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The Relationship Between Auditory Stimulation and Gross Motor Activity of Short-Gestation Infants

Jacqueline S. Chapman

The short-gestation infant is at risk for both mortality and morbidity. His writhing contributes to weight loss; his extrauterine environment does not contain the multimodality patterned afferent stimuli that excite the developing brain *in utero*. Sound is the most effective modality to achieve concurrent decrement in motility along with enhancement of cortical activity. It was anticipated that by 36 gestational weeks, subjects exposed to 5 min. of patterned sound 6 times a day would (a) evidence less gross motor activity and (b) evidence a greater decrease in motor actitvity with a maternal auditory stimulus than with a musical auditory stimulus. The sample consisted of 80 males and 73 females whose gestational age at birth was 26 to 33 weeks. Fifty-two subjects were randomly assigned to the control group, 50 to a tape of their mother's voice, and 51 to a lullaby. Limb activity was measured just before discharge by accelerometers worn unilaterally for a 24-hr. period on the ankle and wrist prior to transfer to the alternate side for a further 24 hr. No statistically significant differences were demonstrated among the three groups' limb patterns. Large intragroup variation in gross activity precluded demonstration of between-group differences. The majority of subjects evidenced predominance of upper limb activity and laterality.

The short-gestation infant, defined as one born at 34 weeks or less after conception, was the focus of this study. Continual uninhibited limb movement is characteristic of this immature human being (Brackbill & Fitzgerald, 1969, p. 181). Since these gestationally younger infants concurrently have low birth weights ($r = .67$; Chapman, 1975, p. 114), such motility poses a threat to their survival (Brackbill, 1971, p. 25). All newborns lose weight after birth. A 7-pound infant can tolerate the average weight loss of 8% of his birth weight. For the infant who, at birth, weighs 2 or 3 pounds, however, such a weight loss may be life threatening.

One-third of the 12,000 short-gestation infants born in New York City in 1968 died (Chase, 1973, p. 25). Short-gestation infants who survive have been found, later in life, to have varying degrees of deficits. Virtually no short-gestation infant escapes being placed somewhere along the minimum brain damage continuum (Braine, Heimer, Wortis, & Freedman, 1966, p. 46). Few of 91 subjects born at or before 34 weeks in one study were devoid of some developmental handicap at 10 years of age (Lubchenco, Delivorio-Papadopoulos, & Searls, 1972, p. 510).

Normal human development is believed to be contingent on the impact of varied stimuli on the organism (Fiske & Maddi, 1961, p. 13). During the last trimester *in utero* it is assumed that the human fetus has opportunity for frequent interaction with a variety of stimuli—vestibular, auditory, kinesthetic, and tactile environmental stimuli. In contrast, the short-gestation infant in the Isolette is restricted to an environment where the potential for interaction with the various sensory modalities is very small.

An increasing body of evidence indicates that some of the same environmental stimuli believed necessary for the promotion of normal brain development also decrease the extent of gross limb activity in the neonate (Brackbill, 1971, pp. 17–26). On the basis of the existing evidence it seems reasonable to ask whether the introduction into the Isolette environment of some type(s) of external stimulation might be associated with a reduction in both the current mortality and morbidity statistics for the short-gestation infant.

The *problem* that this study investigated was: Can auditory stimulation decrease gross limb activity in the short-gestation infant?

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The literature indicates that two internal factors contribute to the short-gestation infant's characteristic gross motor activity. First, the immaturity of his cerebral cortex does not allow the suppression of the subcortical bursts of spontaneous discharge (Scheibel & Scheibel, 1964, p. 513). Second, tissue hypoxia, due to his respiratory impairment, acts as a stimulus to mass movement (Windle, 1950, pp. 216–19). Aside from these two internal factors, the perceptual monotony of the external environment of his Isolette (Davis, 1959, p. 313) is an additional cause of increased motility.

