References

1. G. Weber, *Biochem. J.* **51**, 145 (1952).
2. J. R. Frey and P. Wenk, *Int. Arch. Allergy* **11**, 81 (1957).
3. C. F. Barker, in *Advances in Biology of the Skin*, W. Montagna and R. E. Billingham, Eds. (Appleton-Century-Crofts, New York, 1969), pp. 199–211.
4. H. P. Godfrey and H. Baer, *J. Immunol.* **106**, 431 (1971).
5. E. Macher and M. W. Chase, *J. Exp. Med.* **129**, 81 (1969).
6. ———, *ibid.*, p. 103.
7. D. Parker and J. L. Turk, *Immunology* **18**, 855 (1970).
8. H. P. Godfrey, H. Baer, R. C. Watkins, *J. Immunol.* **106**, 91 (1971).
9. J. L. Turk and S. H. Stone, in *Cell Bound Antibodies*, B. Amos and H. Kaprowski, Eds. (Wistar Inst. Press, Philadelphia, 1963), pp. 51–60.
10. J. R. Frey and P. Wenk, *Dermatologica* **112**, 265 (1956).
11. H. P. Godfrey and H. Baer, *J. Immunol.* **107**, 1643 (1971).

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"Walking" in the Newborn

Abstract. *Brief daily exercise of the walking and placing reflexes in the newborn leads to a high rate of responding by 8 weeks and to an earlier onset of walking alone. There appears to be a critical period during which the walking response can be transformed intact from a reflexive to an instrumental action.*

If a newborn infant is held under his arms and his bare feet are permitted to touch a flat surface, he will perform well-coordinated walking movements similar to those of an adult. If the dorsa of his feet are drawn against the edge of a flat surface, he will perform placing movements much like those of a kitten. Normally, the walking and placing reflexes disappear by about 8 weeks (*1*). The discovery that they could be preserved intact beyond the second month through active exercise occurred in our pilot investigation with a single infant.

Experiments involving the manipulation of antecedent variables in research on infant mobility have been practically nonexistent; past research is descriptive, defining the various steps in the progression from lifting the head, to sitting, to walking alone (*2*). It has been accepted that this sequence of motor development is invariant, and most tests of infant intelligence are predicated, in large part, on this assumption. Sitting alone momentarily, early stepping movements, and walking alone, for example, are items on the widely used Bayley scale of infant development at 5.3, 7.4, and 11.7 months, respectively (*3*).

Intervention in the motor sequence has been reported with kittens (*4*), but the paradigm is one of deprivation—it shows that restriction of certain activities leads to impairment and not that stimulation can lead to facilitation. In contrast, the present experiment is a test of the generality of the observation that stimulation of the reflexes during the first 8 weeks promotes increased walking and placing.

Twenty-four white, 1-week-old male infants from middle-class and upper-middle-class families were enlisted with the assistance of two local physicians. The birth order of the infants and the ages and socioeconomic status (education and occupation) of the parents were controlled. Six infants each were assigned to the experimental and three control groups.

Infants in the active-exercise group received stimulation of the walking and placing reflexes during four 3-minute sessions each day from the beginning of the second through the end of the eighth week. During each session, the walking reflex was exercised for 2½ minutes and the placing reflex for 30 seconds. Fathers assisted in one of the daily sessions by supporting the infant's knees while the mother held the child erect. Stiffening the knees, it was assumed, would help the infant to learn to support his weight.

Infants in the passive-exercise group received equal amounts of gross motor and social stimulation but without elicitation of the walking and placing reflexes. The infant's legs and arms were gently exercised in a pumping motion while he was lying on his back in his crib or infant seat. When the father was present one of the parents would hold the baby while the other moved his limbs. Infants in the no-exercise group were tested along with the active-exercise and passive-exercise babies at consecutive weekly intervals, but received no special training. A fourth group of infants was tested only once, at 8 weeks of age, to control for the possible facilitative effects of repeated examination.

