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Does Early Crawling Experience Affect Infants' Emerging Spatial Orientation Abilities?*

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Experience in voluntary locomotion has often been suggested as an important factor in the emergence of infants' ability to localize fixed objects or events during their movement through large-scale space. In a direct test of this suggestion, 30 infants, with either 2- or 8-weeks crawling experience, were trained to expect an event at one of two windows to their right or left. Constant landmark information was provided at the "correct" window. After training they were moved through 180° to the other side of the test room, where their view of the window positions was reversed. The differences in the crawling experience of the subjects was not associated with any differences in their use of the landmark information to search correctly on the first or subsequent test trials. It is concluded that claims about the importance of early locomotion experience for infants' development of an objective representation of space may need to be treated more cautiously at present and that more emphasis needs to be placed on the potential quality of perceptual exploration available to novice locomotors.

Almost a decade has passed since Yonas & Pick (1975) remarked that the question of what strategies infants use to orient themselves in large-scale space had hardly been investigated at all. They suggested that discrimination experiments, similar to the old place versus response experiments with rats, might be worthwhile. This suggestion was taken up in the work of Acredolo (1978), who showed initially that one could train infants from 6 months of age to look for an interesting event that occurred regularly at one particular place and then test their orientation response after their position relative to the training place had been changed by rotating them through 180°. Acredolo has used this procedure subsequently to show that the presence, salience and location of landmark information (Acredolo & Evans, 1980), and the familiarity of the infant with the testing environment, (Acredolo, 1979; 1982) can significantly influence an infant's ability to relocate an initially highly rewarding place after the infant's spatial perspective had changed. Acredolo has concluded that there is a developmental sequence from initially self-referent or egocentric spatial representation in 6-month-old infants, to predominantly object-centred or allocentric orientation behaviour in infants from about one year of age onwards. Acredolo (1978) and Bremner (1982) are two prominent reseachers who have suggested that the changes in infants' orientation abilities in large-scale space may be related to the emergence of self-locomotion capacitites after 6 months of age.

The general question of the relation between the onset of locomotion and the development of space perception in infancy has been well investigated in the area of infants' wariness of heights on visual cliffs, but has only very recently begun to be explored through the issue of spatial orientation abilities. In cliff avoidance studies Campos, Hiatt, Ramsay, Henderson and Svejda (1978) found that 7-month-old infants who had 4 or 5 weeks locomotor experience had a significantly greater change in heart rate than prelocomotor infants during descent to the deep side of the visual cliff. This finding was supported by Svejda and Schmid (1979), but Rader, Bausano and Richards (1980) and Richards and Rader (1981) found that it was the age when the infant first crawled that was the important predictor of behaviour, not crawling experience. Infants who learned to crawl before 6.5 months of age crossed the visual cliff, while those who commenced crawling after 6.5 months avoided it. However, most of the infants in these experiments of Rader and Richards had at least 30 days of self-locomotion experience before being tested. Potential effects due to their earlier weeks of locomotion experience may have escaped detection. Recently, Caplovitz-Barrett & Campos (1983) found that there was a significant increase in visual cliff avoidance between 11 and 41 days

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after the onset of crawling. In summary then, these visual cliff studies have yielded conflicting interpretation of the importance of locomotion onset, perhaps because of differences in the extent of locomotion experiences of the subjects recruited by the different investigators.

The present study set out to examine directly the hypothesis that early experiences following the onset of self-mobility would lead to a greater propensity for infants to respond objectively, than egocentrically, on the spatial orientation task used by Acredolo (1978). Infants were assessed either in the first two weeks after locomotion onset, or after two months of locomotion experience. In the time since these data were collected a completely independent test of the same hypothesis has been reported by Bertenthal, Campos and Barrett (in press). Using groups of prelocomotor and locomoting infants, matched in chronological age, they have indicated that the experienced locomotors showed greater use of objective spatial orientation responses than did the infants without locomotion experience. A more detailed comparison of our own study with that of Bertenthal et al (in press) will be made in the discussion section.

Method

Subjects

A total of 38 infants were recruited initially for the study when they were only 4 to 5 months of age. They came from white, middle-class families in Auckland. Parents of the infants were contacted before their infant could crawl. All parents were told that the purpose of the study was to see if crawling had any influence on how well babies know where they are in a room. An accurate date for crawling onset was obtained by telephoning parents, at first fortnightly, and then weekly, when their infant was close to crawling. Crawling was defined as the ability to move forward at least 2m in less than 2 minutes. This criterion was chosen because the infants could locomote actively through large-scale space by a range of methods. Creeping forward with the torso scraping the floor and crawling on hands and knees or hands and feet were the methods used by the great majority of the infants. However, two subjects who began their self-locomotion experience with the aid of infant walkers were also included in the study. Hence the term "crawling experience" is used here as a shorthand version of self-locomotion experience.