Of the auditory, visual, and tactile modalities, sound has been found to be the most effective in decreasing the activity of full-term neonates (Wolff, 1966, p. 40). The sound of a taped heartbeat played to an experimental group of full-term neonates also produced a faster weight gain in them than in the controls who were not similarly exposed (Salk, 1960, pp. 172–173). It could be postulated that infants in a state of quiescence consume fewer calories and hence gain weight faster.

An effective external stimulus—in any modality—enhances the sensitivity of all cortical sensory receptors (Sokolov, 1963, p. 13). Stimulation that is continually varied in pattern (Fiske, 1961, p. 30) is effective and creates excitation in the reticular activating system (Moruzzi & Magoun, 1949, p. 470). In relation to auditory input, either the words in a taped monologue or the melody of a piece played by an orchestra would meet the criterion of continually changing patterned stimuli. In two previous studies, short-gestation infants were exposed to a taped monologue of their mother's voice. They were found to be more responsive to their auditory environment and to demonstrate greater development in the early postnatal period than were the control groups (Segall, 1971, pp. 119–129; Katz, 1971, pp. 196–201).

In the last trimester the human cortex not only has the greatest capacity for brain growth (Davison & Dobbing, 1966, p. 41) but at a critical point axodendritic sprouting replaces somal reproduction (Scheibel & Scheibel, 1964, p. 513). Evidence from neonatal rat studies suggests that effective stimulation not only produces significant gains in brain weight but also significantly increases the number of cortical dendrites (Schapiro & Vukovich, 1970, p. 292). Dendrites that act as inhibitors develop predominantly in the latter stages of fetal life (Barron, 1941, p. 20). Such maturation processes in the cerebral cortex are observable in the changing sleep patterns of the short-gestation infant.

During gestation both total sleep time (TST) and the proportion of TST designated as "active sleep" decrease (Ellingson, 1972, p. 169). Dreyfus-Brisac (1968, p. 163) claimed that the 24- to 27-gestational week infant is in an immature sleep state that has some characteristics of both active and quiet sleep. By 28 weeks the majority of sleep can be classified as typical active sleep, although very brief periods of characteristic quiet sleep begin to appear on the electroencephalogram (Dreyfus-Brisac, 1966, p. 290). At 33 to 34 weeks, active sleep comprises 68% of TST (Parmelee, K. Bruck, M. Bruck, Wenner, Akiyama, Schultz, & Stern, 1967, p. 74). The successive decrements of active sleep in relation to TST during ontogeny reflect the maturation of the cerebral cortex as it gains increasing influence over subcortical activities (McGinty, 1972, p. 275). Polygraphic findings demonstrate that 80% of active sleep is correlated with activity (Parmelee, K. Bruck, M. Bruck, Wenner, Akiyama, Stern, & Flescher, 1967, pp. 469–470). The 36-week infant still spends 75 to 80% of a 24-hr. period in sleep (Hasselmeyer, 1961, p. 43), the majority of which is active sleep (Parmelee at al., 1967, p. 472). Active sleep is known to decrease during development, and a high proportion of active sleep is accompanied by limb movement. Since the neonate prior to the 37th gestational week spends 75 to 80% of a day in sleep, it would seem feasible to measure maturation in terms of reduced limb activity.

The *purpose* of this study was to determine, in short-gestation infants, the effect of three types of patterned auditory stimulation upon gross motor limb activity.

The *research hypotheses* formulated for this study were that (a) introduction of a purposive auditory stimulus into the infant's environment will be associated with decreased motor activity and (b) maternal auditory stimulus will be associated with greater decrease in motor activity than will the application of non-maternal type of stimulus.

METHOD

Subjects

Cluster sampling (Treece & Treece, 1973, p. 82) was used. Every short-gestation infant who was admitted during 1972 or 1973 to one of three high-risk nurseries in New York City and who met stipulated eligibility requirements was included in the study. The subjects were either born in or were transferred soon after birth from 1 of 29 community hospitals to the three metropolitan centers used. During the first four days of the subject's life the investigator visited the infant's mother to explain the study and to secure her written consent for her child's inclusion.

