we have tested the stability of positive "responses" by repeating the injections. We believe that the differences in methodology between the two studies could fully account for our failure to replicate.

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6. Twelve rats received intraperitoneal injections of morphine sulfate in doses of either 10, 20, or 30 mg per kilogram. All doses produced catalepsy. Naloxone (0.4 mg, given intravenously) immediately blocked the catalepsy; the duration of naloxone effect ranged between 10 and 30 minutes, depending on the dose of morphine. Injection of saline aroused the animals, but the duration of this effect did not exceed 10 seconds.
7. We thank Mary Ginther for technical assistance.

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Vestibular Stimulation Influence on Motor Development in Infants

Abstract. *Preambulatory, normal human infants were exposed to sessions of mild semicircular canal stimulation on 2 days per week for 4 weeks. The gross motor ability of each child was assessed before and after the 4-week period. The vestibular stimulation effected a significant improvement in gross motor skills.*

Physical and occupational therapists working with developmentally delayed children have advocated the use of various forms of vestibular stimulation in their therapy programs (*1*). Vestibular dysfunction has been related to slow development of motor skills and learning disorders (*2*), but little evidence exists to support the claims of beneficial effects of vestibular stimulation. In one study, premature infants were exposed to daily sessions of sinusoidal vestibular stimulation, beginning on the fifth day after birth, and showed improved scores on tests involving auditory and visual responses, motor development, and maturation at 36 weeks of age (*3*). In a second study, we exposed three preambulatory children (one normal and two with Down's syndrome) to ten sessions of semicircular canal stimulation in 2 weeks. Motor skills test scores were markedly improved compared with those of four control subjects (*4*). We hypothesized that exposure to vestibular stimulation influences motor development in infants.

Twenty-six normal, preambulatory infants between 3 and 13 months of age, with a mean age of 7 months, were examined for level of motor performance on reflex and motor skills tests. The reflex test was developed by Chee (*5*) from existing tests (*6*). For each child examined, the elicited reflex was first determined to be normal or abnormal for his or her age and then scored from 1 (abnormal) to 4 (normal). Seventeen reflexes were examined, with a maximum possible score of 68. The motor skills test, developed by Kantner (*7*) from existing tests (*8*), allows an observer to quantitatively evaluate motor skills of the infant successively in five areas of increasing difficulty: prone and supine position, sitting, creeping, standing, and walking. Each area was subdivided into three to seven tasks, with each task further subdivided into five levels of difficulty. One point was scored for accomplishment of one level of each task. The maximum possible score on the motor skills test was 150. In both tests, a low score reflects immature motor ability and a high score more mature motor ability.

Tests were administered during the pretreatment week by a physical therapist (F. C. or J. K.) and each infant's performance was scored independently by two observers, both of whom were physical therapists experienced with young children. Correlation between observers, with pre- and posttreatment scores combined, was 0.90 for the reflex test and 0.98 for the motor skills test. Infants' scores were rank-ordered on the basis of the sum of the pretreatment mean scores on both tests, and infants were assigned as matched pairs to either the treatment (N = 13) or the control group (N = 13). To control for handling effects, the control group was subdivided into control handled (CH) (N = 6) and control nonhandled groups (CNH) (N = 7).

Each infant assigned to the treatment group received 16 sessions of semicircular canal stimulation during the 4 weeks after the pretreatment week. Two sessions, separated by 30 minutes, were given on each of 2 days of every week. The session days were separated alternately by 1 and 4 days. A session consisted of ten spins in a rotating chair. One of the investigators held the infant in his lap while he sat in the rotating chair in a dark room. Each spin consisted of a rapid (1- to 3-second) angular acceleration, a 1-minute period of constant velocity rotation at 100 deg/sec (16.7 rev/min), followed by an impulsive stop in less than 1 second. The infant was held in an upright sitting position during two spins, one clockwise (CW) and one counterclockwise (CCW), with his head tilted forward at about 30°, which placed the horizontal semicircular canals in the horizontal plane. The infant was shifted to a side-lying position to place one anterior and the opposite posterior semicircular canal in the horizontal plane during four spins, two CW and two CCW, alternating directions. The side-lying position was then reversed during four spins, two CW and two CCW, alternating direc-

Table 1. Mean scores on the reflex and motor skills tests before and after adjustment with the covariate; T, treatment group (N = 13); CH, control handled group (N = 7); CNH, control nonhandled group (N = 6); S.D., standard deviation.

Group	Pretreatment	Posttreatment		
	Unadjusted (mean ± S.D.)	Adjusted (mean)	Unadjusted (mean ± S.D.)	Adjusted (mean)
		Reflex test		
T	50.54 ± 11.87		62.54 ± 5.64	63.03
CH	55.83 ± 8.68	51.52	58.00 ± 9.73	55.83
CNH	49.64 ± 10.54		53.93 ± 7.76	54.87
		Motor skills test		
T	59.00 ± 34.84		86.38 ± 35.66	85.95
CH	68.17 ± 32.49	58.56	77.83 ± 35.10	68.40
CNH	49.50 ± 33.30		60.50 ± 39.94	69.39

tions, to stimulate the remaining pair of vertical semicircular canals.

Infants assigned to the CH group were transported to the testing center and were held in the investigator's lap in the chair for approximately the same length of time as the treatment group infants. The chair, however, was not rotated. Infants assigned to the CNH group were not in contact with the investigators during the 4-week treatment period.

