The Impact of Temporally Patterned Stimulation on the Development of Preterm Infants

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BARNARD, KATHRYN E., and BEE, HELEN L. *The Impact of Temporally Patterned Stimulation on the Development of Preterm Infants.* CHILD DEVELOPMENT, 1983, **54,** 1156–1167. To test the efficacy of temporally patterned kinesthetic and auditory stimulation for promoting development of infants born prior to term, 88 preterm infants, below 35 weeks gestation, were assigned to 1 of 4 experimental or control groups. Control subjects received regular hospital care; fixed-interval subjects received 15 min of rocking/heartbeat stimulation each hour; self-activating subjects received rocking stimulation for 15 min after every 90 sec of inactivity; quasi-self-activating subjects received 15 min rocking/heartbeat when inactive for 90 sec, but only for 1 stimulation period per hour. Assessments included measures of neurological functioning, sleep-wake activity, mother-infant interaction, and mental and motor development at 8 and 24 months. All experimental infants, compared to controls, showed decreased rates of activity while in the hospital, fewer abnormal reflexes, and better orienting responses. At 24 months, experimental infants scored significantly higher on the Mental Development Index of the Bayley Scales. Few differences were found in parent-infant interaction patterns. The results indicate that both temporal patterning and contingent responsiveness in the preterm infant's early environment contribute positively to some aspects of the development of such infants.

A number of recent investigators have demonstrated that it is possible to improve certain aspects of the preterm infant's early development by intervening in the early environment in specific ways. The most common intervention program has involved extra tactile or kinesthetic stimulation (e.g., stroking or cuddling) of the infant (Kramer, Chamorro, Green, & Knudtson, 1975; Solkoff, Yaffe, Weintraub, & Blase, 1969; White & La Barba, 1976) or extra stimulation provided by the mother to the infant after hospital discharge (Powell, 1974; Scarr-Salapatek & Williams, 1972, 1973). These studies are essentially based on a deficit stimulation theory. The preterm is seen as having insufficient stimulation in the typical hospital nursery, particularly insufficient social/kinesthetic stimulation. If more such stimulation is provided, then there should be more rapid development of the infant. In fact, most of the cited studies do show significant improvement for an added-stimulation group compared to a no-treatment control on such measures as weight gain.

Our initial view, however, was that the preterm infant suffers not so much from insufficient stimulation as from *inappropriate* stimulation. The preterm shows considerable inability to organize and synchronize his own physiological and behavioral responses. This lack of what Condon and Sander (1974) call "self-synchrony" may well be exacerbated by the temporally unpredictable quality of the stimulation received in the intensive care nursery. Regular, predictable stimulation, in contrast, might aid the infant in developing better self-regulating systems at a more rapid rate. An earlier study by Barnard (1973), involving a small sample of 15 preterm infants, provided some support for this view. Com-

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pared to control infants, those given 15 min each hour of rocking on a rocking bed combined with the sound of a heartbeat showed increased quiet sleep and more rapid weight gain. The present study was a larger and more complex attempt to test the same hypothesis, namely, that appropriately timed stimulation provided to preterm infants in the weeks following birth would aid the infants in regulating their own state and thus lead to an increase in quiet sleep. Such improved self-regulation should also be reflected in more rapid physical and neurological development, better parent-infant interaction, and ultimately in better cognitive performance.

The treatment provided consisted of a gentle horizontal movement and a heartbeat sound (Barnard, 1973) presented on differing temporal patterns and contingencies. Both movement and sound are thought to occur in utero (Grimwade, Walder, & Wood, 1970) and have been shown to lower infant arousal or activity level in term infants (Brackbill & Fitzgerald, 1969; Van den Daele, 1970). Thus these stimulus modalities were chosen to test the effect of repetitive low-frequency stimuli in lowering state (Barnard, 1973). It was assumed that since quiet sleep increases with neurological maturity and there is greater physiological stability in quiet sleep, this state would be a desirable one to increase with the preterm infant.