A total sample was
males and 73 females.
35, Hispanic, and 4 w
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Apparatus

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A total sample was composed of 153 infants, 80 males and 73 females. Seventy were black; 44, white; 35, Hispanic, and 4 were classified as Other. Their average age at birth was 30 to 31 gestational weeks; their average weight, 3 pounds, 2 ounces. The majority were born by vaginal delivery to married multiparous women whose average age was 26. The median of their fathers' occupational categories (58) ranked well below the national socioeconomic average (69.8) as classified on Anderson's modification of the North-Hatt scale (Anderson, 1972, p. 303; Broom & Selznick, 1963, p. 200).

Apparatus

The instrument selected to measure gross motor limb movement is called an accelerometer (Schulman & Reisman, 1959, p. 455). The investigator had a horologer modify an Omega calendar watch so that the arc and the vigor of any movement in the same plane as the face of the instrument were recorded (Mario Marcel, Mario Jewelers, Closter, N.J.). In view of their antigravity position most of the limb activity of the subjects would occur in the sagittal plane (Wells, 1971, pp. 9–12). Placement of the accelerometers on the lateral aspects of the ankle and wrist, therefore, should assess sagittal movement.

The validity of gross motor activity, as recorded on accelerometers, as an indicator of the overall state of the living human organism has been demonstrated by $r = .73$ ($p < .01$) correlation between externally registered units on accelerometers worn on the upper and lower extremities and internal oxygen consumption (Schulman, Kasper, & Throne, 1965, p. 108). Accelerometer units also are correlated at $r = .78$ ($p < .01$) with movement scores assigned for specific exercises (Rose & Mayer, 1968, p. 19). Concurrent readings between accelerometers worn on four-day-old infants' ankles and a movement sensing unit in their mattress were correlated $r = .59$ ($p < .01$) (Campbell, Kuyek, Lang, & Partington, 1971, p. 113).

To establish intra- and interinstrument reliability, the seven accelerometers to be used in the study were mounted in the sagittal plane on a motor driven wheel in the New York University biophysics research laboratory. The number of revolutions made by the wheel are recorded on a counter. For repeated trials of 100 revolutions, both the intra- and interinstrument error, expressed as the mean difference between readings, was less than 5%.

Design

A three-group experimental design was used (Treece & Treece, 1973, p. 153). Subjects were assigned at random to one of three groups: the routine auditory stimulation of the Isolette, a tape recording of their mother's speech, or an orchestral arrangement of Brahms' "Lullaby." Fifty-two subjects were in the control (routine) group, 50 in the maternal speech group, and 51 in the music group.

Procedure

Each infant was given a pretest for functional hearing. On the fifth day of life, after the effect on the infant of any analgesic, sedative, or anaesthetic administered to the mother during labor presumably had abated (Brazelton, 1961, p. 517), the subjects were tested for gross functional hearing ability. The Zenith Neometer (Model 440) emits a sound like a bird tweet. This tone of approximately 3,000 Hz was introduced into the neonate's sound field for 2 sec.

Acceptable behavioral responses, which were observed and recorded independently by two members of the high-risk nursery staff, could be any one of the following: first, a palpebral reflex (Downs & Sterritt, 1964, p. 79); second, any component of the Moro reflex (Miller & Polisar, 1964, p. 16); or third, any change in the prestimulus pattern of chest and abdominal respiratory movements (Goldstein & Tait, 1971, p. 15).

All but 12 of the 151 subjects tested (2 subjects were not tested for hearing) responded to this initial test. The majority responded to the lowest sound level pressure possible (70 decibels) elicited from the testing device. Subjects not responding to the initial test were related at 2-day intervals. Ten responded to the second trial on their 7th day of life; the remaining two responded on the 9th and 11th days of life, respectively.

