9, 11) = .21, p < .05$). Analysis of variance (groups x time) on the transformed scores revealed a significant difference among groups ($F(2, 33) = 7.46, p = .002$), a significant change in activity levels over time ($F(2, 66) = 13.95, p < .001$), and a significant interaction of group and time ($F(4, 66) = 2.86, p = .03$).

In Figure 1, the average activity per trial for each group is plotted as a function of time. A Scheff' comparison of the burst and pause groups versus the silent group indicated a significant difference in activity levels of infants exposed to sound and infants not exposed to sound ($F(1, 33) = 8.60, p < .01$). In

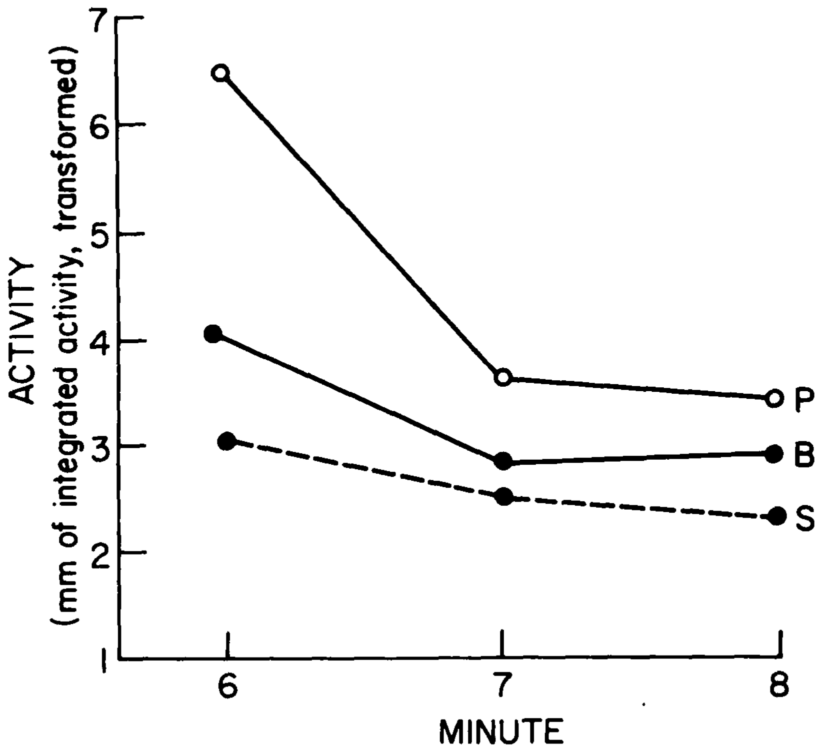

Figure 1. Stimulation period activity during trials: Mean levels of cumulated activity (in mm) per trial for the burst (B), pause (P) and silent (S) groups in each minute of the stimulation period. Scores for each infant were transformed according to the equation $X' = \sqrt{X} + \sqrt{X + 1}$.

addition, the two experimental groups differed significantly from one another ($F(1,33) = 6.32, p < .05$). During the initial minute of the stimulation period, infants receiving sound presentation during pausing responded with higher levels of activity than infants receiving sound during bursting or infants in the silent group. The Newman-Keuls test at minute 6 revealed a significant difference between the pause and silent groups ($p < .01$), and a significant difference between the pause and burst groups ($p < .01$). There was no difference between activity levels of the burst and silent groups. In the remaining two min, the most disparate sets of scores, those for the pause and silent groups, did not differ significantly.

While the previous presentation of the activity change over time covered the entire stimulation period, it is possible to focus more directly on the activity response to stimulation in each succeeding individual trial of sound presentation. In Figure 2, the average activity levels of each group over the first 10 trials of stimulation are plotted. For those few instances where a child did not receive 10 trials in total, the mean for the remainder of the group on that trial was used. Analysis of variance (group x trial) revealed a significant effect for groups ($F(2, (33) = 10.62, p < .001)$, for trials ($F(9, 297) = 11.42, p < .001$), and for the interaction of group x trial ($F(18, 297) = 2.68, p < .001$).

Figure 2 shows that the rate of response reduction differed across groups, contributing to the group by trial interaction. In addition, it appears that infants in the pause group sustained markedly higher levels of activity than infants in the burst and silent groups, even after the first few trials of stimulation. Within the burst group, it should be noted that the apparent rise in activity at the fourth trial can be accounted for by the extremely high activity of one child. The remaining 11 infants in that group exhibited an average of 2.50 mm activity (transformed) with a range from 1.00 to 5.10 mm.

