DOCUMENT RESUME

ED 145 958 PS 009 642

AUTHOR Herman, James F.; Siegel, Alexander W.
TITLE The Development of Spatial Representations of Large-Scale Environments.
INSTITUTION Pittsburgh Univ., Pa. Learning Research and Development Center.
SPONS AGENCY National Inst. of Child Health and Human Development (NIH), Bethesda, Md.
PUB DATE 77
GRANT NICHHD-HD-09694
NOTE 25p.

EDRS PRICE MF-$0.83 HC-$1.67 Plus Postage.
DESCRIPTORS Age Differences; Cognitive Development; *Cognitive Processes; Elementary Education; *Elementary School Students; Measurement Instruments; *Models; *Perceptual Development; Research; Topology
IDENTIFIERS *Large Scale Environments; *Spatial Perception

ABSTRACT

This experiment investigated the effect of children's successive encounters with a large scale environment on their subsequent reconstructions of that environment. Twenty children (10 boys, 10 girls) at each of three grade levels (kindergarten, two, and five) reconstructed from memory the spatial laycut of buildings in a large model town. All children walked through the model three times. Half the children at each grade level constructed the town after each walk; the other half constructed the town only after the third walk. Accuracy of construction improved as a function of motor experience with the town (number of walks) for children at all grade levels. On the first construction, fifth graders placed buildings more accurately on both topological and Euclidean measures than did younger children. On successive constructions, age differences diminished greatly on both measures. No significant sex differences in performance were found in any of the analyses. Results are discussed in relation to previous research and theory concerning children's understanding of spatial relationships. (Author/SB)

THE DEVELOPMENT OF SPATIAL REPRESENTATIONS OF LARGE-SCALE ENVIRONMENTS

James F. Herman and Alexander W. Siegel

Learning Research and Development Center

University of Pittsburgh

1977

This research was supported by NICHHD Grant #HD-09694 to the second author, and by the Learning Research and Development Center, which is supported in part by funds from the National Institute of Education (NIE), United States Department of Health, Education, and Welfare. The opinions expressed do not necessarily reflect the position or policy of either agency, and no official endorsement should be inferred. The authors wish to thank the following individuals for their assistance in various phases of this research: Jeff Thieret for testing subjects, Robert Kail and James Pellegrino for their comments on an earlier draft of the manuscript; and the principal, teachers, and students of Saint Anselm School, Swissvale, Pennsylvania, for their cooperation.

Abstract

Twenty children at each of three grade levels (kindergarten, two, and five) reconstructed from memory the spatial layout of buildings in a large model town. All children walked through the model three times. Half the children at each grade level constructed the town after each walk; the other 10 constructed the town only after the third walk. Accuracy of construction improved as a function of motor experience (number of walks) with the town for children at all grade levels. On the first construction, fifth graders placed buildings more accurately (on both topological and Euclidean measures) than did younger children. On successive constructions, age differences diminished greatly on both measures. No significant sex differences in performance were found in any of the analyses. Results are discussed in relation to previous research and theory concerning children's understanding of spatial relationships.

THE DEVELOPMENT OF SPATIAL REPRESENTATIONS OF LARGE-SCALE ENVIRONMENTS

James F. Herman and Alexander W. Siegel

University of Pittsburgh

Thousands of children walk to and from school every day without getting lost and seem to have little difficulty finding their way around in their neighborhoods. Until recently, psychologists have made few attempts to study the development of the spatial knowledge system that is necessary for this accurate way finding in the large-scale environment. After a review of the available literature, Siegel and White (1975) hypothesized that cognitive representations of space result from the integration of percepts of the environment with movements that accompany and sequence those different percepts. In other words, with repeated walking or traveling experience in the environment, movements and percepts become increasingly integrated with one another until an accurate cognitive "map" or spatial representation is developed.

If the integration of movement and percepts is necessary for the development of spatial representations, it would seem appropriate to study this development in an environment that maximizes the opportunity for locomotor experience. Unfortunately, small scale models of the environment have been used in most of the studies on spatial representation conducted by psychologists (Laurendeau & Pinard, 1970; Piaget & Inhelder, 1967; Piaget, Inhelder, & Szeminska, 1960; Pufall & Shaw, 1973; Siegel & Schadler, in press). Large-scale environments have been utilized only infrequently (Shemyakin, 1962).

A second methodological problem in research on the development of spatial representations concerns the manner in which children convey their spatial knowledge to the experimenter, i.e., the method by which the representations are externalized. Procedures such as verbal recall (Flavell, Botkin, Fry, Wright, & Jarvis, 1968), drawing (Piaget & Inhelder, 1967), and techniques in which children encounter the environment on one scale (real world) and then are tested on another one (small scale model) (Birch & Lefford, 1968; Siegel & Schadler, in press) confound spatial knowledge with other abilities. Using these techniques, researchers have found that young (i.e., "preoperational") children rely invariably on the topological properties (e.g., proximity, inclusion, etc.) of space. It is only later (e.g., during the concrete operational period) that children have been found to utilize projective and Euclidean relationships (e.g., perspective and distance relations). However, these findings might be artifacts of the methodologies used in the studies.