All groups received routine auditory stimulation of the Isolette. In addition, the experimental groups were exposed to taped maternal speech or taped musical auditory stimulation for 5 min every 2 hrs six times daily. The regimen of additional auditory stimulation began on the fifth day of extrauterine life for all experimental subjects. The daily regime continued until several days before discharge. Since a 48-hr test period was required, choice of the time to discontinue the stimulation regimen was based on attainment of a minimum weight of 1,843 g (4 lb, 1 oz). In the nurseries used, short-gestation infants are not discharged until they weigh at least 2,041 g (4 lb, 8 oz).

When the infant attained at least 1,843 g the taped maternal or musical auditory stimulation was discontinued. The average duration of the auditory regimen before assessment of gross motor limb activity was 34 days; this did not differ among groups. After discontinuation of the taped auditory stimulation, instruments designed to measure

motion were placed unilaterally, as determined at random by a coin toss, on the lateral aspect of the subject's wrist and ankle for a 24-hr period. During the next 24 hrs they were placed on the opposite side. The averaged daily upper and lower limb activity scores were then summed to give a total limb activity score in hours per day.

RESULTS

Prior to the major analysis of each group's scores to determine if group differences existed in gross motor activity, two possible confounding variables, both the influence of sex on activity and gestational age at Test Day 1, were examined. Data pertinent to these two variables are presented in the following paragraphs. The alpha level for the study, determined a priori, was $p = 0.05$.

Female subjects were found to have significantly less upper (t [151] = –2.896), lower (t = –2.574), and total (t = –3.111) limb activity scores than males; the point biserial relationship value between sex and total activity score was .24. A rationale proposed to explain this finding is that female subjects had more of the smooth-controlled movements indicative of advanced development than did male subjects, whose significantly higher limb activity scores may have reflected more immature tremulous movements.

A second variable that might have affected activity was the gestational age of the three groups at Test Day 1, the day the accelerometers were initially applied. Although there had been no significant difference among the three groups in either weight or gestational age at birth, analysis of variance of gestational age at Test Day 1 demonstrated a significant difference among the groups, F (2, 150) = 4.33, $p < .05$. Subsequent Scheffé tests indicated that the group exposed to music was significantly younger than the routine group, $F = 4.33$, $p < .05$. The average age for the entire sample at Test Day 1 was 36 gestational weeks. The musical group, however, at 35½ weeks had already achieved the discharge weight that took the control group more than another week to attain.

Since the musical group was significantly younger on Test Day 1 than the control group, for the major data analysis, it was necessary to assess the effects of age. Multiple classification of covariance (Wert, Neidt, & Ahman, 1954, pp. 352–362) was done as a subclassification by sex was necessary within each of three auditory stimulation groups. The research hypotheses had predicted that both maternal speech and musical auditory stimulation would reduce gross limb activity and that maternal auditory stimulation would reduce it more than musical auditory stimulation. Although the mean total activity scores of the experimental groups were lower than the control group, as shown in Table 1, a large intragroup variation contributed to the difficulty in demonstrating between-group differences.

None of the statistical hypotheses formulated to test the research hypotheses was supported. No significant differences in activity scores were found among the black, white, and Hispanic subjects in this study.

Examination of activity scores pointed up three unanticipated findings in relation to limb movement. First, normal predominance of upper limb activity over lower limb activity (Dargassies, 1966, p. 310; Larroche, 1966, p. 267) was already

TABLE 1 Means of Total Limb Activity for Subjects Exposed to Three Types of Auditory Stimulation

Type of Stimulation	n[a]	Range	Means	Standard Deviation	Standard Error of the Mean
Routine (control)					
female	25	109–600	253.000	139.171	27.834
male	25	111–819	319.064	159.194	31.839
Maternal speech					
female	25	110–451	238.696	98.050	19.610
male	25	125–958	292.926	156.468	31.294
Music					
female	25	111–615	227.172	103.340	20.668
male	25	76–535	302.182	136.952	27.390
Total	150	76–958	272.173	134.315	10.967

[a]A harmonic mean of 25 was considered the best estimate available (Arafat, 1972, p. 195), as subclass frequencies were not equal for males and females.