In order to compare groups on changes in sucking characteristics from the prestimulation to the stimulation period, each infant's rate, burst length, and IBI duration averaged over minutes 3, 4, and 5 (prestimulation) served as covariates to behavior during the stimulation period (minutes 6, 7, and 8) in a multivariate analysis of covariance. Rather than examining a main effect for treatment groups, the following weighted comparisons were made: (1) the burst group versus the pause group, and (2) the burst and pause groups versus the silent group. No significant shift in response patterning was revealed in either comparison. The time zones examined were reduced, so that performance in the minute just prior to stimulation served as covariate to performance in the initial minute of stimulation. Once again, there were no significant differences in response levels across the groups.

Visual examination of performance means, however, revealed that all groups apparently increased response rate and decreased IBI duration from minute 5 to 6. This shift over time was found to be reliable when examined in a multivariate analysis of variance, using two time trials as a repeated measure ($F(3, 31) = 3.71, p < .05$). Average response rate increased significantly from minute 5 to minute 6 ($F(1, 33) = 7.03, p < .05$).

Several other aspects of suckle behavior, beyond those of central tendency, or mean performance, were also examined for their potential sensitivity to change as a function of sound presentation. In particular, a characteristic of shift over time, the linear trend component of responding, was identified in three-mode factor analysis (Tucker, 1966) as a sensitive index of differential reactivity.

Comparison of a linear shift in the sound stimulated groups and the silent group, using parameter values for the prestimulation period as covariates, showed a significant multivariate pattern difference ($F(3,28) = 3.29, p < .05$). Shifts over time in the duration of pausing apparently contributed most strongly to the pattern change. Prior to sound stimulation, IBI durations for all groups were changing minimally. Over the stimulation period, IBI duration increased for the silent group, but showed no shift for the burst and pause groups. The difference in the linear component of IBI duration between the silent group and the two groups exposed to sound was substantiated by analysis of covariance

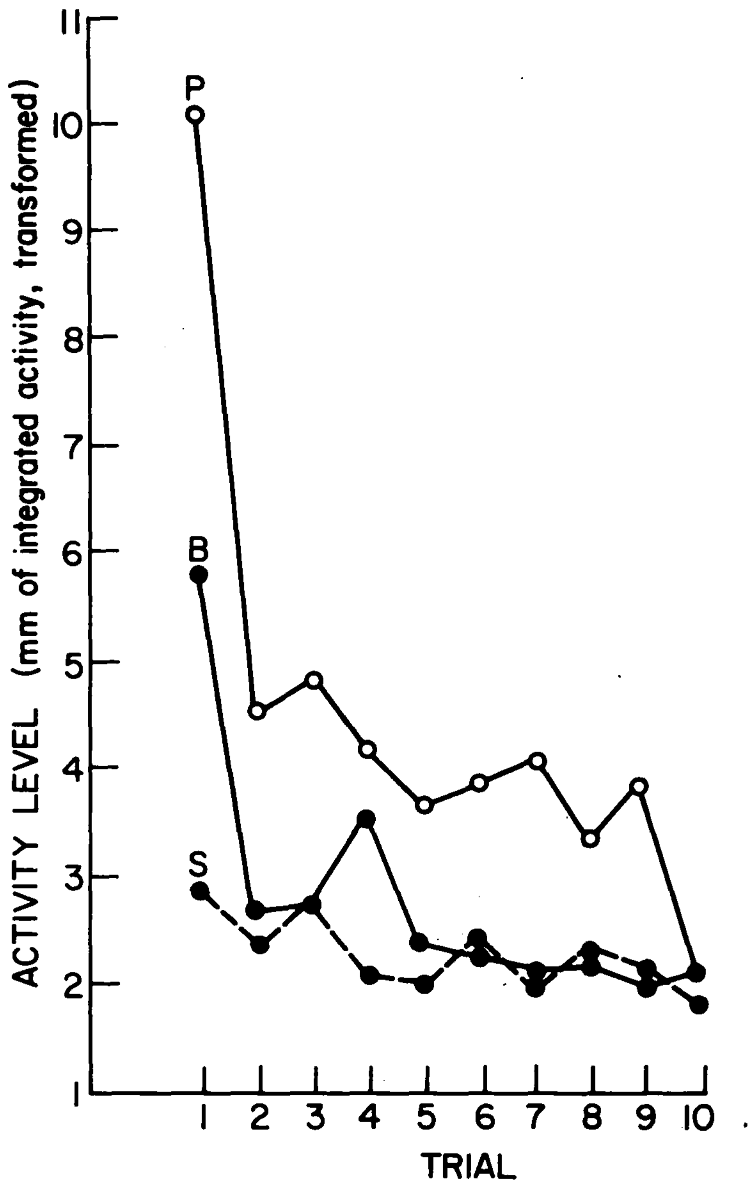

Figure 2. Stimulation period activity over the first 10 trials: Mean levels of cumulated activity in each of the first 10 trials for the burst (B), pause (P) and silent (S) groups. Scores for each infant were transformed according to the equation $X' = \sqrt{X} + \sqrt{X + 1}$.

