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Way Finding and Cognitive Mapping in Large-Scale Environments: A Test of a Developmental Model

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First, fourth, and seventh graders (7, 10, and 13 years of age, respectively) were given a series of tasks to assess their spatial competency in and their cognitive mapping of their school campus. Measures of way-finding, landmark, route, and configurational knowledge were obtained and analyzed to (1) assess way-finding skills in the same environment as that in which their cognitive representations were inferred and assessed; (2) determine the validity of the hierarchical model of cognitive mapping development proposed by Siegel and White by examining individual children's performance patterns as well as between-group performance; and (3) investigate the relationship between grade level and familiarity within an environment where familiarity within subsets of the environment varied by grade. Subjects were asked to create and walk three novel and efficient routes, to select photographs of scenes belonging to the three routes, to correctly order and metrically relate those scenes, and to make bearing and distance estimates from four sighting locations to six targets within the environment. Results indicated that all children were extremely competent way finders. Guttman scale analysis revealed that 93% of all children exhibited performance patterns predicted by the proposed model. Further support of the model was found in grade level differences on cognitive mapping measures. Reversals in the developmental trend were found, however, on some portions of the route and configuration measures, and were significantly related to degree of familiarity within the environment.

In the last decade, the field of developmental psychology has witnessed the inception and growth of a research enterprise concerned with the development of cognitive representations of large-scale space. A considerable amount of the research conducted in the past 5 years has been focused on a model of development of cognitive mapping proposed by

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Siegel and White (1975). In this model, it is proposed that the development of spatial representations of large-scale space is composed of four components and is cumulative and hierarchical: landmarks are first recognized and remembered; acting in the context of these landmarks, children (or adults) construct routes along which these landmarks are first ordered and later organized according to their metric interrelationships. With additional experience and/or the development of higher-order cognitive skills (e.g., perspective taking), it is proposed that multiple routes are organized into configurations, that is, coordinated representations that can be used flexibly for environmental navigating and for other forms of spatial and nonspatial problem solving.

Using a variety of research methods, a number of researchers have found evidence of developmental differences in these component processes supportive of Siegel and White's (1975) model (Allen, Kirasic, Siegel, & Herman, 1979; Cohen & Schuepfer, 1980; Curtis, Siegel, & Furlong, 1981; Hazen, Lockman, & Pick, 1978). Allen et al. (1979) simulated a walk through an urban area with a slide presentation to children and adults to assess developmental differences in the types of landmarks subjects selected to help them remember the route. They found that adults were more likely to choose scenes that portrayed actual or potential changes in heading, defined as "critical areas of high landmark potential" (Carr & Schissler, 1969; Lynch, 1960). In the same study a separate group of adults and children from the same grade levels viewed the simulated walk and then ranked the distances among the scenes previously selected either by adults or their peers. Allen et al. (1979) found that distances among the high-landmark-potential scenes were judged more accurately than those among the low-landmark-potential scenes, suggesting that the ability to select useful landmarks may precede the development of accurate route knowledge. Cohen and Schuepfer (1980) also used slide presentations to simulate a configuration of hallways and found that landmarks were central to second graders' knowledge of the simulated environment, that sixth graders exhibited relatively well-formed route knowledge of the environment, but that only the adult subjects were able to successfully coordinate route knowledge into an accurate configuration. Hazen et al. (1978) gave children repeated walks through a playhouse and found that young children's spatial representations were routelike and poorly integrated in comparison with those of older children. Curtis et al. (1981) assessed children's configurational knowledge using a technique which combines distance and bearing estimates and found a significant increase in accuracy of configurational knowledge with age.

Although the results of these investigations support the proposed developmental differences in various components of the model, this research has not assessed each and all of the component processes in the same children. If the development of cognitive mapping follows the proposed sequence from landmark to route ordering and metric organization, to configurational representations, each child's performance on measures of these components should conform to one of a few, specifiable patterns, independent of the age of the child. This study attempted to assess the validity of the hierarchical sequence of components of the proposed model by assessing first, fourth, and seventh graders' landmark, route (ordering and metric), and configurational knowledge of their school campus and determining the extent to which their individual performance patterns conformed to the patterns predicted by the Siegel and White (1975) model.