The stimuli were available to the infants in one of three patterns. The first was a *fixed-interval* presentation in which the rocking and heartbeat automatically turned on for a 15-min period each hour. This was intended to provide the immature organism with a pattern around which quiet periods would be entrained to the environmentally programmed stimuli. The second treatment group, which we called *self-activated,* was contingency based. These infants were monitored for body activity. When they had maintained a 90-sec period of inactivity, the 15-min episode of stimuli was activated. The stimuli were reactivated each time the infant maintained a 90-sec period of no motor movements; therefore, they were reinforced for being quiet. The third pattern was termed *quasi-self-activated.* For this group, the same contingency criteria of inactivity used for the self-activated group were operative, with the exception that once the stimulation had been on for 15 min, the infant's state of activity would not reactivate the rocking/heartbeat stimuli until an arbitrary 45-min period had elapsed. Thus the infant had a discrimination learning task, learning when he could control the stimuli and when he could not.

We expected all experimental treatment groups to exceed the control group on the major dependent variables in the study. In addition, we expected that the self-activating and quasi-self-activating groups should show more rapid improvement in sleep patterning and neurological development than the fixed-stimulation group, since in the former case the treatment was reinforcing the child's preexisting temporal patterning rather than imposing one externally.

Method

Subjects

All subjects in this study were born at or prior to 34 weeks of conceptional age (as assessed with the Dubowitz, Dubowitz, & Goldberg, 1970, scale within 5 days of birth), and were admitted to the University of Washington Neonatal Intensive Care Unit. In order to make the results as representative as possible and to comply with the technical demands of the stimulation provided, infants with the following problems were excluded from the sample: Down's syndrome, late pregnancy substance-addicted mothers, central nervous system dysfunction, those being put up for adoption, and those requiring assisted respiration (which was not compatible with the design of the rocking bed). Subject recruitment began in September 1975 and continued until June 1978.

A total of 126 infants meeting the criteria were accepted into the study and assigned to experimental or control groups at an average of 7 days of living age. Of these, however, 38 were dropped during the initial hospital period due to early transfer to another hospital, death, not completing at least 7 treatment days, or because their initial hospital data were incomplete. Complete or nearly complete hospital data are available on the remaining 88 infants, and this group comprises the sample for the present report. Eighty-two of these infants were seen at the 4-month clinic visit, 77 at 8 months, and 72 subjects at 24 months. Table 1 presents the means and standard deviations for basic clinical status variables for the sample as a whole and for each group.

The information in the table suggests that as a group these study infants were not critically ill, although many of them did dis-

TABLE 1

COMPARISON OF EXPERIMENTAL AND CONTROL GROUPS ON CLINICAL STATUS IN THE FIRST MONTHS OF LIFE

	GROUP									
	Total Sample		Control Subjects		Fixed Interval		Self-Activating		Quasi-Self-Activating	
MEASURE	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Birth weight (grams)	1355	320.7	1352	240.6	1420	410.8	1320	348.4	1277	145.2
Gestational age (weeks)	31.38	1.43	31.09	1.26	31.21	1.68	31.02	1.70	30.48	0.89
Age at discharge (days)	39.26	17.28	41.41	16.06	37.21	21.20	40.40	17.08	36.10	10.25
Subjects on oxygen (%)	63		60		62		70		60	
Subjects under bililights (%)	61		71		58		52		70	

NOTE.—None of the differences shown is statistically significant.

play serious symptoms such as respiratory distress or infections.

The mothers in the sample were moderately well educated, ranging from 7 to 19 years of schooling (mean = 12.41, SD = 1.89), and were experiencing relatively high levels of life change as measured by Holmes's Social Readjustment Rating Scale (mean = 284.4, SD = 145.5) (Holmes & Rahe, 1967). Fifty-six percent of the infants were female.

Experimental Conditions

The original study design called for two experimental variations of temporally organized stimulation along with a nonstimulated control group. However, inadvertent variations in the rocking-bed settings led to the third experimental group (the quasi-self-activating group) with a limited number of subjects. The resulting three experimental treatment groups were as follows:

Fixed-interval stimulation group (N = 26).—The stimulation provided this experimental group was a replication of the procedures used in Barnard's original study (1973). It consisted of 15 min each hour of the rocker bed combined with a recording of a heartbeat. The rocker bed moved on a horizontal plane with a maximal displacement of 3 inches and a movement rate of 30 strokes per minute. The heartbeat sound was played through a speaker approximately 22 inches from the infant's head. The audio intensity was 85 decibels with the majority of acoustical energy below 500 cycles per second.