These methodological problems may be reduced by requiring the child to construct his/her representation of the large environment with the actual elements in that environment on the orginal scale. Acredolo, Pick, and Olsen (1975) studied the effect of differentiated cues (i.e., distinctive objects or landmarks such as trees and chairs) on children's ability to remember the location of different events in a large-scale environment. Three-, four-, and eight-year-olds were asked to remember the location of an event in a large environment. The two younger groups of children were much less accurate than eight-year-olds in remembering the location of an event when the environment was undifferentiated, but not when landmarks were present. On the basis of these findings, Acredolo et al. argued that the younger children used only topological cues provided by the distinctive objects for locational accuracy, while eight-year-old's used Euclidean (distance) spatial relationships as well. Thus, even though Acredolo et al. had eliminated several potentially confounding factors by using a large-scale environment, young children still appeared unable to use Euclidean relationships.

However, Siegel and White's (1975) hypothesis would suggest that it is necessary to not only test the children in a large-scale environment but also to give them repeated experience with that environment, thus providing them with repeated opportunities to integrate their percepts of the environment with the movements associated with those percepts. More specifically, it is suggested that previous results regarding young children's inability to use Euclidean as opposed to topological relations might also be an artifact of giving them only limited experience with the environment.

The present experiment was designed to investigate the effect of children's successive encounters with a large-scale environment on their reconstructions of that environment. Based upon Seigel and White's (1975) hypothesis that the development of spatial representations may be facilitated by repeated walking or traveling through the environment, we predicted that: (a) increased walking (motor) experience would help children to produce more accurate constructions of the environment. This prediction also follows from Zaporozhet's (1965) "motor copy" theory of perception, which suggests that accuracy increases as a function of practical experiences and learning. With only minimal motor experience in the environment (one encounter), we predicted: (b) older children should construct the environment more accurately than younger children because they should be better able to understand and more readily use Euclidean spatial relations (Piaget & Inhelder, 1967). However, the older and younger children's accuracy should increase significantly over repeated encounters (motor experience). Finally, since only topological cues have been found to aid preoperational children in spatial representation (Laurendeau & Pinard, 1970), we predicted that: (c) younger children should have difficulty (on their initial construction) in accuracy when placing landmarks in the environment that have either ambiguous or minimal topological cues. However, as a function of successive encounters with the environment, even the youngest children should be able to place all buildings with considerable accuracy.

Method

Subjects. Ten boys and ten girls from each of three grade levels in a suburban parochial school participated in the study: Kindergarten (Mean Age = 5-7, Range = 5-3 to 6-2), Grade ~~2~~ (Mean Age = 7-7, Range = 7-2 to 8-1), and Grade 5 (Mean Age = 10-7, Range = 10-1 to 11-0).

Materials. The experiment was conducted in a large classroom in which all objects had been moved to the perimeter. The perimeter of a 4.88 x 6.10 m area on the floor (homogeneous surface) was lined with masking tape. In this area a road and railroad track were depicted with paper and black paint (see Figure 1) and divided the area into four 2.44 x 3.05 m quadrants.

Nineteen buildings, each approximately 6.35 cm in height, 11.43 cm in length, and 7.62 cm in width, were used. The buildings were highly differentiated in terms of color and shape. Each building was glued to a masonite circle (1.27 cm thick and 17.78 cm in diameter) that was covered with green felt. Eight of the buildings were located on the floor in the same positions for all children (see Figure 1). Duplicates of these eight buildings and three other "distractor" buildings (split-level house, barn, and men's store) were used.

For purposes of recording children's placements, a sheet of paper (approximately 30.48 cm wide) was placed parallel to, and outside of two adjacent edges of the 4.88 x 6.10 m area. A half-foot (15.24 cm) scale was marked on this paper with black paint. This

