Self-Regulation of Stimulation by Premature Infants

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ABSTRACT. Premature babies are capable of seeking contact with a source of rhythmic stimulation that reflects their own breathing rhythm. Optional stimulation, in the form of a "breathing" stuffed bear, was made available to premature infants, 32 to 35 weeks' gestational age. The bear's breathing rate was matched to that of each individual infant during quiet sleep. Other infants were exposed to a bear that did not breathe, and some infants were not exposed to a bear. All infants were monitored continuously using time-lapse video. After 2 to 3 weeks' exposure, those infants with a breathing bear showed significantly more contact with their head, body, or limbs than either of the control groups (for the no-bear group, contact with the area that would have been occupied by the bear was determined to describe the contact that might have been expected by chance). In addition, the infants given the opportunity to self-regulate their stimulation showed greater amounts of quiet sleep than the other two groups. *Pediatrics* 1986;78:855–860; *stimulation, premature infant, breathing rhythm.*

With growing evidence for plasticity of the immature CNS, an understanding of environmental influences on the premature infant has become an imperative. This is especially the case in view of the increasing number of lower weight prematurely born survivors who are at higher risk for developmental dysfunction as a consequence of early perinatal trauma.

Various forms of stimulation have been used with the aim of facilitating the neurobehavioral maturation of premature infants. In general, such procedures are based on the assumption that the prematurely born infant is deprived of some specific form of stimulation that would be available in utero; the stimulation is provided the neonate on the rationale that it is possible to compensate for the deprivation, at least in part.

The present study presents a different perspective for selecting and presenting stimulation to premature infants. This perspective is based on two premises. First, the premature infant is not considered to be an externalized fetus, with the same needs as a fetal organism. With the event of birth, and the associated transformation of cardiopulmonary processes and other biologic functions necessary for survival as an autonomous, self-regulating organism, the needs of the premature infant differ dramatically from those of the fetus. Second, the prematurely born infant, like the infant born at term, is not viewed as a passive organism always in need of having something done to him or her. Rather, the infant is assumed to be capable of interacting with the environment and thus participating actively in events that affect the ongoing organization of neural circuitry.[1]

This perspective has major implications for the kind of stimulation that may be most biologically relevant for the premature infant. Accordingly, we have developed a stimulation procedure that is unique in several respects: (1) the stimulation is rhythmic, a characteristic that is generally considered appropriate for premature infants; however, the rate parameter is determined by the physiologic functioning of the infant rather than using an arbitrary rhythm or one derived from the mother; (2) the rate is determined for each infant based on that infant's own biologic rhythm; and (3) the stimulation is optional for the infant—the infant regulates the amount and temporal distribution of stimulation received. Thus, the integrity of the adapting, responsive infant is recognized by the procedures. The sensitivity of premature infants to overstimulation[2-5] is also taken into account by making it possible for each infant to titrate his or her own "dosage" of input.

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These considerations were based on the assumption that the premature infant is capable of seeking out biologically relevant stimulation. Evidence supporting this assumption first came from animal research which demonstrated that newborn rat pups, separated from their mother, will approach and stay continuously on or under a mother surrogate, which consisted of a warm, moist, pulsating tube.[6] The stimulation from the surrogate assured the pups' survival in the absence of the licking and manipulations typically provided by the rat mother. Because of the greater mobility of premature infants during the preterm period,[7,8] the possibility exists that they, too, can exhibit adaptive approach or avoidance responses to stimulation.

The source of stimulation in the present study was a "breathing" stuffed bear that is placed in the isolette with the infant, with a pump outside the crib to produce the breathing motion.[8a] The bear's breathing rate is based on that of the infant during quiet sleep. The bear is placed along one side of the crib so that the infant can seek and maintain contact with the bear or be elsewhere in the crib, without contact.

The purposes of this study were: (1) to demonstrate that premature infants can indeed seek and maintain contact with such a source of self-reflecting rhythmic stimulation, and (2) to obtain evidence for the effects of such experience on a major form of neurobehavioral functioning, namely, the amount of quiet sleep shown by the infants.

The subjects were 18 stable, growing premature infants, without congenital anomalies or neurologic disorders. They were enrolled when they were free of major medical complications and only if they were not experiencing life-threatening apneas. The ages of the infants at enrollment ranged from 32 to 35 weeks' gestational age. Gestational age was based on the mother's reported estimated date of confinement and confirmed by assessing the baby using the Dubowitz scales.[9] Demographic characteristics of the infants in these groups are presented in the Table.