Self-activating stimulation group (N = 23).—For the subjects in this group, the rocking bed/heartbeat stimulation was triggered by the infant's own behavior. The infant was lying on a special mattress with a transducer to detect body movement. If the infant was motorically inactive for 90 sec, the bed automatically turned on and continued for 15 min. The stimulation could then be retriggered by the infant with any subsequent 90-sec period of quiet. It should be noted that because there was no limit set to the number of times an infant in this group could turn on the stimuli, the total amount of time an infant spent rocking could vary widely.

Quasi-self-activating stimulation group (N = 10).—At one point during the early phase of the study, the switches controlling the temporal patterning were set by mistake to produce a combination of the fixed-interval and self-activating conditions. For the infants in this group, the rocking bed was triggered by 90 sec of inactivity and continued for 15 min, just as for the self-activating group. But, after completion of a 15-min cycle of stimulation, the bed could not be activated until 45 min had elapsed. Thus the maximum amount of rocking-bed stimulation available to this group, like the fixed-interval group, was 15 min per hour. The difference was that the stimulation was only activated by the infant rather than at a fixed interval.

For all three treatment groups, stimulation was available during the entire 24-hour day. In retrospect, it would have been appropriate to arrange the stimulation availability to match diurnal cycling, but at the inception of the study, existing evidence pointed to approximately 60- to 90-min sleep/wake cycles in newborns, with little sign of diurnal cycles. Since constant availability of the rocking-bed stimulation was logistically simpler to arrange, and there was little evidence to point to the need for diurnal variation, the 24-hour plan was adopted.

Subjects in all three treatment groups typically began the stimulation at a mean of 7 days after birth (range 3–15 days), after parental consent had been obtained and baseline data had been collected. Experimental subjects averaged 20.87 days on treatment (SD = 11.40), and the three experimental groups did not differ in number of days on the rocking bed.

Control group (N = 28).—The control group, drawn at random from the same population of prematures, received the normal hospital care but no additional stimulation with the rocking bed or heartbeat.

Dependent Variables

In order to determine as fully as possible the nature of the impact of temporal stimulation on infant development, assessments were made in four areas: (1) neurological status of the infant, (2) infant activity and sleep/wake behavior, (3) infant cognitive and perceptual development, and (4) parent-infant interaction. All assessment times were based on the child's postpartum unless specified otherwise; this reflected our concern with the influence of the extra-uterine environment on the infant's behavior and development.

Neurological status.—Three measures were included in this group: the Brazelton

Neonatal Behavioral Assessment Scale (BNBAS; Brazelton, 1973), a measure of brain stem evoked response, and an individual neurological examination by a pediatrician. The BNBAS consists of 27 behavioral items, each scored on a nine-point scale, and 20 elicited reflexes, each of which is scored on a three-point scale. Behaviors assessed include the infant's responsiveness to physical manipulation, specific auditory and visual stimuli, and capacity to control state. Infants were assessed at three time points: 34 weeks conceptional age, prior to hospital discharge, and 1 month postdischarge.

Six cluster scores, developed by Lester (Note 1), designed to reflect the underlying dimensions of the scale have been used in the present analyses. They are *orientation* to visual and auditory stimuli, *regulation of state* (including cuddliness, consolability, and self-quieting activity), *habituation*, *autonomic stability* (including tremulousness and startle), *range of state* (peak of excitement, irritability, and others), and *motor reflex*.

Brain stem evoked response (BER) is a short latency response (less than 10 msec) that can be elicited by brief duration of auditory stimuli and recorded by electrodes attached to the infant's scalp. Five to seven waves comprise the BER, each arising from a specific nucleus within the central auditory pathway in the brain stem. Of particular interest were waves 3 (originating from the region of the superior olivary nucleus) and 5 (from the region of the inferior colliculus). Since it is well documented that the latency of the BER decreases with increased maturation until 18 months (Hecox, 1975), this measure was included to provide a check on the neurological impact of the experimental treatment. Assessment using this technique occurred at 4 months postnatal and included 18 repetitions of the auditory stimulus. Average latencies for waves 3 and 5 were used in subsequent analyses, as was a difference score comparing the latencies of wave 5 and wave 3.

An individual neurological examination was completed within the first 15 days after birth. Muscle tone and changes in state of arousal in response to a specific fixed-sequence series of manipulations were observed. Every 5 sec the examiner noted the infant's state on a five-point scale ranging from quiet sleep to awake and crying. A measure of the infant's initial sleep state and the mean sleep state were used in later analyses, along with one measure of muscle tone, namely, the total number of asymmetries found in individual body parts and for the body as a whole.