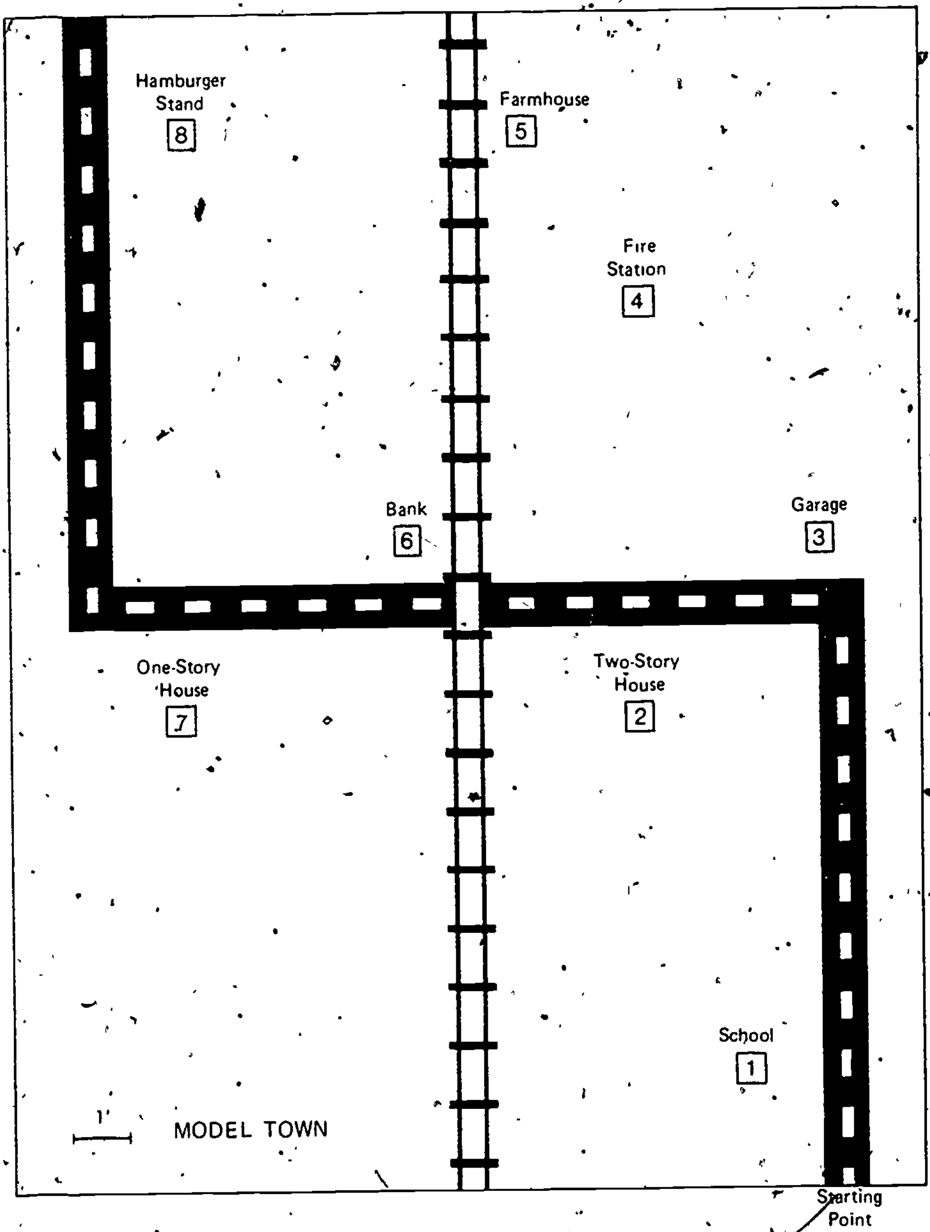

Figure 1. Schematic diagram of the layout of the model town.

scale was then covered with paper to prevent children from seeing it (and possibly using this metric scale to guide their placements).

Procedure. Five boys and five girls at each grade level were tested in one of two experimental conditions. In both conditions, children walked through the town three times (walking phase). The conditions differed in that children in the construct condition constructed the town after each walk (i. e., walk-construct, walk-construct, walk-construct), while children in the walk condition built the town only after the third walk (i. e., walk, walk, walk-construct).

Children were tested individually. Each child entered at the front of the classroom and was directed immediately (with his back to the model town) to a table where the duplicates of the eight buildings were displayed. The experimenter pointed to each building and labeled it for the child.

Walking phase. The child was taken to the starting point. He was told that what he saw on the floor was a town with buildings, a railroad track, and a road. The child was informed that he was going to take a short walk along the road and that he was to remember the locations of all the buildings in the town because he would have to build a town exactly like the one in front of him. The experimenter and the child then took a "walk" through the town. They stopped at each building along the road while the experimenter pointed to and labeled a building and told a 15-second story concerning the building. For example:

> This is the schoolhouse of the town. All of the children of this town go here to study very hard. But, as you can see, they also have a lot of fun on the playground during recess with all of those nice playground toys.

While walking between buildings, the child was able to look anywhere he chose; however, when a building was being described, the experimenter insisted that the child look at the specified building.

The buildings were encountered according to the numbered sequence in Figure 1. At the end of the walk, the experimenter and child walked along the outside edge of the area to the front of the room. The experimenter obstructed the child's view of the town by walking directly between the child and town. When the experimenter and child reached the front of the room, they sat with their backs to the model town and talked. Children in the walk condition began their second walk after 10 minutes (the average time taken by children to construct the town). Children in the construct condition went on to the building phase.

Building phase. During the 2-minute conversation between experimenter and child, an assistant removed the eight buildings from the town and arranged them and the three distractor buildings randomly on the top of a shelf near the starting point. Then the experimenter took the child to the shelf, pointed in a random order to each building, and asked the child if it had been in the town. Buildings identified correctly by the child as not in the town were placed on a ledge behind the shelf. If the child made a mistake, the experimenter would repeat the question and point to the buildings on the shelf in a different random order. All buildings that the child said were not in the town were placed on the ledge. (For children in the construct condition, this procedure was not repeated on subsequent trials if the child was successful by this second attempt.)

The child was then taken to the starting point and asked to put each of the buildings (on the shelf) in the exact place it had been when he had walked through the town previously. There was no time limit for construction. The child was permitted to place buildings that he had said originally did not belong in the town.

When the child finished, he was taken to the starting point and asked if the town looked "exactly like the one in which you and I walked through before?" If the child said "no," he was told to make the town look "exactly the same." This procedure was repeated until the child indicated that he was sure that all buildings were placed correctly. He then returned to the chairs at the front of the room to talk with the experimenter.

After the child had placed the buildings, the assistant removed the paper that covered the scale at the adjacent edges. Based on its position, each building was assigned a coordinate value on graph paper (1 inch = 1 foot). Then buildings were placed in their original positions and the scale was covered.