All training and test sessions were conducted in the infants' homes. The observer explained the program, tested the infant, and demonstrated the training procedure (in the active and passive groups) during the initial visit. With this exception, all training was conducted by the parents, primarily the mother. Each observer tested three infants in each of the four groups. One minute was allowed for testing each of four responses. The observer recorded the number of walking, placing, and straightening (*5*) responses and the age of onset and the frequency of the social smile to the observer when face-to-face at a distance of about 30 cm. An unambiguous walking or placing response with one foot was counted as one, with both feet as two. Only the walking and placing responses resulted in reliable differences among groups.

A strong increase in walking was observed in infants who were allowed to use the walking reflex. The rise to a mean of nearly 30 responses per minute and the low order of responding for all three control groups ($P < .001$) are illustrated in Fig. 1. Individual records revealed that by the end of 8 weeks all six active-exercise infants showed increments in the number of walking responses ranging from 32 to 617 percent over their level at the second week ($P < .01$).

Active-exercise infants also produced more placing responses than any of the control infants ($P < .05$), but there was no consistent increase over base level. Placing in the active group at 8 weeks was similar to the base level (mean = 9.0 responses), whereas infants in the

Table 1. Distribution of ages in infants for walking alone. There is a significant difference among the means [Kruskal-Wallis one-way analysis of variance, $P < .001$ (*11*)].

	Active-exercise group (months)	Passive-exercise group (months)	No-exercise group (months)	8-Week control group (months)
	9.00	11.00	11.50	13.25
	9.50	10.00	12.00	11.50
	9.75	10.00	9.00	12.00
	10.00	11.75	11.50	13.50
	13.00	10.50	13.25	11.50
	9.50	15.00	13.00	
Totals	60.75	68.25	70.25	61.75
Means	10.12*	11.38	11.71	12.35

* Infants receiving active exercise walked sooner than infants in the passive-exercise group [Mann-Whitney U, $P < .025$ (*12*)].

passive-exercise and no-exercise groups declined to averages of 1.7 and 3.2 steps per minute, respectively—rates comparable to those of the 8-week control babies, who averaged one response each. It is impossible to determine from the present design whether the difference between walking and placing responses reflects the differential lengths of the exercise periods (forced, incidentally, by the tolerances of the mothers and infants), or a difference in instrumentality—that is, it may be that walking produces a greater reward than placing.

The results strongly confirm the hypothesis based on the study with a single subject. Walking among the active-exercise infants seemed to progress from a reflexive to an instrumental response. There is little doubt that learning occurred. The behavior of one 5-week-old infant, in particular, is difficult to dispute; he made vigorous walking motions while the observer suspended him in midair over the table. It is possible in his case that the sight of the table elicited classically conditioned walking, but the linear increase within the active-exercise group defies a Pavlovian explanation. Typically, the unconditioned stimulus–unconditioned response association occurs in an all-or-none manner; repetition of the unconditioned stimulus usually does not produce an increment in the unconditioned response. There is normally no increase in salivation with repeated presentations of meat powder in the dog's mouth, nor does the pupil constrict more and more with each flash of light. Similarly, the number of walking responses elicited by contact of the sole of the foot with a flat surface should remain constant. Moreover, it seems unlikely that the limited external stimulation introduced in this study would be sufficient to alter the physiological structure of a reflex programmed to disappear.

Not only were there more responses by the active-exercise infants, but they were better executed. Walking responses in the control groups were sluggish, especially around the eighth week; often the toes curled over, the feet bent to the side, and extension of the legs failed to occur. These data indicate that there is a critical period for maintaining the walking response (*6*). If stimulation occurs during the first 8 weeks the response may be retained intact; without stimulation these programmed behaviors are lost. Beyond the second month learning of walking movements is tedious, requiring greater time and effort. Retention, therefore, is efficient and even without further intervention should lead to an earlier onset of walking.