Successively enrolled infants were randomly assigned, within sets of three, to one of three treatment groups: (1) a breathing bear in the isolette, (2) a nonbreathing bear in the isolette, and (3) no bear.

For the infants in the breathing bear group, a stuffed sheepskin bear was placed in the isolette with the baby. The bear was made to "breathe" by the expansion and contraction of a bladder within the bear's torso which was connected by Tygon tubing to a small-animal respirator outside the isolette.

Sheepskin was used to make the bear because of its special properties. These include (1) the sturdy material withstands repeated sterilizations for hospital use, (2) the nap is sufficiently thick that the baby's nose cannot be occluded when pressed against it, and (3) sheepskin is fire retardant. The bear is 11 in high and is constructed so that the arms, legs, snout, and torso are all on the same plane. Thus, all parts of the bear are equally accessible to the baby and no feature obstructs the baby's contact with the bear's torso, the area of maximal motion during its breathing. This arrangement also minimizes the amount of space occupied by the

TABLE. Demographic Characteristics of the Three Groups

	Breathing Bear	Nonbreathing Bear	No-Bear
Birth order (No. of infants)			
First	3	3	3
Later	3	3	3
Sex (No. of infants)			
Male	1	2	3
Female	5	4	3
Delivery route (No. of infants)			
Vaginal	2	1	1
Cesarean section	4	5	5
Gestational age (wk)	29.2 ± 1.8	30.0 ± 1.9	27.8 ± 2.3
Birth wt (g)	1,040.0 ± 67.9	1,159.2 ± 167.7	912.5 ± 137.8
Maternal age (yr)	26.2 ± 4.0	24.0 ± 4.7	23.2 ± 4.2
Obstetric complications*	12.2 ± 2.8	13.6 ± 1.4	12.3 ± 1.6
Apgar score			
1 min	5.5 ± 3.0	4.0 ± 3.1	4.5 ± 3.0
5 min	7.7 ± 1.8	6.4 ± 1.5	7.3 ± 1.9
Neonatal complications†	4.3 ± 1.6	4.8 ± 1.2	4.7 ± 2.0

* Scored on Prechtl scale. Possible number of nonoptimal events ranges from 0 to 42.
† Scored on Postnatal Complications Form. Possible number of nonoptimal events ranges from 0 to ten.

bear in the isolette. Nurses, parents, and observers agree that the bear is an attractive "companion" for the infant. It is soft blue in color, a shade that previous research has suggested to be preferred by newborn infants. The sheepskin pelts are dyed by a leather company in accordance with our specifications.

The breathing bear for the first infant in the study was larger than the ones used for the other infants. The same-sized bear was used for the two matched control groups (one in the nonbreathing bear group and the other in the no-bear group).

Because the pump determines the nature of the breathing bear's "breathing," its functioning is a very critical element in the procedure. A Harvard Apparatus small-animal respirator was modified to conform to the following specifications: (1) delivery and withdrawal of air creates a constant level of expansion of the bladder within the bear; (2) the air exchange occurs very smoothly, that is, without abrupt motions at the peaks and troughs of the bear's breathing motions; (3) the air exchange rate is constant and is the same for input and output (inspiration and expiration), so that the bear's breathing motions simulate the sinusoidal wave-type motion of an infant's breathing at this age; (4) an open air system is required so that the above conditions are sustained despite small losses of air from the bear's bladder and hose connections; (5) the bear's breathing is adjustable so that the rate can be set for each infant; (6) a safety release valve assures that the bear is never overexpanded; (7) the air exchange is achieved with minimal sound and without any vibratory motion that could be transmitted to the bear; (8) the pump is built for continuous function, making approximately 75,000 strokes per day; (9) the relatively small size of the pump is critical for placement in a crowded neonatal intensive care unit; and (10) the pump meets hospital requirements for safety. These characteristics of the pump assure the precision in movement of the bear that are necessary for a smooth, gentle, unvarying source of stimulation for the baby.

From direct observation of the baby during sleep, the baby's respiration rate during quiet sleep was determined; then, the pump was set to make the bear "breathe" at one half of that rate. This procedure was repeated once a week throughout the treatment period to adjust for any changes in the baby's rate of breathing.

For the infants in the nonbreathing bear group, a motionless bear was placed in the isolette with the baby, and the infants in the no-bear group did not have a bear placed in the isolette. These treatment conditions were maintained for 3 weeks or until the infant was moved from the isolette into a regular nursery crib.