Results and Discussion

Topological and Euclidean measures were derived to assess the accuracy of each construction. The topological measure was designed to reflect the accuracy with which children placed the buildings in the correct quadrant of the town. For each construction, the total number of correct placements was divided by eight (the total number of placements) to yield a proportion correct.[1] The Euclidean measure was designed to determine the "goodness-of-fit" between the child's construction and the original layout. All 28 possible inter-building distances in the child's construction were calculated and compared to the 28 actual distances. Analyses were performed on *Z* transformations of the resulting Pearson product-moment correlations. Extra buildings in the construction were ignored but missing buildings were given 0 values for both measures. Generally, all children recognized accurately the buildings that belonged in the town, e.g., no child

[1] For this and subsequent dependent measures that are expressed in proportions, analyses were performed on both raw scores and arcsin-transformed scores. Since both analyses yielded identical effects, only the raw scores and analyses on them are reported.

misrecognized more than one building, and that occurred only in the first construction. All post-hoc analyses were Scheffe comparisons at the .05 level. The results are presented and discussed in terms of the three predictions presented in the introduction.

1. It was predicted that two additional walks would result in greater accuracy in children's placement of buildings. To assess this, performance after one walk in the <u>construct</u> condition was compared to performance after three walks (but the first construction) in the <u>walk</u> condition. Scores on the topological and Euclidean measures were subjected to a 3 (Grade) x 2 (Condition) x 2 (Sex) x 5 (Subjects/Cell) mixed factorial analysis of variance. The results from this analysis are presented graphically in Figure 2.

The proportion of buildings placed in the correct quadrant was greater after three walks (.96) than after only one (.73), $F\ (1,48) = 11.29$, $MSE = .02$, $p < .001$, and this proportion increased with grade level, $F\ (2, 48) = 39.26$, $MSE = .02$, $p < .001$, from kindergarten (.73) to second (.85) to fifth grade (.95). The significant Grade x Condition interaction, $F\ (2,48) = 4.04$, $MSE = .02$, $p < .05$, indicated that second and fifth graders were more accurate than kindergarteners in the <u>construct</u> condition, but there were no differences between grades in the <u>walk</u> condition.

The results for the Euclidean measure of accuracy are presented graphically in Figure 3. The "goodness-of-fit" was better after three walks (.92) than after only one (.63), $F\ (1, 48) = 76.02$, $MSE = .17$, $p < .001$, and again, this accuracy increased with grade level, $F\ (2, 48) = 21.12$, $MSE = .17$, $p < .001$. Overall, kindergarteners (.66) and second graders (.76) did not significantly differ from one another, and both were less accurate than fifth graders (.91). At each grade, children in the <u>walk</u> condition placed buildings more accurately than did children in the <u>construct</u> condition. Despite the similarity between Figures 2 and 3, the Condition x Grade interaction

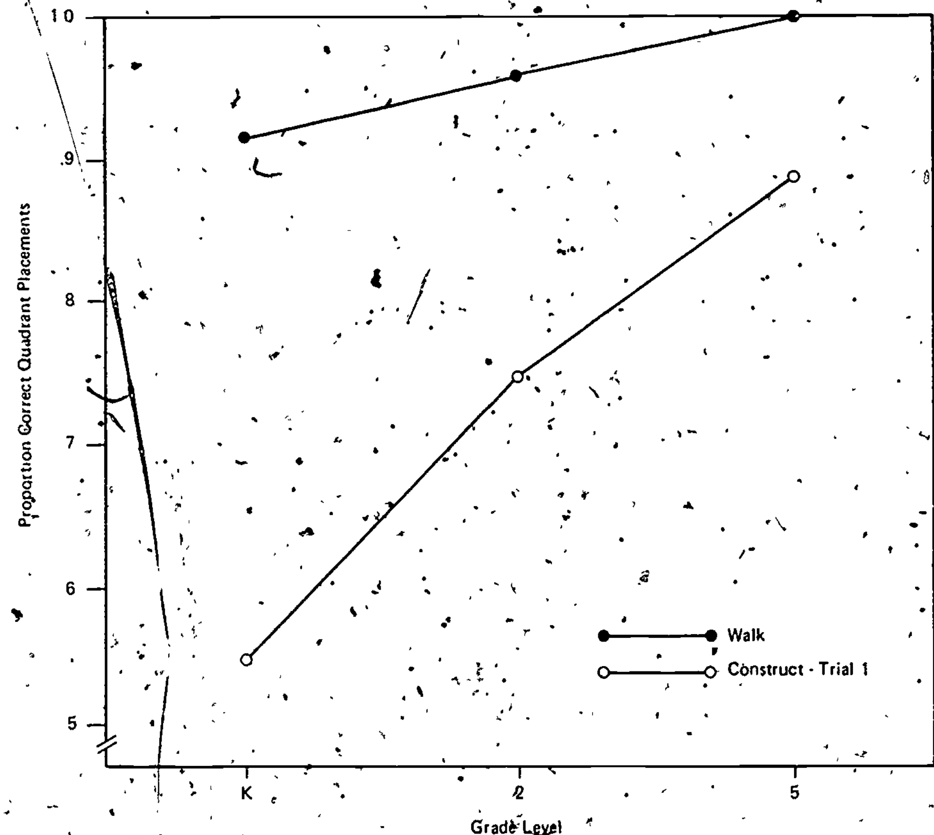

Figure 2. Proportion of correct quadrant placements after one and three walks at each grade level.