In most cognitive mapping research, children's cognitive mapping competence is inferred on the basis of some externalized product, which is, in effect, a second-order re-representation of spatial experience (Siegel, 1981). Much of this literature has involved the development of procedures to externalize for study and analysis the subject's internal representation. As pointed out by many researchers (Acredolo, 1977; Cohen & Schuepfer, 1980; Hardwick, McIntyre, & Pick, 1976; Herman & Siegel, 1978), both the scale of the space being investigated and the type of externalization procedures used to infer the spatial representation significantly affect the assessment of performance. Procedures which require the translation of large-scale space to small-scale space, such as sketch maps (Piaget, Inhelder, & Szeminska, 1960) or table-top models (Piaget et al., 1960); Siegel & Schadler, 1977) confound congitive mapping abilities with the praxic or representational skills required by the procedures. Recently, Kirasic, Siegel, Allen, Curtis, & Furlong (Note 1) found evidence that even the use of multidimensional scaling procedures, which require only ordinal distance rankings on the part of the subjects, tends to underestimate adults' knowledge of landmarks and their interrelationships when compared to direct distance and bearing estimates.

Complicating the methodological issues involved with inferring and assessing internal representations is the apparent conflict of conventional wisdom and our own everyday observations regarding young children's spatial knowledge and their spatial competence. The results of age-group differences on cognitive mapping measures seem to indicate that young children are spatially incompetent, egocentric or lacking Euclidean concepts or even route-like knowledge (Cohen & Schuepfer, 1980; Piaget et al., 1960). Yet conventional wisdom suggests that young children are spatially competent in the sense that they are rather skilled way finders in their own neighborhoods by the age of four and can quite easily get to school and back home by the age of six. To date, no research has been conducted that assesses children's environmental way-finding competence in the same environment in which their cognitive mapping competence is formally inferred and assessed. A second major purpose of the present study was to assess spatial behavior within, and spatial knowledge of, the same large-scale environment.

A final issue in the literature centers on the role of environmental familiarity in the development of spatial representations. Since age of the subjects and experience within the environment are unavoidably confounded in the majority of naturalistic studies looking at cognitive mapping development, the relative effects of each have only been speculative (Anooshian & Young, 1981). The school campus selected for this study offered an unusual opportunity to assess cognitive mapping differences in three age groups with three unique levels of experience within sections of the campus. Therefore in the present study, it was of interest to compare the relative effects of age and degree of experience within the environment on each of the component measures of the proposed model (Siegel & White, 1975).

METHODS

Subjects

The subjects were 40 children attending a large private school in Houston, Texas: 16 first graders (mean chronological age (CA) 7;4, range 6;9–7;8), 12 fourth graders (mean CA 10;3, range 9;8–10;7), and 12 seventh graders (mean CA 13;5, range 12;9–13;10). At each grade level, the number of boys and girls tested was approximately equal.

Material and Apparatus

A 21.6 × 55.9-cm reduction of the architectural blueprint of the campus was used by the experimenter to mark the path traveled by the child and experimenter during the way-finding task. The blueprint was not visible to the child at any time.

Photographs (8.8 × 13.2 cm) of the buildings and scenes visible along each route were used to assess landmark and route knowledge. The photographs were taken from a height of 1.4 m and from the perspective of one facing forward while moving along each route in the direction specified and traveled. Additional photographs of environmental features which were located near but not along each route were used as decoys in the landmark task. All photographs were mounted on cardboard stands so they could be placed vertically on a table top in front of the child.

Configuration bearing estimates were obtained using a 36-cm black acrylic arrow mounted on a 35.5-cm (diameter) circular particle board compass, with 1° increments marked on the underside not visible to the child. Both pointer and compass were mounted on a tripod which allowed the pointer to be moved 360° about its axis. The child's bearing estimate was read from the underside of the compass with a hand-held mirror.

Configuration distance estimates were obtained with a 19 (wide) × 50 (long) × 9-cm (high) plywood box constructed with a metal lever and handle running along a center slot in the top of the box and extending its length. When moved along this 1 × 40-cm slot, the lever connected with an electrical current supplied by a detachable 6-volt lantern battery, and lighted one of a series of 20 lights (unnumbered) which were spaced approximately 1 cm apart alongside the slot. The child's distance estimate was taken to be the number of the light (from 1 to 20) at which the child positioned the lever.