Infant activity and sleep-wake behavior.—Twenty-four-hour time-lapsed-videotape recordings of each infant were obtained at intervals during hospitalization (day 1, day 4, day 8, day 12, at week 34 of gestation, and after the infant had been moved to a crib) (Fuller, Wenner, & Blackburn, 1978). These videotapes were recorded at 2.3 frames per second on a time-lapsed mode with 13 hours of real time compressed into 1 hour of recording. Observers rated the level of infant activity on a three-point scale each 4.5 sec, which equaled a minute of real time. On this scale a score of 1 represented no activity and a score of 3 a great deal of activity. Activity scores for each minute were then examined over time for each infant to determine average levels and to assess activity/inactivity cycles. A cycle was defined as the period from a point of lowered activity (in comparison to that infant's habitual level), followed by a period of heightened activity (above the habitual level), to the next point of lowered activity (Barnard, Fuller, Wenner, Blackburn, & McDonald, 1981). Because infants varied in the number of days they remained in the intensive care nursery, and in their initial gestational age, we have varying numbers of observations on the infants. For most subjects, however, at least the first three observations (initial, 4, and 8 day) were available.

Sleep-activity patterns were assessed after discharge by having mothers keep a 7-day record of the infant's sleep/wake behavior (Barnard & Eyres, 1979). They noted the beginning and end of sleep and awake periods and of feeding and crying episodes. Mothers were asked to fill out such a form once at 1 month postdischarge and again at 4 and 8 months. Several measures were obtained from these records at each time point: (1) longest sleep, (2) longest awake period, (3) average night sleep, (4) average day sleep, (5) day/night sleep ratio, and (6) total sleep time per day.

Infant cognitive and perceptual development was assessed with the Bayley Scales of Infant Development (Bayley, 1969), which were administered at 8 and 24 months postnatal age. Two summary scores were analyzed, the Mental Development Index (MDI) and the Psychomotor Development Index (PDI).

Measures of parent-infant interaction.—Three measures that touch on aspects of parent-infant interaction were used. Feeding Interaction Scales were completed in the hospital just prior to discharge and at the 4- and 8-month clinic visits. For these scales, 11 aspects of the mother's behavior and 10 aspects of the infant's behavior were rated on seven-point scales by an observer who watched a complete feeding interaction. Scales assessed the mother's arrangement of the environment for feeding; her attentiveness or distractibility; modes of stimulation used (visual, auditory, tactual, kinesthetic); the mood, tension, and irritability of the mother; and the give-and-take of control between mother and infant during the interaction. The infant was rated on attentiveness, level and mode of response, mood, tension, and irritability. Following the procedure developed by Barnard and Eyres (1979), each scale was subsequently rescored so that the optimum behavior was scored highest and any deviation from the optimal was scored lower. These new scores were then summed across all scales to yield a single score for the mother and a single score for the child. The mother's summary score reflects her sensitivity and adaptability to the infant; the infant's total score describes the child's adaptiveness and responsiveness.

Teaching Interaction Scales were used to describe the mother and infant in a specially designed teaching episode at 4, 8, and 24 months. At each time point, during the clinic visit the mother was asked to teach the infant a task taken from the Bayley Scales that was appropriate for the age of the child (the "easy" task) and one that was several months above the child's age (the "hard" task). As one example, an "easy" task at 4 months was to teach the baby to reach for and grab a dangling ring. The mother's activity during the teaching was rated on 15 five-point scales, while the infant's activity was rated on nine scales. Most of the scales reflect implicit frequency counts, such as the amount of the mother's verbalizations or infant's vocalizations; some reflect more global qualities, such as a judgment of the mother's overall timing or sensitivity. Factor analyses of these scales in a larger term sample suggested that the items could profitably be combined into five clusters, four of which describe the mother and one the infant. The four maternal clusters are positive messages (amount of positive contingent feedback plus amount of affection displayed), negative messages (amount of contingent negative feedback plus disapproval displayed), techniques (the sum of four separate types of teaching techniques: modeling, verbal directions, physical guidance, and physical forcing), and facilitation (the sum of the mother's timing, sensitivity, her management of the materials, and her positioning of the infant). The single child cluster was infant involvement, which was the sum of ratings of the child's responsiveness to the mother's task help, the intensity and duration of the infant's involvement, and alertness. Scores on these five clusters, computed separately for the hard and easy tasks, have been used in the present analyses. Interobserver reliability coefficients for these scores ranged from .64 to .86, with a median value of .82.