The infants were monitored by means of a video camera mounted over the infant's isolette, with time-lapse recording at a 72:1 ratio. Thus, three days' continuous recording was obtained on a one-hour tape.

Eleven of the infants (three in the breathing bear group, three in the nonbreathing bear group, and five in the no-bear group) were continuously recorded for three days at the beginning of the intervention period. It was not possible to obtain these early recordings from every infant because of crowded conditions in the neonatal intensive care unit. All 18 infants were recorded for three days at the end of the intervention period.

The videotapes were scored by code recording for each 5-second epoch (six minutes in real time) the presence or absence of the following conditions: (1) the baby was in the isolette, (2) the baby was in the prone (tummy) position, (3) the baby was propped, (3) the baby was in physical contact with the bear, (4) an intervention occurred, and (5) the baby was in quiet sleep. Exact epoch-by-epoch agreement between two scorers (one who was experimentally naive) ranged from 92% or 100% on these codes.

Approach behavior toward the bear can only be exhibited when the baby is able to move about in the crib. This requires being in the tummy position and not restrained by propping. Thus, contact with the bear was scored only during epochs when the baby was (1) in the isolette, (2) in the tummy position, (3) not restrained by propping, and (4) no intervention was occurring. All 5-second epochs (six minutes in real time) that met these criteria were defined as "Baby Available" epochs.

For contact to be scored for an epoch, it was necessary for the following conditions to hold for that epoch: (1) it was a baby available epoch; (2) the baby was touching the bear with an arm and/or a leg, head, or body for more than three minutes in real time (brief contacts can occur when the baby is crying and very active); and (3) the infant was not placed in contact with the bear by a nurse or caretaker (in such instances, contact is not scored for an epoch unless the baby moves and achieves closer contact with the bear).

For the no-bear infants, it was necessary to measure the amount of contact with the area of the crib occupied by a bear. This group of infants was included to determine the level of contact with a bear to be expected by chance alone. For this purpose, when the tapes for the babies in the no-bear group were scored, a paper cut-out the same size and shape of the bear (a shadow bear) was placed over the TV monitor to cover the area that was occupied by a bear in the isolette. Then, the baby's contact was scored for the shadow bear in the same manner as for a breathing bear.

Quiet Sleep was scored for any epoch in which the baby's eyes were closed and there was an absence of gross motor activity throughout the six-minute period, except for occasional startles or jerks.[10]

Contact time with the bear and the amount of time in quiet sleep were measured as a percentage of baby available time during each three-day recording. The babies spent bout 40% of the day in baby available during both recording periods, and there were no differences among the groups at either time.

For each of the three groups, the mean amount of contact with the bear during the three-day periods at the beginning and end of the intervention is shown in Fig 1. There were no differences among the groups during the initial three-day recording. By the end of the intervention period, the breathing bear group showed significantly more contact than each of the control groups: breathing bear *v* non-breathing bear, $F = 65.29$; $df = 1{,}15$; $P < .001$; breathing bear *v* no-bear, $F = 53.10$; $df = 1{,}15$; $P < .001$. In addition, a repeated measures analysis for the 11 babies who were measured at both the beginning and end of the intervention period found a significant groups × time interaction ($F = 8.32$; $df = 2{,}8$; $P < .01$). This was the result of a significant change over time in the breathing bear group. There was no change in contact for the other two groups. Clearly, only the breathing bear elicited approach behavior from the premature infants.

The measure of quiet sleep, shown in Fig 2, revealed the same pattern of differences as that found for contact. The groups did not differ at the beginning of the intervention ($F = 3.36$; $df = 2{,}8$; nonsignificant). By the end, there were significant

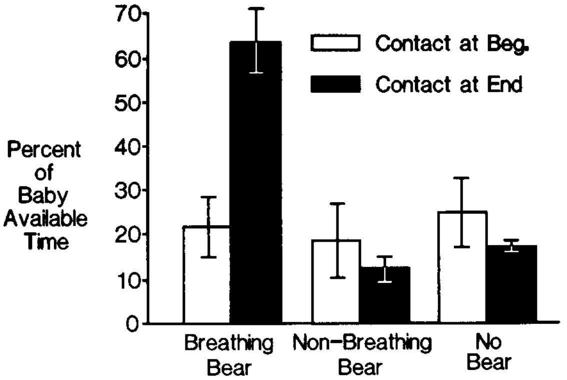

Fig 1. For each of three groups, percentage of baby available time spent in contact with bear (or shadow bear, in no-bear group) at beginning and end of intervention period.