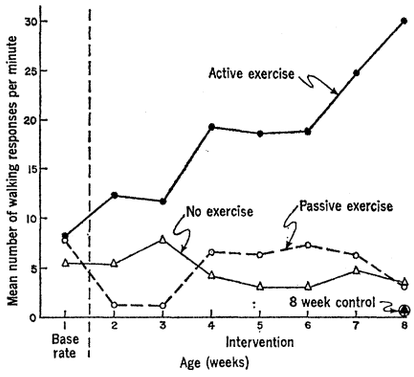

Fig. 1. Mean number of walking responses for the experimental and control groups during the first 8 weeks of life.

At the end of 8 weeks all the parents were informed of the research objectives and how they could encourage their infants' motor development during the first year, although no further supervision or training was given. Mothers reported the dates and ages at which their infants walked alone (see Table 1); the earliest walking occurred for the active infants and the latest for the 8-week controls. All the groups showed earlier independent walking than the Gesell-Thompson (*7*) norm of 14+ months, which probably reflects heightened parental interest. Because parents of infants in the active and passive groups were treated identically, however, the earlier walking by the active infants is probably attributable to the retention of the walking response in the newborn.

It is conceivable that the function of the walking reflex may be to assist the infant in developing mobility and that it should therefore be stimulated. The efficiency and adaptability characteristic of nature would be violated if these responses were programmed in the newborn only to fade with disuse. Gesell and Thompson (*8*) concluded that the development of independent walking is a complex process requiring the learning and integration of many separate abilities; the reflexive walking response is only one component in this process. Moreover, Sperry (*9*) has noted that the relation between myelination of nerve fibers and function is reciprocal; myelination seems to indicate the order in which various systems become functional, yet function stimulates and facilitates myelination. Thus, retention of the newborn walking response may facilitate development without producing immediate independent walking. If so, our widespread belief in the invariance of the motor sequence probably reflects more about our childrearing practices than about the infant's capacities.

A major benefit of retaining the walking response and encouraging early mobility may be that it promotes an earlier sense of competence (*10*). It was shown that by 4 weeks an infant learns to control his environment. Walking movements produce spatial, visual, and kinesthetic-tactile changes in his world, and these accompanying sensory changes may serve as the inherent reward that reinforces walking. Delaying the infant's opportunity to act instrumentally may result in some fading of his propensity for effectiveness, much as delaying stimulation of the walking reflex leads to fading of the walking response. The subtle forces in society that erode the self-rewarding activities underlying the infant's curiosity may begin their work during the first weeks of life.

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References and Notes

1. R. Illingworth, *The Development of the Infant and Young Child* (Williams & Wilkins, Baltimore, ed. 2, 1963), p. 138.
2. M. Shirley, *The First Two Years* (Univ. of Minnesota Press, Minneapolis, 1933), vol. 1; D. Crowell, in *Infancy and Early Childhood*, Y. Brackbill, Ed. (Free Press, New York, 1967), pp. 125–203. The only exception found was the intervention with one set of twins [see M. McGraw, *Growth: A Study of Johnny and Jimmy* (Appleton-Century, New York, 1935)].
3. N. Bayley, *Manual for the Bayley Scales of Infant Development* (Psychological Corporation, New York, 1969).
4. R. Held and A. Hein, *J. Comp. Physiol. Psychol.* **56**, 607 (1963).
5. The straightening reflex is a supportive extensor thrust of the legs that results in the body becoming straightened from its usual flexion.
6. Critical periods have been shown for the following response in birds and primary socialization in dogs [D. Freedman, I King, O. Elliott, *Science* **133**, 1016 (196 → J. P. Scott, *ibid.* **138**, 949 (1962)].
7. A. Gesell and H. Thompson, *Infant Behavior: Its Genesis and Growth* (McGraw-Hill, New York, 1934), p. 89.
8. ———, *ibid.*, p. 96.
9. R. Sperry, in *Handbook of Experimental Psychology*, S. Stevens, Ed. (Wiley, New York, 1951), pp. 236–280.
→ R. White, *Psychol. Rev.* **66**, 297 (1959).
11. S. Siegel, *Nonparametric Statistics for the Behavioral Sciences* (McGraw-Hill, New York, 1956), pp. 184–193.
12. ———, *ibid.*, pp. 116–127.
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