A third measure of parent-infant interaction available was an adaptation of the *HOME Stimulation Inventory* (Caldwell & Bradley, Note 2). The version of this instrument that is suitable for infants 0–36 months of age consists of 45 binary items that are normally completed by a home visitor. Aspects of the mother's observed interaction with the infant are noted (e.g., mother smiles at infant at least once), as are the mother's descriptions of her typical activities with the infant and the toys and other stimulation available in the home. This instrument yields six subscale scores as well as a total score: emotional and verbal responsivity of the mother, avoidance of restriction and punishment, organization of physical and temporal environment, provision of appropriate play materials, maternal involvement with child, and opportunities for variety in daily stimulation.

Since all observations of the mother-child interactions in this study were done in the clinic rather than at home, a modified questionnaire version of the HOME, developed for an earlier study (Barnard & Eyres, 1979), was used. Twenty-seven of the 45 items were changed to questionnaire form and completed by the mother during the clinic visit. Sixteen items were completed by the interviewer, who had an opportunity to observe the mother-child interaction during encounters at the clinic. Two items were not scored by either method, one relating to the safety of the child's play environment and the other relating to the provision of toys by the mother during the interview. Subscales 1 and 2 (emotional and verbal responsivity and avoidance of restriction and punishment) are largely made up of observation items, while the remaining subscales include primarily items completed by the mother by questionnaire. This questionnaire/observation method has not yet been compared directly to the more usual home observation method on a single sample, but we have noted that scores from the questionnaire version obtained on a group of term infants at 24 months (Bee, Barnard, Eyres, Gray, Hammond, Spietz, Snyder, & Clark, 1982) were as strongly correlated with 4-year IQ scores as Bradley and Caldwell (1976) had reported for scores obtained from home observations.

For all dependent measures, the examiners were unaware of the subjects' treatment/control group status.

Plan of Analysis

Treatment and control groups were compared using an analysis of covariance in which the effects of gender, gestational age, infant initial health status, days on treatment, mother's education, and level of life change experienced by the family were covaried. Since the covariance analysis is somewhat unorthodox for data of this kind, a word of justification is in order.

Subjects were initially assigned to treatment groups using a modified random system, with blocking on infant health, gestational age, and mothers' previous child-care experience. In part because of the success of this blocking, the treatment and control groups did not, in fact, differ on any of the six covariates used. Given this, one could argue that a straightforward analysis of variance is sufficient. However, one of the characteristics of groups of preterm infants is that they show high *within-group* variance because of their differences in gestational age and health. Families of preterms likewise often vary markedly in life change and education. Thus, although there are no *mean* differences among experimental and control groups on these variables, there is nonetheless considerable within-group variability. Since we wished to detect relatively subtle effects of our treatments, we chose to reduce the within-group variability as much as possible through covariance analysis, so that between-group differences would stand out in clearer relief.

Results

The results of the covariance analysis are presented in Table 2. The means in the table have been adjusted, that is, the variance associated with the six covariates has been removed. Significant differences were found on only 15 of 109 variables analyzed, suggesting most generally that there was less than the expected impact from this form of treatment. Several effects of interest were obtained, however.

The most notable immediate effect of the treatment was to produce lowered levels of overall activity while on the rocking bed among infants in the fixed and self-activating groups in comparison to the control and quasi-self-activating groups. At the same time, all three experimental groups had shorter activity cycles than the control group (significant at 8 days), and thus more such cycles. These shorter cycles were still present in the self-activating group at the end of treatment, while both the fixed and quasi-self-activating groups had increased cycle length by the end of treatment and no longer differed significantly from the controls.

This pattern of findings for activity level can be grasped readily with a graphic presentation of the data. In Figure 1 we have plotted the mean activity rates for the four groups over time, with an indication at the bottom of the figure of the significance level of the group comparisons at each age.

The figure shows clearly that the experimental treatment had an initial effect of lowering activity for all experimental groups. This "suppression" of activity persisted through about the eighth day on the rocking bed, after which infants in all treatment groups began to increase activity rate and cycle length. The quasi-self-activating group began with higher levels of activity and longer cycles, but their response to treatment was highly similar in pattern to the response of the other two experimental groups. In contrast, the control group showed little change in activity and an initial increase in cycle length.