Spatial Layout of the School

The campus was selected for its large size and number of buildings, which offered a variety of landmarks, routes, and bearing degrees and distances for the configuration tasks. A diagram of the physical layout of the school is presented in Fig. 1, which indicates the positions of landmarks, routes, sighting locations, and targets. The school was divided into two approximately equal sides by a major urban thoroughfare. School traffic flowed from one side to the other via a tunnel which ran under this street. Because of this arrangement, each task was constructed to contain elements from each side in roughly equal proportions. For example, the routes used for the way-finding, landmark, and route tasks included one route contained entirely within each side and one route which included parts of both sides and the tunnel crossing. Four sighting locations (SLs) were chosen with two in each of the north and south sides of campus. There were six targets (Ts), three on each side of the campus. Each of the targets were features along the routes in the other tasks but were not visible from any of the four SLs.

Of particular importance was the degree of experience each grade level had within the environment at the time of testing. All children had at least limited experience within both the north and south sides of the campus: Each grade attended gym and assemblies on the south side and all went to lunch and chapel on the north side of campus. However, the extent of their activities, and thus their experience, varied by grade according to which side of the campus contained their classrooms and major activities. The first graders' classrooms and all other activities except those noted above were located within the south side during the entire academic year; the seventh graders were located in the north side during the entire year; and the fourth graders were located within the north side during the fall term and within the south side in new classrooms during the spring term (at the end of which data were collected).

Procedure

Way finding. Each child was tested individually and testing began at the same point for each child (see Fig. 1). From that position, the child was told "I want you to take me to "x" the quickest or shortest way that you know how to go. I'll be walking a little behind you so that you

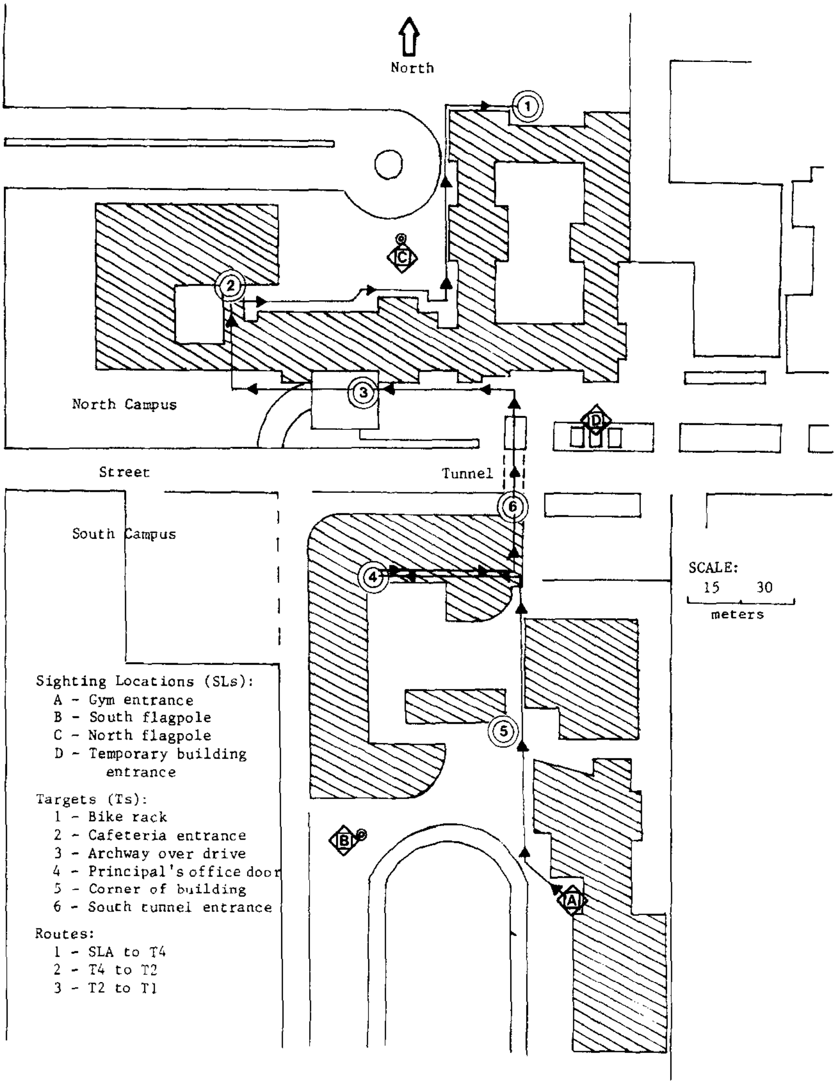

FIG. 1. Modified reduction of campus blueprint illustrating the three walks/routes used in the way-finding, landmark, and route tasks, and the four sighting locations and six targets used in the configuration tasks.