($F(1, 30) = 5.76, p < .05$). The same performance characteristics of the burst and pause groups did not differentially change when compared with each other.

Evidence of qualitative change in sucking behavior immediately after

TABLE 1
Proportion of First Six Trials Scored as Response Change for Each Group

Burst Group	0.44
Pause Group	0.71
Silent Group	0.62
(Silent on burst)	(0.61)
(Silent on pause)	(0.64)

stimulation was also obtained. Response cessation, defined as burst termination within three sec of the start of a trial for infants receiving stimulation (or mock trials) at the initiation of bursts, and response initiation, defined as a burst or single suck beginning within three sec of the start of a trial, were scored for the first six sound presentation trials for each infant. These two measures were pooled and termed "response change" for the purpose of analysis. The frequency of response change differed significantly across the three groups ($F(2, 33) = 3.92, p < .05$). Each group's frequency of response change is shown in Table 1 as a proportion (i.e., a ratio of the frequency of change occurring in the first six trials). The Newman-Keuls test showed a significant difference between the burst and the pause groups ($p < .05$). From Table 1, it is evident that infants stimulated during pausing seemed more likely to change response (i.e., initiate sucking) than control infants, and infants stimulated during bursting seemed less likely to change response (i.e., cease sucking) than controls.

DISCUSSION

The results of this study indicate that sound stimulation differentially affects activity levels conditional on sucking characteristics. However, this is not reflected in the more obvious parameters of the infants' sucking behavior. Specifically, for the burst contingent group and the pause contingent group, sound altered only general activity and not the more obvious quantitative measures of sucking. For general activity, there was also a shutdown of gross body movement with repeated presentations of stimulation.

Researchers of neonatal sucking behavior have traditionally separated bursting from pausing as two distinct response components in the sucking record. But there is no strong foundation of evidence that bursting and pausing differently mediate interactions with the environment. In the current study, infants presented with sound during active sucking demonstrated less body movement than infants exposed to sound when they were not actively sucking. For the actively sucking infant, movement of the mandible may create changes in muscle tension in the middle ear, decreasing sound conduction, and thereby decreasing apparent loudness. While it could be argued that, relative to the pause group, the decreased activity response to sound during bursting obtained here involved only a physical impedance of hearing, the fact that other researchers (Wolff & Simmons, 1967) obtained a similar result using tactile, not auditory stimulation, suggests that the effect is not purely a function of sensory impedance.

The organization of nonnutritive sucking, evaluated over mean response rate, burst length, and IBI duration, did not change for infants who were exposed to auditory stimulation when compared to those measures for infants who were not exposed to stimulation. In contrast to these findings, previous reports have shown modification in neonatal sucking during auditory stimulation (Crook et al., 1977; Kaye, 1966; Keen, 1964; Semb & Lipsitt, 1968; Sameroff, 1970). The majority of these investigations did not use dependent measures comparable to those here, and for some, changes were observed only in certain treatment groups. The methods used in each of these studies differed in potentially critical ways from the methods of the present study.

In each of the previous reports, control trials involving no sound presentation were either randomly presented or predesignated in a period before stimulation for the same infants who received sound presentations. None of these studies used a between-subject methodology for a sound versus silent comparison. In addition, sound stimulation began after some time period of base line sucking that was less than the 5-min period used here; and comparison of the stability of the response dimensions used in evaluating change are not easily obtained across studies. Furthermore, although stimulation characteristics differed across each of the previous reports, all used a pure tone. In the present study, a complex sound was used. Finally, in all but Sameroff's (1970) work, the tone was louder than the sound used in the current experiment.

The alterations in sucking reported in earlier works are not easily comparable to the changes which were identified in the present study. Semb and Lipsitt (1968) found differences in the probabilities of initiation and cessation of sucking between stimulation and control trials. However, they did not report quantitative change in burst or pause duration. On the other hand, Crook et al. (1977) found a decrease in pause duration, with a decrease in the length of the burst following stimulation of pauses when compared with control trial pauses and bursts. In the present study, when adjustment was made for response characteristics prior to stimulation, the more general profile of sucking (reflected in average response rate, burst length and IBI duration) did not shift as a function of auditory stimulus presentations. An overall rise in response rate from the prestimulation to the stimulation period was obtained, but this included the control group. The fluctuation in sucking for the control group along with the experimental groups suggests that some cyclical changes may be present, independent of stimulation.