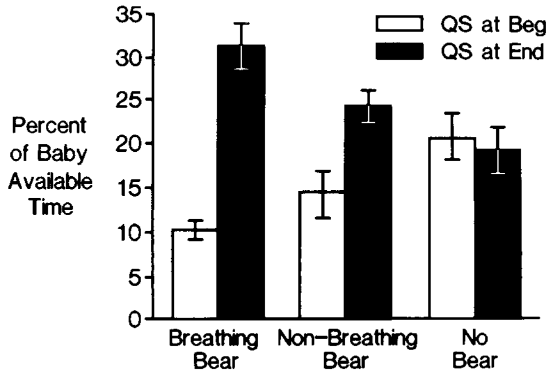

Fig 2. For each of three groups, percentage of baby available time spent in quiet sleep at beginning and end of intervention period.

differences between the breathing bear infants and each of the other two groups ($F = 6.18$; $df = 1{,}15$; $P < .03$; $F = 14.84$; $df = 1{,}15$; $P < .01$). The two control groups did not differ from each other. For the 11 infants measured at the beginning and end of the intervention, a significant groups × time interaction effect was found ($F = 4.44$; $df = 2{,}8$; $P < .05$), reflecting a change over time for the breathing bear group. Neither control group showed a significant increase over the intervention interval. Thus, the infants who were self-regulating their stimulation showed greater amounts of quiet sleep as a function of the intervention.

These results have several major implications. First, they reveal a dramatic form of competence in infants during the preterm period. By 35 weeks' conceptional age—5 weeks before a full-term infant is born—these small infants are able to seek contact with an "attractive" stimulus. The presence of a bear with a breathing motion was clearly more attractive than a bear that was motionless.

It should be noted that seeking contact with the bear requires not only sensory perceptiveness but directed motor activity as well. This is possible for premature infants because, by 34 weeks' conceptional age, they are much more mobile than either the full-term counterpart or the premature infant at term age.[8,11] However, this mobility has generally been considered to be the result of movements that are random and undirected in nature, reflecting a lack of inhibitory controls over the motor system by an immature CNS.[12-15] The findings of the present study indicate that preterm infants are capable of organizing their motor movements in a directed fashion. Thus, they have greater central integration than has been attributed to them at this early stage of life.

The results also have implications for the biologic relevance of the stimulation provided by the breathing bear. This is indicated (1) by the infants' greater preference for the breathing bear than one that does not breathe and (2) by the increased quiet sleep associated with exposure to the breathing bear. An increase in quiet sleep is indicative of a more mature sleep pattern.[8,16] Thus, the findings suggest that the self-regulated stimulation may affect the central integrative controls for sleep.

The optional aspect of the bear is an important consideration in viewing this source of stimulation as biologically relevant for infants. Premature infants are highly susceptible to overstimulation because the mechanisms for coping with stress are undeveloped.[4,5,17] As a consequence, an infant may decompensate physiologically even with a seemingly mild intervention. Thus, stimulation that is too intense, too complex, or inappropriately designed or timed in relation to the maturity, physiologic status, or even the state of the infant can be as harmful as a lack of stimulation.[18] Unfortunately, routine care of premature infants involves many overwhelmingly stressful events as medical requirements. Thus, it is imperative that an intervention should not contribute to this overload of stimulation. Because the results of this study indicate that infants are capable of regulating their contact with the bear, the provision of optional stimulation addresses this major concern by allowing each infant to titrate his or her own dosage of stimulation.

These considerations lead to the conclusion that biologically relevant stimulation for premature infants involves more than merely providing supplemental environmental input. The vulnerability as well as the functional status of the infant needs to be taken into account. Not only is the movement stimulation from the bear optional but also no other input is imposed on the baby—the bear even breathes silently. Furthermore, the bear's breathing reflects that of the infant and thus avoids exposing the infant to an extraneous form of rhythmic stimulation. The appropriateness of these characteristics of the breathing bear is indicated by the dramatically high level of contact it elicits from the infants (more than a threefold increase over control values).

The experience of self-regulating stimulation may, in itself, be a most potent condition for facilitating the maturation of the immature CNS. This inference is suggested by research indicating the effectiveness of stimulation that involves active participation on the part of infant animals in contrast to passive exposure.[19] Premature infants are exposed to the stimulation from the breathing bear as the result of actively seeking contact with it. Thus, they are given an opportunity to exercise a function of which they are capable at this early age.