Performance of all 26 infants on the reflex and motor skills tests was reassessed 4 days after the last day of vestibular stimulation by the same protocol as during the pretreatment week. The independent observers were unaware of the group assignment of each infant.

All infants tolerated the spinning well. The individual holding the infant reported, in most cases, a marked reduction in muscle tonus of the infant during passive rotation and the period of postrotatory nystagmus. Infants fell asleep several times during the constant-velocity portion of the spin. They would usually babble or laugh during the rotation, after the first 2 or 3 days of treatment. They appeared to enjoy the periods of rotation and postrotatory nystagmus immediately following the impulsive stop. Often, the infant would begin to fuss and cry during the 30-second interspin interval.

Analysis of covariance was used to test for differences in posttreatment test scores between groups, with the pretreatment score as the covariate (Table 1; Fig. 1). Significant differences were found on both the reflex test [$F(2, 22) = 8.14, P < .01$] and the motor skills test [$F(2, 22) = 10.36, P < .01$]. Separate t-tests were used to identify the source of these differences; the error term from the analysis of covariance was used in the calculations. The treatment group scored significantly higher than the CH ($t = 2.85, P < .01$) or CNH group ($t = 3.40, P < .01$) on the posttreatment reflex test. The treatment group also scored significantly higher than either the CH ($t = 3.60, P < .01$) or CNH group ($t = 3.57, P < .01$) on the posttreatment motor skills test (*9*).

These data support our hypothesis that exposure to vestibular stimulation accelerates motor development in infants. The preambulatory children under our control conditions showed 3.8 percent improvement on the reflex test and 6.7 percent improvement on the motor skills test over the 4-week period. Preambulatory children who received regular sessions of vestibular stimulation during the same period showed 12.2 percent improvement on the reflex test and 27.4 percent improvement on the motor skills test (*10*). These differences were clearly seen in the behavior of a pair of 3-month-old fraternal twins. They had identical pretest scores; one was placed in the treatment group and the other in the control group. At 4 months of age, the end of the study, the control group twin was developing head control but had not progressed beyond motor behavior in the prone and supine positions. The co-twin in the treatment group had mastered head control and could sit independently.

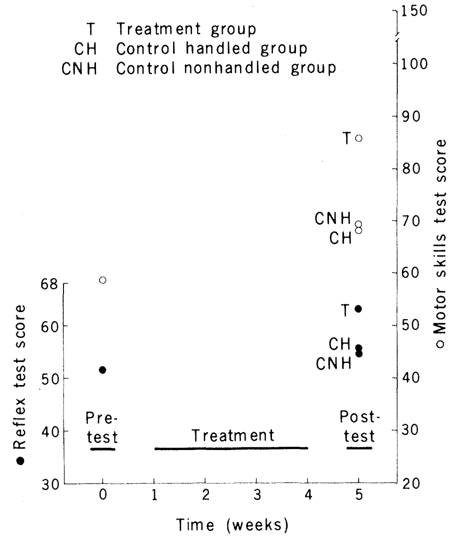

Fig. 1. Pre- and posttreatment test scores for infants on the reflex and motor skills tests. The treatment group received sessions of semicircular canal stimulation 2 days per week for 4 weeks.

A survey of parents and daycare personnel, most of whom were unaware of group assignments, corroborated the results of the motor skills and reflex tests. In addition, the survey suggested an improvement in hand-to-mouth coordination, a skill not measured by our tests.

Preambulatory children normally receive semicircular canal stimulation daily, during passive handling and rocking or during active head movements. Semicircular canal stimulation provided in this study differed from the usual canal stimulation in two ways. First, because head position was controlled, the stimulation was directed to specific pairs of canals in order to maximize the duration of cupula deflection and postrotatory nystagmus associated with those specific canals. Second, the magnitude of the stimulus was greater in this study. Most head-turning movements are of short duration and provide episodes of semicircular canal stimulation lasting up to about 5 seconds. The magnitude of canal stimulation provided in this study is similar to that produced by the cessation of prolonged whirling enjoyed by older children on small manually propelled merry-go-rounds and in games such as ring-around-a-rosy.

The vestibuloocular reflex arc enables the eye to maintain a stable retinal image during head movements. Components of this reflex are modified by vestibular experience in the adult (*11*); such experience in infants and young children may be important in developing effective use of semicircular canal–controlled eye movements. Vestibular stimulation of the infants in this study may have facilitated maturation of the vestibuloocular reflex and, in turn, provided the visual system a more stable retinal image against which motor involvement with the environment developed more rapidly. Semicircular canal stimulation also elicits vestibulospinal reflexes. Many of the reflexes and motor skills used in our evaluation are dependent, to some degree, on the maturation of vestibulospinal reflexes. The stimulation in this study may also affect motor behavior through vestibulospinal reflex facilitation.

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9. A third t-test is limited because there were only 2 degrees of freedom. However, the differences between posttreatment scores of the CH and CNH groups would not be statistically significant on either the reflex test ($t = 0.34$) or the motor skills test ($t = 0.18$). All data were also analyzed by using a series of mixed model analysis of variance tests, which produced similar results.
10. The percentage of improvement was calculated as 100 times the difference between post- and pretreatment scores divided by the maximum possible score.
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