Four infants were never tested because changes in family circumstances necessitated their withdrawal before the predetermined crawling experience was achieved. Another four infants (one from the 2-week group and three from the 8-week group) were excluded, because they failed to reach the training criterion within 20 trials. The 2-week group was comprised of 5 female and 9 male infants, whose mean crawling experience was 1.79 weeks (SD =0.80) and whose mean age at testing was 36 weeks (SD = 7.25). The 8-week group was comprised of 4 female and 12 male infants, whose mean crawling experience was 8.29 weeks (SD = 0.54) and whose mean age at testing was 40.54 weeks (SD = 5.77)

Apparatus

The apparatus used was similar to that described by Acredolo (1978). All testing was done in a 2.5 x 2.5m enclosure made from four tan-coloured, opaque, vinyl curtains. The height of the curtains was 2.05m and they were hung from rods located 60cm from the ceiling of a larger, carpeted, windowless room. Strip fluorescent lights located on the ceiling were centred over the curtained area to eliminate extraneous landmark information within the test environment. In the centre of two opposite walls were two windows, each 0.25m high x 0.3m wide and covered by identical white curtains. One of the windows was surrounded by a large yellow star which served as a landmark.

Infants were strapped into an armless secretarial chair which could be swivelled 180° and easily rolled in a straight line on fixed castors. The chair was located 30cm from the middle of one of the windowless walls. A buzzer which was used to initiate the trials was located under the infant's chair. The buzzer was activated by the experimenter using one of two silent hand-held switches located behind the curtained walls near each window.

Procedure

The experimental procedure was very similar to that described by Acredolo (1978). Two noteworthy differences were the use of a more extensive familiarization period and a baseline check on any pre-training difference in the attention-getting qualities of the windows. While being carried around in the mother's arms each infant was familiarized with the room, the window, the chair movement and buzzer onset during a 5-min period, which was followed by a 20-s baseline period of silence. The entire procedure was videotaped with two cameras positioned in small holes placed in the middle of opposing walls which gave recordings of the infant's looking behaviour during the experiment. The cameras were attached to a special effects generator which enabled a continuous recording of the frontal view of each infant's head and shoulders.

After the baseline phase, the training trials were initiated by a 1 s buzzer sound followed 2 s later by the appearance of the female experimenter at the star window for approximatley 10 s. The buzzer was only sounded when the infant's head was in the midline position. For half the infants the star window was located on the left during the training trials and for the other half it was on the right.

Observations of the infants' response to the buzzer were made both by the experimenter looking through a small hole next to the star window and by an observer watching a video monitor in an adjacent room. It was possible to observe clearly the turn of the infant's eyes to look at the window from these positions. The infants could anticipate the experimenter's appearance by looking at the correct window after the buzzer, but before the experimenter actually appeared. The observer was always blind to the age and crawling experience of the infant. Training trials were continued until criterion was reached. The criterion for learning was defined as the infant correctly anticipating the experimenter's appearance on four out of five consecutive trials, excluding the first trial. The criterion decision was made by the blind observer and this was signalled to the experimenter.

After the criterion was achieved, the experimenter signalled the mother to move the chair to the opposite side of the room. The mother pushed the chair very slowly straight forward past both windows to a line 30cm out from the far wall. She then swivelled the chair so that the infant was turned initially in the direction of the star window, but finally toward the centre of the room. The mother once again stood directly behind her infant. The mother and infant remained in this position for all five test trails. The experimenter took up a new position directly opposite the infant and could view the infant's looking behaviour through a small peephole in the curtain. When the infant was looking straight ahead the buzzer was sounded for 1 s to initiate the first of five test trials. Each of the test trials was 5 s in duration and on each occasion the buzzer was sounded, but the experimenter did not appear. The observer categorized the infants response each test trial as correct, incorrect, or no response. A correct response required the infant to look in a body-related direction opposite to the one learned in training (a look to the star window). An incorrect response was recorded if the infant continued to look in the same body-related direction learned in training (a look to the blank window). Very occasionally an infant looked to both windows during the same 5-s test trial. The first response made after the buzzer was the response coded. Only two infants out of the 30 showed such mixing of responses on the first test trial.