The issue of whether we have selected the optimal parameters for the bear's breathing motion is an empirical question. The methodology presented here by which the infant regulates the temporal parameters of stimulation provides a procedure for future exploration of preferences and their consequences.

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REFERENCES

1. Schneider GE: Is it really better to have your brain lesion early? A revision of the "Kennard Principle". *Neuropsychologia* 1979;17:557–583
2. Affonso D: The newborn's potential for interaction. *J Obstet Gynecol Neonatal Nurs* 1976;5:9–13
3. Clark A, Affonso D: *Childbearing: A Nursing Perspective.* Philadelphia, FA Davis, 1976, pp 547–596
4. Rose A, Schmidt K, Bridger W: Cardiac and behavioral responsivity to tactile stimulation in premature and fullterm infants. *Dev Psychol* 1976;12:311–320
5. Field T: Games parents play with normal and high-risk infants. *Child Psychiatry Hum Dev* 1979;10:41–47
6. Thoman EB: *Effect of Early Social Deprivation in the Rat.* PhD dissertation. Lincoln, University of Nebraska, 1965
7. Prechtl H, Fargel J, Weinmann H, et al: Postures, motility, and respiration of low-risk pre-term infants. *Dev Med Child Neurol* 1979;21:3–27
8. Booth C, Thoman EB, Leonard H: Sleep states and behavior patterns in preterm and fullterm infants. *Neuropediatrics* 1980;11:354–364

8a. Thoman EB: *Method and Apparatus for Testing Breathing Irregularities,* patent No. 4,606,328. Washington, DC, US Patent Office, Aug 19, 1986

9. Dubowitz L, Dubowitz V, Goldberg C: Clinical assessment of gestational age in the newborn infant. *J Pediatr* 1976;77:1–10
10. Anders TF, Keener M: Developmental course of nighttime sleep-wake patterns in full-term and premature infants during the first year of life: I. *Sleep* 1985;8:173–192
11. Prechtl HFR: Assessment and significance of behavioral states, in Berenberg SR (ed): *Brain: Fetal and Infant.* The Hague, Martinus Nijhoff, 1977, pp 77–90
12. Parmelee AH, Stern E: Development of states in infants, in Clemente C, Purpura D, Mayer F, (eds): *Sleep and the Maturing Nervous System.* New York, Academic Press, 1972, pp 199–228
13. Prechtl HFR, Fargel JW, Weinmann HM, et al: Development of motor function and body posture in pre-term infants. *INSERM* 1975;11-12:55–66
14. Brierly JK: *The Growing Brain: Childhood's Crucial Years.* Windsor, England, NFER Publishing Co, Ltd, 1976
15. Corner MA, Baker RE, Vander Poll NE: Spontaneous motor rhythms in early life—Phennomalogical and neurophysiological aspects, in Corner MA (eds): *Maturation of the Nervous System, Progress in Brain Research.* Amsterdam, Elsevier/North Holland, 1978, vol 8, pp 349–366
16. Roffwarg HP, Muzio JN, Dement WC: Ontogenetic devel-

opment of the human sleep-dream cycle. *Science* 1966; 152:604–619
17. Sehring P, Gorski D, Sweet J, et al: Bradycardia in preterm infants: One response to caregiven touch. Presented at the Society for Research in Child Development Biennial Meetings, Toronto, April 1985
18. Blackburn S: Fostering behavioral development of high-risk infants. *J Obstet Gynecol Neonatal Nurs* 1983;(suppl):76S–86S
19. Held R, Hein A: Movement produced stimulation in the development of visually guided behavior. *Journal of Comparative and Physiological Psychology* 1963;56:872–876.

SUNLIGHT GOOD FOR BABY

It has long been a tradition that babies are delicate and must be carefully protected from direct sunlight. When a baby was put outdoors he was bundled up in many clothes and wraps, and the hood of the baby carriage was pulled up to keep out every ray of sunlight. The carriage might be placed in the sun, but the ultra-violet rays could not penetrate the hood and the clothes to reach the baby.

It has also been believed that a baby's eyes are weak and sensitive to light. The sun does not cause inflammation, however, when the baby's eyes are closed or when his head is turned so that the eyes are not in the direct line of the rays.

Traditions such as these, handed down from generation to generation, are founded more on hearsay than on fact.

Submitted by Anthony Shaw, MD

From *Sunlight for Babies.* US Department of Labor: Children's Bureau, Folder No. 5. Government Printing Office, 1926.