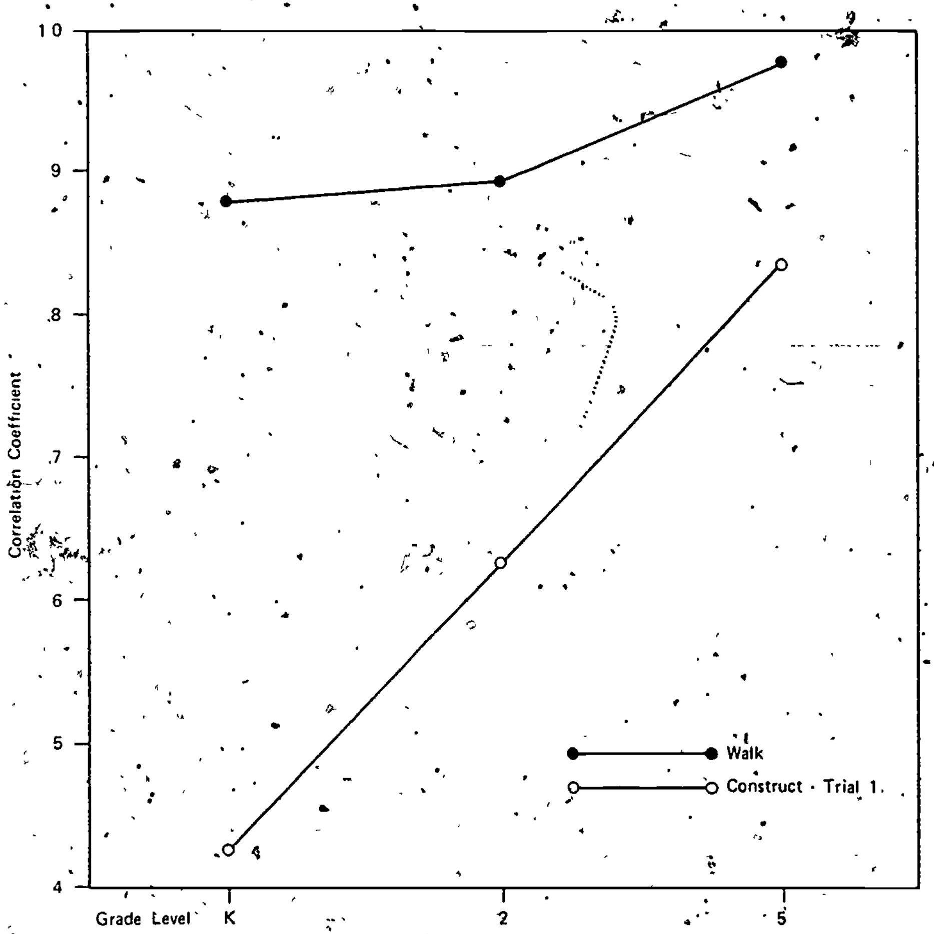

Figure 3 "Goodness-of-fit" between the original layout and the child's construction after one and three walks at each grade level.

(due to the large MSE) was not significant, F (2, 48) = 1.12, MSE = .17, p >.10, indicating that similar developmental differences in Euclidean accuracy were found in both conditions. There were no significant differences in the accuracy of boys and girls on either the topological or Euclidean measures.

As predicted, the children who had had three walks placed the buildings more accurately than children with only one walk. Thus, the experience of walking through the town helped children to improve both the topological and Euclidean accuracy of their spatial representations. Interestingly, the second and fifth graders' topological accuracy was greater than the kindergarteners' after one walk and one construction, but not after three walks and one construction. The Euclidean accuracy of the fifth graders was greater than that of the kindergarteners and second graders in both conditions. Previous researchers have indicated that preschoolers may understand topological but not Euclidean relations (Piaget & Inhelder, 1967; Pufall & Shaw, 1973; Smothergill, Hughes, Timmons, & Hutko, 1975). However, with the additional walking experience provided in this study, the topological and Euclidean accuracy of the younger children improved greatly. Thus, it appears that kindergarteners do understand Euclidean relations, but they must have additional experience in the environment in order to remember and use these relations with considerable accuracy.

2. It was predicted that the older children would place the buildings in the town more accurately than the younger children after one walk and one construction, but that the younger children's accuracy would increase over successive constructions. To test these predictions, accuracy of placement was assessed across the three constructions in the construct condition. The topological scores for each subject were subjected to a 3 (Grade) x 2 (Sex) x 5 (Subjects/Cell) x 3 (Constructions) mixed factorial analysis of variance with repeated

measures on the last factor. Only the scores on the first two constructions were analyzed, due to a ceiling effect (i.e., zero variance) on the third construction. The results from this analysis are presented graphically in Figure 4.

The proportion of buildings placed in the correct quadrant was greater on the second trial (.96) than on the first (.73), F (1, 24) = 50.99, MSE = .01, p < .001, and this proportion increased with grade level, F (2, 24) = 9.33, MSE = .02, p < .001, from kindergarten (.74) to second (.86) to fifth grade (.94). The significant Grade x Trial interaction, F (2, 24) = 5.39, MSE = .01, p < .01, indicated that on the first construction, older children were more accurate than younger children, but this superiority was absent by the second construction. On the third construction, two of the ten kindergarteners placed one building in the incorrect quadrant, but all of the second and fifth graders had perfect scores.