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TABLE 2 Distributio and Treatment Group

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present in all but 38 of the 153 subjects at Test Day 1, as shown in Table 2. Of the 38 who had not reached this maturational stage and who still moved their lower limbs more than their upper limbs, 50% (19) were in the routine (control) group, whereas the maternal speech and musical groups had only 9 and 10 subjects, respectively, who fell into this category.

TABLE 2 Distribution of Subjects by Limb Movement and Treatment Group

Type of Stimulation	*n*	Upper Limb Greater	Lower Limb Greater
Routine (control)	52	33	19
Maternal speech	50	41	9
Music	51	41	10
Total	153	115	38

Note. Nonsignificant when tested by chi square.

Second, not only was the normal pattern of predominant upper limb movement evident in most subjects, but the majority of subjects developed sidedness, as shown in Table 3. Laterality was most marked in the maternal speech group, where 68% (34/50) moved their right arm less than their left arm. These subjects' receptive speech center, believed to be located in the dominant hemisphere (Luchsinger & Arnold, 1965, p. 435), had been exposed, on the average, to taped maternal auditory stimulation for over a month.

TABLE 3 Distribution of Subjects by Pattern of Upper Limb Movement and Treatment Group

Type of Stimulation	*n*	Left Limb Greater	Right Limb Greater
Routine (control)	52	26	26
Maternal speech	50	34	16
Music	50[a]	29	21
Total	152	89	63

Note. Nonsignificant when tested by chi square.

[a]One subject in the music group had exactly the same movement score on both arms.

The third phenomenon observed was that subjects in the maternal group did not appear to require a 24-hr period of adaptation to wearing accelerometers, whereas subjects in the other two groups tended to move their extremities less on the first than on the second Test Day (see Table 4).

TABLE 4 Distribution of Subjects with Greater Total Limb Movement by Test Day and Treatment Group

Type of Stimulation	*n*	Test Day 1	Test Day 2
Routine (control)	51	19	32
Maternal speech	49	26	23
Music	51	16	35
Total	151[a]	61	90

[a]One subject in both the ambient and the speech group had exactly the same total movement score on Test Day's 1 and 2.

Note. Nonsignificant when tested by chi square.

DISCUSSION

In the light of the theoretical framework proposed for the study, the differential gross motor activity between the sexes could be interpreted as more rapid development in female than male subjects. Such a finding is congruent with previous research that has demonstrated that low-birth-weight males obtained significantly lower scores than similar females during the first year of life on both motor and cognitive functions (Braine et al., 1966, p. 42).

Animal and human research has demonstrated the detrimental effects of maternal-infant separation upon both infant development and maternal behavior (Barnett, Leiderman, Grobstein, & Klaus, 1970, p. 198; Bell, 1971, p. 71). Musical auditory stimulation, for this sample, not only helped to prevent prolongation of mother-infant separation but also resulted in financial savings. The deletion of the cost of an additional week of high-risk nursery care represented a collective saving of over $42,000 for the musical group's parents and/or third-party payers. Although the difference in gestational age at test between the maternal speech and routine groups did not achieve statistical significance, the direction of both experimental groups' ages was to be younger than the routine group's age at discharge.

The finding that the maternal speech group appeared to adapt most readily to the accelerometers raises the question whether, as in the classic canine studies, development under restricted human contact results in "freezing" behavior when confronted with the unfamiliar (Clarke, Heron, Fetherstonhaugh, Forgays, & Hebb, 1951, p. 151).