In the days and weeks immediately following the treatment, the effects of the treatment can be seen in several measures from the Brazelton examination. In these comparisons the quasi-self-activating group had the best orientation to auditory and visual stimuli at discharge and 1 month post-discharge and shared "best performance" status with the fixed group at 34 weeks. In addition, the quasi and fixed groups displayed a wider range of states at 34 weeks than did the controls, and all three experimental groups showed fewer abnormal reflexes than the control infants at discharge. On these measures from the Brazelton, the quasi-self-activating group was most consistently different from the control group.

The major long-term effect is a sizable difference on the MDI at 24 months. Subjects in all three treatment groups exceeded the control group in mental development at 2 years, with the quasi-self-activating group significantly highest of the three. Additional long-term effects of the treatment can also be seen in two measures from the HOME, both of which reflect aspects of the variety and predictability of the stimulation available to the child. Two-year-olds who had been in the fixed or quasi groups of the experimental groups encountered more varied experiences at age 2 than did control or self-activating group subjects, while all experimental subjects experienced more organized environments than did control subjects.

Discussion

The findings from this study extend and replicate the results of Barnard's original study of the impact of the rocking bed/heartbeat stimulation on the development of preterms. In both cases the immediate effect of the stimulation was a reduction in activity, or an increase in quietness, in the infant. In addition, the hint in the original study of a long-range effect of the treatment on later cognitive functioning, as assessed by a standardized instrument like the Bayley, has been confirmed in the present data. Such replication of preliminary findings lends credence to the original theoretical assumptions underlying the research and suggests implications for practice with preterms.

However, this research has also raised a number of puzzling questions. The most intriguing puzzle concerns the performance of

TABLE 2

MEANS AND COVARIANCE RESULTS FOR THOSE VARIABLES ON WHICH SIGNIFICANT GROUP DIFFERENCES WERE OBTAINED WHEN RAW MEANS WERE ADJUSTED FOR CHILD'S SEX, GESTATIONAL AGE, INITIAL HEALTH STATUS, DAYS ON TREATMENT, MATERNAL EDUCATION, AND LIFE CHANGE

	ADJUSTED GROUP MEANS					
VARIABLE	Control	Fixed Interval	Self-Activating	Quasi-Self-Activating	F	R^2
Overall activity, 4 days	1.92_a	1.79_b	1.74_c	1.90_a	5.62**	.31
Overall activity, 8 days	1.93_a	1.82_b	1.75_c	1.91_a	5.44**	.34
Overall activity, 12 days	1.95_a	1.84_b	1.79_c	2.00_a	3.96*	.29
Overall activity, 34 weeks GA	1.96_a	1.83_b	1.68_c	2.00_a	5.94**	.29
Cycle length, 8 days	72.0_a	60.7_b	56.6_c	66.3_d	3.33*	.25
Cycle length, in crib	72.2_a	53.9_b	68.9_a	74.1_a	9.70***	.55
Brazelton orientation, 34 weeks	3.01_a	4.13_{bc}	3.82_{ba}	4.94_c	3.54*	.19
Brazelton orientation, discharge	4.34_a	5.12_b	5.08_b	6.48_c	4.78**	.20
Brazelton orientation, 1 month postdischarge	5.33_a	5.70_a	5.77_a	7.07_b	3.05*	.29
Brazelton range of state, 34 weeks	2.16_a	3.06_b	2.74_{ab}	3.48_b	2.84*	.27
Brazelton abnormal reflex, discharge	51.94_a	45.21_b	45.20_b	43.40_b	5.81***	.32
Negative messages, hard teaching task, 8 months	1.03_a	1.64_b	1.33_{ab}	1.20_{ab}	3.41*	.25
HOME: organization of the environment, 24 months	3.35_a	5.33_b	5.20_b	5.67_b	4.47**	.29
HOME: variety of stimulation, 24 months	3.18_a	4.47_b	3.96_{ab}	4.53_b	3.72*	.33
Bayley MDI, 24 months	92.70_a	108.97_b	109.44_b	125.00_c	5.89***	.40