The Euclidean scores were subjected to a 3 (Grade) x 2 (Sex) x 5 (Subjects/Cell) x 3 (Constructions) mixed factorial analysis of variance with repeated measures on the last factor. The results from this analysis are portrayed in Figure 5. This "goodness-of-fit" measure of accuracy improved over the three constructions, F (2, 48) = 89.21, MSE = .17, p < .001, from .63 to .93 to .97. The main effect of Grade was significant, F (2, 24) = 14.31, MSE = .32, p < .001; fifth graders were more accurate (.94) than kindergarteners (.75) and second graders (.84), but the latter two did not differ significantly from one another. The Grade x Trial interaction was not significant, F < 1, indicating that there were no developmental differences in patterns of performance across the three trials on the Euclidean measure. As in the first set of analyses, there were no differences in the accuracy of boys and girls on either topological or Euclidean measures.

As predicted, the older children were more accurate than the younger children on the first construction for both the topological and

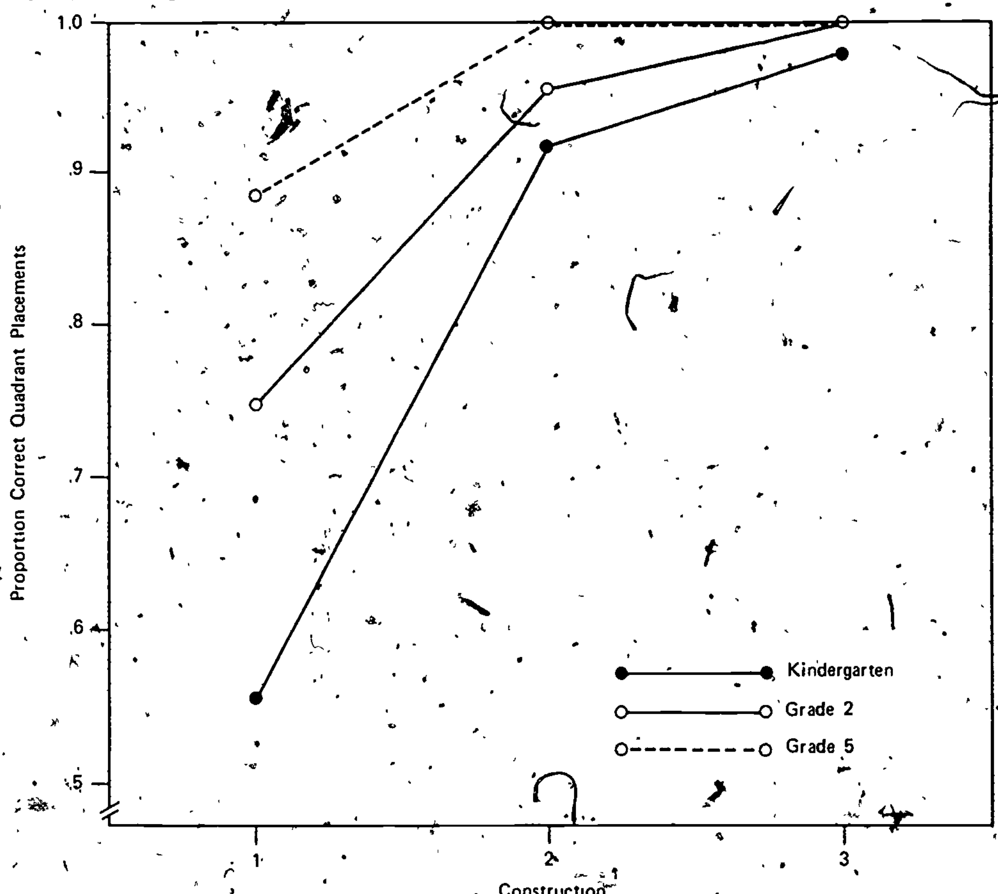

Figure 4. Proportion of correct quadrant placements after each of the three successive constructions at each grede level.