CONCLUSION AND RECOMMENDATIONS

Multiple classification of covariance demonstrated that none of the research hypotheses was supported. There was no significant difference in the limb activity scores of the three groups who were

exposed to different auditory treatments. Female subjects had significantly less gross motor activity than male subjects. The group exposed to music reached the test weight at a significantly younger gestational age than the control group.

The findings also suggest that both music and human voice facilitate development of normal limb activity patterns; that musical stimulation conserves energy and permits use of calories for weight gain; and that exposure to speech advances the complexity of the short-gestation infant's developmental pattern to include laterality and rapidity of adaptation to new elements in the environment.

It is recognized that there were limitations in the study: only three nurseries in one state were used, for example. The sample size was too small to permit rigor for statistical power, and the auditory electronic assembly available did not have the flexibility to be altered with the infant's feeding schedule.

Based on the outcomes of this study, *recommendations* for further research include the following:

1. To attempt to resolve the great individual variation in neonatal activity, a pretest activity score for use as a covariate is required. A mattress containing a movement-sensing unit could be put in an Isolette (Griffiths, Chapman & Campbell, 1967, pp. 438–41). A baseline of daily activity would be available merely by placement of a subject upon such a mattress.

2. A convertible timer that has the flexibility to initiate sound at the mid point of any infant's feeding schedule when the reticular activating system is most receptive to incoming stimuli (Wolff, 1966, p. 55, pp. 82–83) is needed. Similarly, the timer should be in series with a tape recorder that has the capacity to automatically transfer back and forth to either side of a cassette. Such an auditory assembly requires manual intervention only when the infant's feeding schedule is altered. In addition, the number of auditory stimulation periods might better be increased and distributed over 24 hr rather than 12 hr.

3. Since the greatest weight loss occurs in the first week or so after birth, it is suggested that a study be undertaken in which one experimental group would be exposed to musical stimulation for the first 2 weeks of life followed by maternal stimulation initiated in order to observe the effect of this sequential pattern of taped musical-maternal stimulation upon weight gain, laterality, and adaptability. A second experimental group might have musical and maternal auditory stimulation alternated from the outset to see if one-half as much music will be sufficient to contribute to weight gain while, concurrently, early exposure to maternal stimulation is maintained.

4. Since some short-gestation infants appeared to require a period of adaptation to the accelerometers, it is suggested a 24-hr adaptation period be provided before the 48-hr test period.

5. A study might be done to investigate subsequent mother-child relationships of short-gestation infants. The aim would be to determine whether maternal stimulation has differentially influenced mother-child interaction. In addition, since the majority of parents of the subjects in this study were from a lower socioeconomic status, longitudinal follow-up stimulation programs for short-gestation infants might be initiated to see if such programs would be as beneficial to these infants as they have been found to be for disadvantaged low-birth-weight infants (Scarr, Salapatek, & Williams, 1972, p. 665).

6. Since male subjects were found to be significantly more active than female subjects, a randomized block design would allow equal numbers of male and female subjects in each cell.

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An "If" for Researchers

If you can think in terms of high performance
And doing things in new and better ways,
If you can dream of how to make improvements
Yet not make dreams alone fill all your days,
If you have visions of a world that could be
And vow to work to clarify the haze,
If you can read with critical perspectives
And also note the thoughts deserving praise,

If you can set your goals to guide your actions
And see that terms are stated and defined,
If you can read and not get tired of reading
And view your findings with an open mind,
If you can search and read and sift and ponder
And blend ideas that should be combined,
If you can deal with concepts not considered
And then perfect the plan that you've designed,

If you can bear to see your towers crumble
And learn that what you reasoned was not sound,
If you can face the critics and not grumble
And then rebuild your towers from the ground,
If you can once more shift and send thoughts soaring
And have an inner glow that does not end,
You'll work with zeal and you'll report your findings,
And what is more, you'll do RESEARCH, my friend.

Jane Mezzanotte
with apologies to Rudyard Kipling

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Dr. Brown is
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