NOTE.—Means in each set with the same subscripts do not differ significantly; those with different subscripts differ $p \leq .05$.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

the quasi-self-activating group. From the beginning we have argued that there are two aspects of the infant's environment that are particularly critical: the contingent nature of responding to the infant's behaviors and the temporal patterning of stimuli in the infant's environment. Other researchers and theoreticians have shared our emphasis on these features of the infant's experiences (Bradley & Caldwell, 1976; Lewis & Coates, 1980; Ramey, Farran, & Campbell, 1979). For the preterm infant, temporal patterning seemed to us to be particularly important, especially in the first weeks after birth, so as to simulate the predictable temporal patterning of experiences in utero. Our rationale, obviously, was that such temporal predictability in the final months of a term pregnancy was important for the normal development of the central nervous system.

Given that background, how can we analyze the several treatments we provided? It appears to us in retrospect that the four groups in the present study represent all four possible combinations of contingent/noncontingent stimulation and temporally patterned versus non–temporally patterned stimulation, as shown in Table 3. Insofar as the nursing care given to the infants in the NICU was contingent on their individual signals, then all the infants had at least some contingent stimulation. But the control group had no additional contingent stimula-

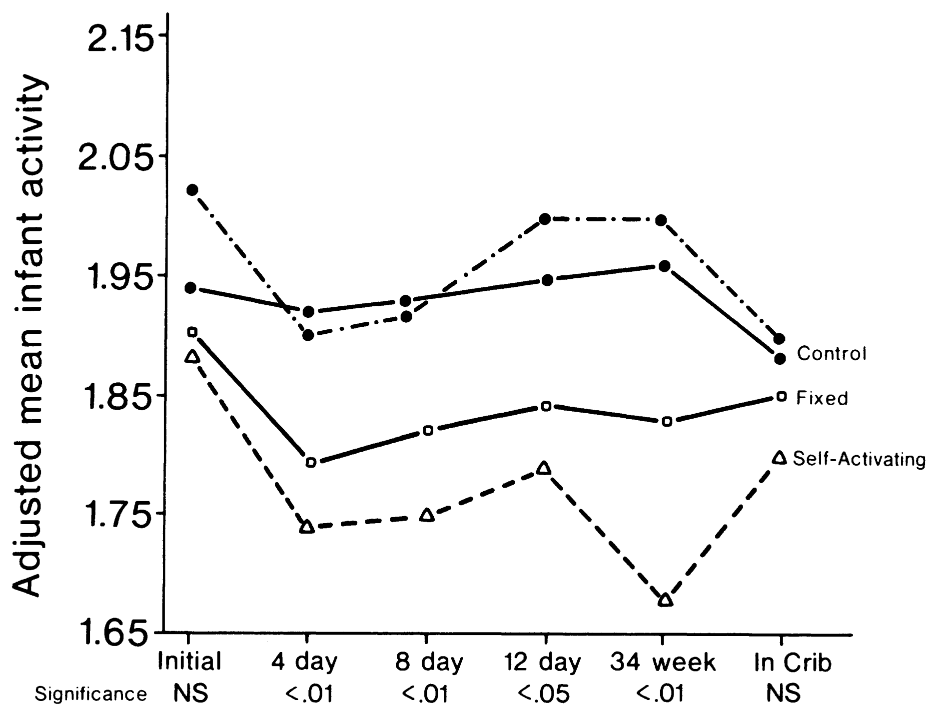

FIG. 1.—Mean infant activity over 24-hour video record

TABLE 3

POSITION OF FOUR TREATMENT GROUPS ON DIMENSIONS OF CONTINGENCY AND TEMPORAL PATTERNING OF STIMULATION PROVIDED

TEMPORAL PATTERNING OF STIMULATION	CONTINGENCY OF TREATMENT	
	Noncontingent	Contingent
Not patterned	Control group	Self-activating group
Patterned	Fixed stimulation group	Quasi-self-activating group

tion provided by our treatment, nor did the fixed-stimulation group. For the latter group, the bed came on for 15 min every hour regardless of what the infant was doing at the time of onset or offset. In contrast, the self-activating group had contingent stimulation, but it was not temporally patterned. The infant could turn on the bed by remaining quiet, and could then turn it on again with only a very brief interlude of bed off. So we added no temporal regularity to the experience of this group. The quasi-self-activating group, however, had both contingency and temporal patterning that involved a discrimination learning task. The bed went on in response to their signal, then remained on for 15 min, and then off for 45 min before they could reactivate the stimulation.