Examination of more constrained time zones, immediately following stimulation, revealed a difference in the effects of sound depending on its presentation during sucking or pausing. Sound during bursting was less likely to cause a shift to pausing than sound during pausing was to cause a shift to sucking. The initiation of sucking for infants engaged in pausing when sound presentations occurred is an outcome which supports that of Semb and Lipsitt (1968). While they also found evidence of sucking cessation, that response was not obtained here. Infants engaged in sucking appeared more likely to continue sucking than controls. The robustness of this initiation or continuation effect over several minutes, or across systematically varied rates of stimulus presentation warrants further investigation.

Beyond the measures of central tendency, the analysis of linear shift in the response profile suggested that IBI duration increased for control group infants over the stimulation period, while the groups exposed to sound demonstrated no appreciable rise or decline in IBI duration. Stimulation apparently stabilized IBI duration, while lack of stimulation increased IBI duration. In procedures which intersperse stimulation and control trials, these sorts of shifts in performance are difficult to evaluate. It seems reasonable to attribute the difference in sucking pattern to arousal shifts resulting from the presence or absence of stimulation, but data on arousal state changes would be needed to document that suggestion. The control group may have been the least alert in the latter minutes.

None of the previous reports of sucking modification during auditory stimulation used general body movement as a measure of responsivity. However, Kaye (1966), and Sameroff (1970) reported changes in respiration during sound presentation. In the present study, the contingency of sound presentation was apparently more likely to influence body movement than the sucking profile. All babies were loosely swaddled for testing and had their arms free. The tightness of swaddle chosen by different researchers might influence the range and intensity of responses available to the baby, and might further influence the probability of responding in one or another modality. If the child is tightly swaddled, the probability of "doing something" on the sucking stimulus may increase. If the child is loosely or not swaddled, body movement may become a more likely response dimension. The influence of body constraint on reactivity patterns has received little empirical attention.

The activity differences in this study suggest that the sucking complex, either directly or indirectly, provides the baby with a changing context for interaction with environmental events. However, the mechanisms underlying differential response to stimulation when bursting and when pausing are not yet understood. It would seem reasonable, at least from an evolutionary perspective, to postulate that active sucking actually facilitates maintenance of behavioral stability during periods of intrusive stimulation. Active sucking might compete with other potential responses, or might indirectly reflect lowered attention to incoming events. One would suspect that since feeding-related behaviors are highly organized in the healthy infant at birth, they may be structured in such a way that the probability of their disruption is minimized if additional stimulation is not strongly intrusive. Sternglanz (1973), and Wolff and Simmons (1967) have each speculated that the newborn might engage in a set of hierarchically organized behaviors which work to produce an increase in the threshold of perceiving aversive stimulation. Bridger (1962) suggested that sucking might reduce stress by reducing sensory input from other modalities when the child is engaged in sucking. One would suspect that in some circumstances, initiation or continuation of sucking may be a method for decreasing intrusive environmental events for the infant.

Cardiac changes examined over the burst-pause pattern of sucking provide converging data for preliminary speculation on receptivity differences which may promote differential responsivity. Gottlieb and Simner (1966) have shown increased cardiac acceleration just prior to the initiation of the sucking burst in newborns. Clifton (1978) has described strong concordance between cardiac change and sucking behavior. In particular, in the study of cardiac rate change to sound presentation during pacifier sucking (Nelson et al., 1978), acceleration was not so strong in response to sound presented early in a burst when a major acceleratory heart rate shift had already occurred at burst onset. Acceleration was large when sound occurred just before the burst began. In general, cardiac acceleration has been associated with decreased receptivity to external stimulation, or defensive responding in the infant, while deceleration is considered as an index of orienting or attending (cf. Clifton, 1974; Graham & Clifton, 1966; Kearsley, 1973). The rise in heart rate which accompanies burst initiation may be one of a complex of physiological changes which decrease the likelihood of receiving other sources of stimulation. This postulation is only speculative at present, as cardiac and other physiological measures were not monitored in the present study. A possible related speculation might focus on shifts in arousal that covary with aspects of sucking. Those arousal fluctuations may act to increase or decrease thresholds for such response events as body movement. Before a general statement of the mechanism underlying the sorts of reactivity differences found here can be provided, reactivity comparisons across several stimulus modalities would need to be documented more fully, along with the arousal, cardiac and other physiological shifts accompanying those behavior changes.

For research purposes, aspects of the sucking response system might best be evaluated with an awareness of the potential interaction between this complex behavior and the stimulus events employed as treatment or independent variables. Beyond its obvious significance as a method of feeding, the sucking system apparently provides the child with a more complex setting for perception and environmental interaction than has previously been considered. The degree to which this response might come into play to either enhance or impede the baby's interactions with several physical and social components of the environment remains to be explored.

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