Results

Three individuals acted as observers and the percentage of agreement between their ratings and the independently recorded judgements of the experimenter averaged 98.18% (range, 96.7% to 98.5%) for the training trials, and 99.33% (range, 99.1% to 100%) for the test trials. The baseline data were analyzed to determine whether the first window fixated after centering was related to the first window examined on the later test trials. However, the result of a McNemar test on infants who were responsive during the baseline period was not significant, $\chi^2(1, N = 27) = 1.79, p > .10$.

There were no sex differences in number of trials to criterion or test reponses and likewise no performance differences between infants who were trained to look to the left and to the right, or infants with siblings and those without. There were no differences in the trials to criterion for the two crawling-experience groups. The mean number of trials to criterion for the 2-week group was 9.00 ($SD = 3.62$) and for the 8-week group it was 9.25 ($SD = 4.82$).

The infants' responses on the test trials are presented in Table 1. The infants were categorized as responding correctly, incorrectly, or not at all, for each test trial. One infant did not respond at all. It can be seen from the results of the first test trial that there was no difference between the two crawling-experience groups. Half of the infants in each group looked toward the correct window and half toward the incorrect window. The data from all five test trials (in the parentheses of Table 1) confirm the results of the first test trial. Infants who turned to different windows over the five test trials were classified as mixed responders. A chi square analysis of these data (excluding the infant who did not respond) revealed no significant difference between groups over five trials in the distribution of response types, $\chi^2(2, N = 29) = 2.79, p = > .05$. Either consistent correct or incorrect orientation on the test trials was defined as 4 out of 5 trials

Table 1: *Numbers of Infants Making Each Category of Response for the First Test Trial*

Crawling Experience Group	Orientation Response Category			
	Incorrect	Mixed	Correct	No Response
2-week	7(2)	0(7)	7(5)	0(0)
8-week	8(6)	0(4)	7(5)	1(1)

Note: Data from all five test trials are in parentheses.

with looks in one direction. Six infants in the 2-week group and 10 in the 8-week group showed consistent orientation. Exactly half of those subjects in each experience group responded correctly and half responded incorrectly.

To determine if age was a factor influencing the reponses over the five test trials each response was assigned a numerical value. A correct response was +1, an incorrect response —1 and if there was no response a 0 was recorded. A Kendall Tau B rank correlation was performed on these transformed scores within each experience group. The results were not significant for the 2-week ($\tau = 0.297, p = .15$), or the 8-week experience group ($\tau = 0.193, p = .315$). The mean testing age for infants who responded correctly on the first test trial was 40.16 weeks and the mean for the incorrect responders was 36.84 weeks. This difference was also not significant, $t(27) = 1.31, p > .05$.

Previously, Richards and Rader (1981) found that it was crawling-onset age and not crawling experience that predicted visual-cliff avoidance in infants. The mean crawling-onset age for the 2-week experience group was 34.21 weeks (*SD* = 7.49), and for the 8-week experience group it was 32.25 weeks (*SD* = 5.67). The mean crawling-onset for all infants who responded correctly was 35.11 weeks (*SD* = 7.27) and for those who responded incorrectly was 31.56 weeks (*SD* = 5.68). This difference was not significant, $t(27) = 1.47, p > .05$. In the present study crawling-onset age was not a significant determinant of the infants' response tendencies.

Discussion

There is no support from our results for the hypothesis that early experience in self-produced locomotion is likely to enhance the development of more objective spatial orientation behaviour around 9 months of age. Of course, the negative findings do not in any way rule out the possibility that the onset of self locomotion may have *some* influence on the development of spatial representation abilities especially by the beginning of the second year. However, while further investigations of the issue are clearly necessary, it does seem reasonable to conclude that claims about the importance of early locomotion experience for the emergence of more accurate spatial orientation capacities need to be treated cautiously in the meantime.

It might be argued that the limited extent of the differences in crawling experience between the subject groups in this study makes for an insensitive test of the experimental hypothesis. However, this line of argument is countered by several factors. First, the extent of the manipulated difference in crawling experience between infant groups in this experiment was greater than that used in two recent studies of crawling experience and visual-cliff avoidance (Caplovitz & Campos, 1983; Richards & Rader, 1981). Second, marked improvements in visual cliff avoidance have been found to occur sometime between about 2 and 8 weeks after locomotion onset by other researchers (Campos et al, 1978; Caplovitz-Barrett & Campos, 1983). Third, Bertenthal et al(in press) reported that their prelocomotor subjects only needed 4 to 10 weeks experience with their walker aids in order to show a marked increase in objective responding in a situation very similar to that of the present study. Finally, if 2 weeks crawling experience was sufficient to give some infants the advantages crawling has to offer, then one would expect infants who had very minimal crawling experience (1 week or less) to respond egocentrically. A check on these infants revealed that not to be the case in this study. The same pattern of response was found as with the total sample, with two responding incorrectly and two responding correctly on their first test trial.