The results of our study could be taken as support for the notion that either of these features of the child's early experience has some beneficial effect, but that the sum of the two has a more powerful influence. The behavior of infants in the fixed and self-activating groups is rarely different from one another, so there is little in our results to allow us to choose one of these two treatments over the other. But both differ from the control group on early sleep/wake measures, and both are better on the 24-month MDI. The quasi group, however, is consistently above both the fixed and self-activating groups on measures that show a difference. We see this both on the Brazelton scores and on the MDI at 24 months. In line with this, Finkelstein and Ramey (1977) reported better performance for infants who had prior contingency experience followed by a discrimination learning task; the quasi-self-activating group had what they describe as both contingency and discrimination learning experience.

This conceptualization of the findings must, of course, remain tentative, if only because of the small size of the quasi-self-activating group. More important, other methods of testing the relative weight of temporal patterning and contingent stimulation need to be found. Are the effects additive? Is temporal patterning particularly important for the premature and of less importance for the term infant, or the older infant? How would one assess temporal patterning in natural settings? These are all questions that require further exploration. For the moment, however, our best interpretation of the results of our study is that temporal patterning and contingent stimulation have each had a separate contribution to improved development in the infant, but that the two effects are additive.

A second puzzle concerns the existence of a large group difference on the 2-year MDI, while there is no pattern of differences on the same test at 8 months, or on other earlier measures of infant functioning or parent-infant interaction. One possible solution is to suggest that there may be two effects produced by the treatment. The first effect, which we see in the immediate lowering of activity levels and shortened cycles, is directly attributable to the "soothing" quality of the rocking bed/heartbeat sound. Perhaps the infants are lulled in some fashion so that they are simply quieter. But there may be a subtler effect as well, a kind of "programming" of the central nervous system that is not reflected fully in the child's behavior until at least age 2, when measurements of the child's cognitive capacity begin to be more heavily language dependent, and when more complex levels of cognitive tasks are included. Thus by assisting the infant to suppress activity, through both the lulling quality of the stimulation and the temporal regularity or contingency of the stimulation, we may have aided the development of crucial, but subtle, aspects of the central nervous system.

The striking absence of differences on measures of mother-child interaction represents a third puzzle. One of the purposes of the present study was to determine if the long-term positive impact of the rocking-bed stimulation was mediated by changes in the infant-parent interaction. If the child was more regular in sleep patterns, more responsive, more alert as a result of stimulation, then that might affect the way the infant entered into interaction with the parents from the beginning. Such a change would in turn affect the way the parents established attachments to or provided stimulation to the baby. Differences in IQ at 24 months could then be a result of differential stimulation during the intervening months and not the direct result of the initial rocking-bed stimulation. We included a variety of measures of mother-infant interaction in order to test this hypothesis and found little or no support for such an interpretation. At least for the sample we studied and the range of techniques we used to assess mother-infant interaction, there were no noticeable effects of the treatment on interaction patterns, except that at 24 months there are hints that the treatment-group subjects encountered more varied and more structured environments at home and at 8 months more negative messages during teaching than did the control subjects.

One possible explanation of this lack of results is that we simply used insensitive measures of parent-infant interaction. This seems unlikely for several reasons. First, in addition to the ratings of teaching and feeding, a far more detailed observation of a subsample of families was undertaken at the time of discharge and at 4 and 8 months. The scores obtained from these observations were highly molecular (e.g., number of smiles, turning toward child, specific tactile stimulations provided, etc.). No group differences were found on any of these measures. Second, although the parent-infant interaction measures do not discriminate among treatment groups, they do correlate significantly with 24-month MDI, which suggests that the measures are tapping relevant dimensions of the mother-infant interaction. What our findings are telling us, however, is that those relevant dimensions of the interaction are not affected by the treatments we gave to the infants while they were in the NICU.

In conclusion, the results of this study demonstrated some immediate and long-term changes in the behavior of preterm infants who experienced a program of stimulation during their hospital confinement. The major long-term effect was apparently to raise the children's IQs compared to untreated controls. But the impact of temporally structured stimulation in the first days of life is much narrower than we had anticipated originally and appears to operate in a somewhat different fashion than hypothesized. In view of the magnitude of the IQ differences and the theoretical importance of the issues raised, a replication of the quasi-self-activating conditions would appear particularly worthwhile.

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