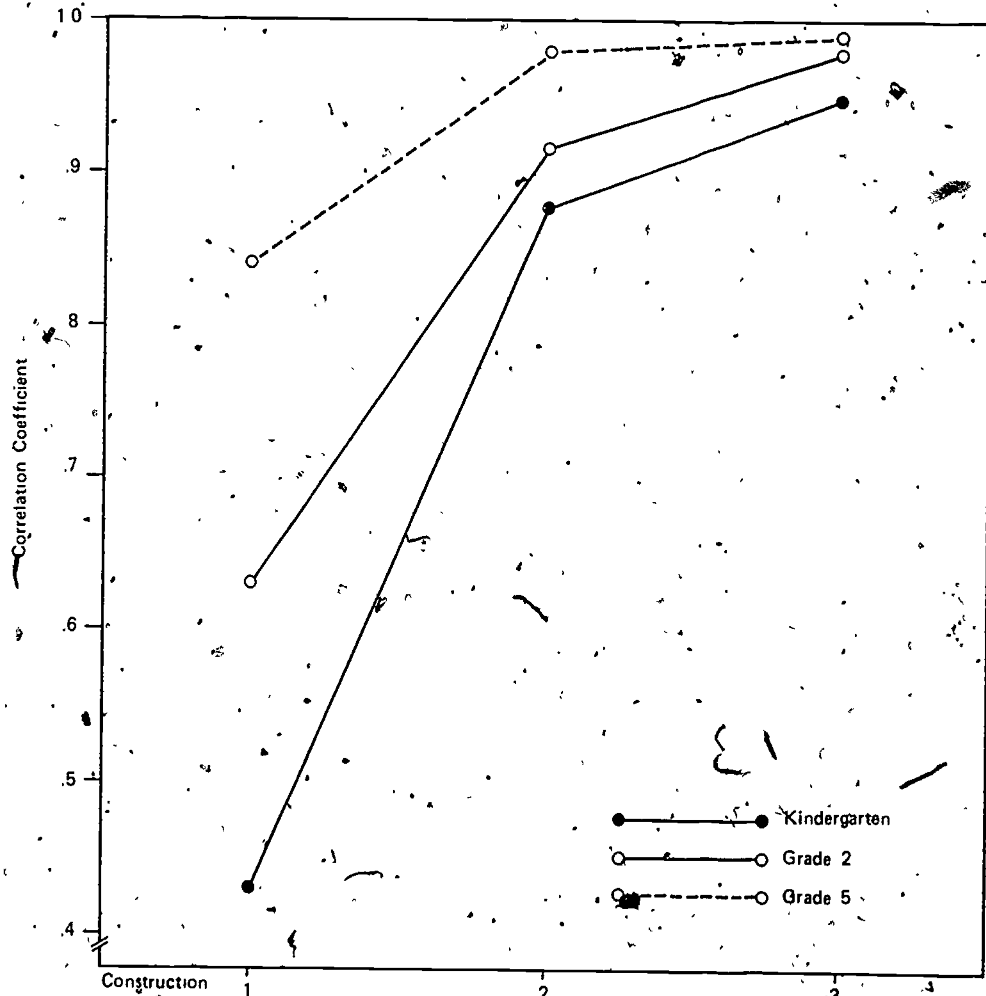

Figure 5. "Goodness-of-fit" between the original layout and the child's construction after each of the three successive walks and constructions at each level.

Euclidean measures. Children's accuracy was improved by walking and construction experience; topological accuracy was about the same for all three grade levels by the second construction, while Euclidean accuracy was equivalent for all grade levels by the third construction. Thus, children improved topological and Euclidean accuracy with repeated walking and construction experience. Since there were ceiling effects on both measures for the older children by the second construction, it was impossible to determine whether older children were increasing their accuracy over trials more rapidly than younger children.

3. It was predicted that the younger children would be less accurate than older children (on the first construction) in placing buildings in the town that had either ambiguous or few topological cues. However, over repeated trials, even the youngest children should be able to place all the buildings with considerable accuracy. To test this prediction, the eight buildings in the model town were divided into three groups: (a) buildings in definite topological positions--at the beginning or end of the road (schoolhouse, hamburger stand) and at one end of the railroad track (farmhouse); (b) buildings located at the turn of the road or at an intersection (garage, bank)--these buildings were in ambiguous topological positions because there were two turns in the road and four quadrants around the intersection; and (c) buildings isolated from most topological cues (both houses and the fire station).

The topological measure used in the previous analyses was calculated separately for each group of buildings. These scores for children in the construct condition were subjected to a 3 (Grade) x 2 (Sex) x 5 (Subjects/Cell) x 3 (Groups of Buildings) mixed factorial analysis of variance. Only the scores from the first construction were analyzed due to a ceiling effect on the second and third constructions. Only the results pertaining to the Groups of Buildings factor are presented (since the "between-subjects" effects have already been reported). As can be seen from Table 1, the building groups differed in the extent to which they were placed in the correct quadrant, $\underline{F}$ (2, 48) = 4.60, $\underline{MSE}$ = .05, $\underline{p}$ < .05. Children placed buildings with definite topological cues more accurately (.85) than those with ambiguous (.70) or few (.70) cues. On the second construction, nine of ten kindergarteners and eight of ten second graders had perfect scores on buildings with definite topological cues, while nine of ten kindergarteners and all the second graders had perfect scores on buildings with ambiguous topological cues; the fifth graders had perfect scores for all three groups of buildings. On the final construction, seven of ten kindergarteners had perfect scores on buildings with few topological cues, but the scores of all other children were perfect.

Table 1

Proportion of Correct Quadrant Building Placements (Topological Measure)

Grade		K			2			5		
Construction		1	2	3	1	2	3	1	2	3
	1	71	96	1.00	85	93	1.00	1.00	1.00	1.00
Building Group	2	39	94	1.00	80	1.00	1.00	.90	1.00	1.00
	3	56	82	83	72	97	1.00	83	1.00	1.00

Since absolute accuracy of placement was of concern only for buildings of specific types, a different Euclidean measure was derived. Buildings that were placed within one foot (in any direction) of their actual position were given a score of 1. For each construction, the total score for each group of buildings (for each child) was divided by the number of buildings in that group. These proportions for children in the construct condition were subjected to a 3 (Grade) x 2 (Sex) x 5 (Subjects/Cell) x 3 (Constructions) x 3 (Groups of Buildings) mixed factorial analysis of variance. Results are presented in Table 2. The

Table 2
Proportion of Correct Building Placements
(Euclidean Measure)

Grade		K			2			5		
Construction		1	2	3	1	2	3	1	2	3
	1	.52	74	82	68	77	.87	.90	.97	1 00
Building Group	2	.28	.72	.89	.30	.65	.90	.35	90	95
	3	11	52	.78	.30	.60	84	40	.87	97

building groups differed in the accuracy with which they were placed, F (2, 48) = 15.13, MSE = .06, $p < .001$; the Construction x Group interaction was also significant, F (4, 96) = 10.07, MSE = .04,

p. < .001. On the first construction, children placed buildings with distinct topological cues more accurately than they placed the other two types of buildings. Across constructions, children became more accurate on all types of buildings, but this improvement was particularly marked for buildings with ambiguous cues and those that were isolated. Most importantly, the Grade x Groups of Buildings and the Grade x Groups of Buildings x Construction interactions were not significant (Fs of 1.14 and < 1, respectively). That is, similar developmental differences in accuracy were found across the three constructions for the three building groups. Again, no sex differences in performance were found.