Bertenthal et al (in press) have used a test procedure quite similar to the present one and have reported that prelocomotor infants at 9 months of age showed incorrect ("egocentric") responses on 45% of trials. These results can be compared with our 2-week experience group who made incorrect responses on 42% of trials. Bertenthal et al (in press) stated that their experienced locomotor infants made incorrect responses on only 26%, and correct responses on the remaining 74%, of trials. These data are in contrast to our findings with the 8-week locomotor group, who showed incorrect and correct responses on 53% and 47% of trials, respectively.

How can this difference in findings be explained? There were two noteworthy differences in methodology that may have contributed to the different outcomes. First, Bertenthal et al (in press) used a more salient landmark, consisting of a striped wall and flashing lights near the target window. Acredolo and Evans (1980), who used subjects unselected for locomotion experience, found that this landmark condition resulted in none of their 9-month-old infants responding incorrectly and 80% of them responding with consistently correct orientations. Second, in contrast to our experiment, the observers in the Bertenthal et al (in press) study were not blind to the locomotion experience of subjects when coding their responses. However, a more general problem that is common to both the Bertenthal et al study and our own has become apparent since these experiments were completed and casts a cloud over the interpretation of the results. The measure of spatial orientation ability that was adopted yields responses that have potentially ambiguous meanings. McKenzie, Day and Ihsen (1984) have recently pointed out that an "egocentric" response may indicate either motor learning or the use of an egocentric spatial framework. An "objective" response may also sometimes reflect attention to an attractive peripheral stimulus. The age change reported by Acredolo (1978) may even be from "egocentric" responding at 6 months to random responding around 9 months and eventually to "objective" responding after 11 months on that particular task.

Even if these methodological issues were momentarily set aside and we were to accept that the onset of self locomotion may enhance the development of objective space perception, there remains the question of how it could increase the young infant's propensity to view position changes objectively. Bertenthal et al (in press) argue that self-produced movement is likely to facilitate infants' attention to changes in their visual world. Acredolo, Adams and Goodwyn (in press) have tried to be more specific and they suggest that there may be enhanced attention to the changes in visual perspective that result from changes in body position. They tested 12- and 18-month old infants on an orientation task that permitted either active or passive body movement and either tracking or no tracking of the target location during body movement. Although tracking of the target did tend to occur more often during active movement at 12 months of age, Acredolo et al (in press) concluded that target tracking was the crucial contributor to spatially-accurate search for 12-months-olds, not the active or passive nature of their position change. In a similar study using younger subjects, Benson (1984) did not find any reliable tendency for infants to track the target while they were moving until 11 months of age. At 9 months less than half the subjects showed any tracking at all. In our experiment too, only 11 of the 30 infants tracked the landmark window during their change in position. Four of these 11 subjects made consistently incorrect responses, 4 made correct reponses and 3 showed mixed responding over the test trials. There was no relationship between the tendency for infants to show tracking and either their crawling experience of the number of training trials that they received.

The present experiment tested whether the *sum* of active locomotion experience might influence the development of objective spatial orientation. The question of whether active locomotion *during* a test of spatial knowledge can influence the objectivity of responses is a theoretically related issue. Benson (1984) reported that self-initiated movement significantly increased the objectivity of searching for 11-month-old infants, but not for younger subjects. Thus, apart from the Berthenthal et al (in press) study, there is as yet no evidence that very early locomotion experience is associated with reliable improvements in the accuracy of spatial orientation responses. In fact, there seems to have been an overemphasis on the quantity of locomotion experience in this research area and insufficient consideration of the quality of such early perceptual motor activities.

It would seem worthwhile for some future work in this area to concentrate on the specific nature of the visual experiences afforded to infants around the onset of locomotion. The detection and discrimination of spatial location information, especially about more distant events, may not be very efficient at the onset of self locomotion, since infants may be attending more to the problems inherent in getting their bodies to move. It also seems worthwhile to remind ourselves that pre-locomotory infants, through their active eye, head, limb and torso movements, are able to obtain information about the stability of object locations despite such movements of their own. Evidence has already begun to surface that, under appropriate test conditions (McKenzie et al, 1984), pre-locomotory infants can use information gained through their looking-around systems to perceive the stability of fixed objects or events in space following transformations in their own positions. The results of the present experiment are in accord with a viewpoint that the emergence of objective spatial representation does not necessarily await the maturation of locomotion capacities.

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