We had predicted that kindergarteners and second graders would place the buildings with ambiguous or few topological cues less accurately (relative to fifth graders) than those with definite topological cues on the first construction, we had expected that these differences in accuracy would be eliminated over subsequent trials. The prediction was only partially confirmed. In fact, all children placed buildings with definite cues more accurately on the first construction, but by the third construction, differences in accuracy (within each grade) for the three building types were insignificant. Again, it appears that children at all three grade levels are using topological and Euclidean spatial relations, and that the children's use of these relations becomes increasingly accurate over repeated experience with the town.

There is some evidence that with increasing grade level, the buildings with definite topological cues (school and hamburger stand) were increasingly being used as anchor points for remembering the other buildings in the town. Overall, the number of times the schoolhouse (at the beginning of the walk) was placed as the first building in the model town was divided by 40 (number of placements per grade in both the walk and construct conditions). The same calculation was performed for the hamburger stand (at the end of the walk). The schoolhouse was placed as the first building by the kindergarteners 41% of the time and the hamburger stand placed as the last building 8% of the time. These percentages rose dramatically to 75% and 25% for the second graders and 73% and 37% for the fifth graders.

Summary and Conclusions

Two major findings emerged from the present study. First, children appeared to develop an accurate spatial representation of a large environment simply by walking through that environment. Second, after repeated experience in the environment, the topological accuracy of the younger children was equivalent to that of the older children, and their Euclidean accuracy was only slightly less. The high level of Euclidean accuracy that the kindergarteners attained by the third construction indicates that they do have a working knowledge of Euclidean spatial relations. This latter finding is in contrast to those studies (e.g., Acredolo et al., 1975; Piaget & Inhelder, 1967) in which preschool children have been found to be unable to deal with Euclidean notions of space. This discrepancy in results might well be attributed to the fact that children in these studies were not given opportunity to repeatedly integrate movement with percepts in a large-scale environment.

There were no significant sex differences in performance in any of the analyses. Interestingly, Siegel and Schadler (in press) found that boys were more accurate than girls in constructing a model of their kindergarten classroom. However, the children's representation of the classroom was tested on a small table-top model. Thus, boys may not have had more accurate spatial representations than girls, but boys might be better able than girls to use the table-top model as a means to convey their spatial knowledge to the experimenter.

In this study, we attempted to simulate the real-world environment. It can be inferred that allowing the child to walk through the town and integrate his movements and perceptions during each walk enabled the child to construct accurate cognitive representations of the town. However, the experimental setup provided a parallel to, rather than a simulation of, the "real world." The children were like giants in a miniature world. Large areas of the model town could be perceived with just one glance, whereas in the real world, many parts of the environment are occluded by other buildings, hills, trees, etc. Thus, to construct a "cognitive map," children and adults must typically integrate a greater number of percepts over time and make many more inferences related to the position of objects or place. Despite these differences, however, the current methodology required children to use the fundamental processes involved in the development of spatial representations. Further research is currently being conducted to specify the boundary conditions of various kinds of experience and environmental features that influence the development of cognitive representations of large-scale space.

References

Acredolo, L. P., Pick, H. L., & Olsen, M. G. Environmental differentiation and familiarity as determinants of children's memory for spatial location. Developmental Psychology, 1975, 11, 495-501.

Birch, H. G., & Lefford, A. Intersensory development in children. Monographs of the Society for Research in Child Development, 1963, 28(5, Whole No. 89).

Flavell, J. H., Botkin, P. T., Fry, C. L., Wright, J. W., & Jarvis, P. E. The development of role-taking and communication skills in children. New York: Wiley, 1968.

Laurendeau, M., & Pinard, A. The development of the concept of space in the child. New York: International Universities Press, 1970.

Piaget, J., & Inhelder, B. The child's conception of space. New York: Norton, 1967.

Piaget, J., Inhelder, B., & Szeminska, A. The child's conception of geometry. New York: Basic Books, 1960.

Pufall, P. B., & Shaw, R. E. Analysis of the development of children's spatial reference systems. Cognitive Psychology, 1973, 5, 151-175.

Shemyakin, F. N. Orientation in space. In B. C. Ananyev et al. (Eds.), Psychological science in the USSR (Vol. 1, Pt. 1). U. S. Office of Technical Reports (#11466), 1962.

Siegel, A. W., & Schadler, M. Young children's cognitive maps of their classroom. Child Development, in press.

Siegel, A. W., & White, S. H. The development of spatial representations of large-scale environments. In H. W. Reese (Ed.), Advances in child development and behavior (Vol. 10). New York: Academic Press, 1975.

Smothergill, D. W., Hughes, F. P., Timmons, S. A., & Hutko, P. Spatial visualizing in children. Developmental Psychology, 1975, 11, 4-13.

Zaporozhets, A. V. The development of perception in the preschool child. In P. H. Mussen (Ed.), European research in cognitive development. Monographs of the Society for Research in Child Development, 1965, 30(Whole No. 100), 82-101.