can be the guide." This walk formed the first of three routes; from that endpoint the instructions were repeated for the next two routes. The routes were novel to the child in the sense that the children did not typically take these routes during their school day activities. The child was instructed that if s/he thought there were several ways to reach the destination, take what s/he thought was the most direct way. The mean length of the three routes was 171.5 m; (Route 1 = 131.2 m, Route 2

= 229.7 m, and Route 3 = 153.6 m). Each child received the way-finding task first. Following this, (a) the landmark and two route tasks which were administered indoors, and (b) the configuration tasks which were administered out of doors, were counterbalanced by grade.

Landmark. Each child was seated at a large table in the testing room and shown eight photographs for each of the routes traveled in the way-finding task. The order of the routes presented was randomly determined. For each route there were five photographs depicting buildings and scenes visible along that route and three decoy photographs of buildings and scenes near the route but not directly visible from any point along the route. All eight photographs were presented simultaneously in a random spatial arrangement in front of the child and s/he was told "Here are some pictures of buildings and scenes on your campus. I want you to pick out the ones you would see if you were walking from "x' to "y." If there are any pictures of things which you think you wouldn't see on this walk, put them over here" (indicating). These instructions were repeated for each of the two remaining routes.

Route ordering. The experimenter placed the five photographs of the landmarks which correctly belonged to a particular route (with the order of the route presentation again randomly determined) before the child. The child was asked to correctly order the photographs: "Here are the pictures of the buildings and things you would actually see if you were walking from "x" to "y." Now I want you to put these pictures in the order in which you would see them on this walk." The directions were repeated for the remaining two routes.

Route scaling. After the child had ordered each route to his/her satisfaction, the experimenter removed the photographs and placed them in front of the child in their correct order, one route at a time. Also placed on the table at this time was a 3.8 (wide) × 81.3-cm (long) strip of paper running the length of the table so that one end was directly in front of the child and the other end at the side opposite the child. The child was then told that the photographs were now in the correct order for that route, going from "x" to "y" and was asked to line them up along the strip of paper,one behind the other, according to their real-world distances: "I want you to put each of these pictures on this strip of paper as far apart as they would be if you were really small and were actually walking along this strip of paper. If you would walk just a little ways between the building in this picture (pointing to one of the photographs) and this building (indicating the next one), you would put this picture just behind this first one. But if you would walk a long ways between the scenes in these two pictures, you would place them further apart." The end of the strip of paper closest to the child was designated as starting point "x" of the route. Occasionally, the instructions were repeated with modifications if the child indicated that s/he did not understand the task. This was necessary only with a few of the younger children.

Configuration. Familiarization with the targets used in the configuration tasks occurred during the way-finding task. As the child walked the experimenter from place to place within the campus, the experimenter pointed out the targets, saying, "Later I am going to ask you where the (T) is. I will be thinking of this/these (T) right here." The experimenter touched the spot, making sure the child was paying attention, and gave a verbal label and description of the spot, for example, "this door right here to the principal's office."

Pretraining was given at the first sighting location (the order of SLs was randomly determined). For each SL, two pretraining targets had been selected, one of which was visible and one which was not. The child was instructed first to point the arrow on the tripod directly to where the visible target was and second to the occluded practice target. Additional instructions and practice were given if the child's response was grossly inaccurate on either target. This was only necessary for a few children. Next the child was given practice with the distance estimation apparatus. S/he was told that pushing the lever to the first light indicated that two objects were very close to each other, as close as s/he and the experimenter were when the experimenter was standing "here" (one yard away), and that pushing the lever all the way to the end light indicated that the two objects were as far apart as the two furthest objects (designated) on campus were apart. The experimenter then gave the child distance estimate practice using the same two practice targets, making sure that the child understood that his or her estimates were based on straight-line or crow-fly distances and not actual walking distances. Testing began when the experimenter was satisfied that the child understood both tasks, usually requiring less than 5 min.

Testing. Each child was randomly assigned to one of eight orders of the four SLs. (Due to time and distance constraints, two SLs on one side were always visited before crossing to the other side of campus and the remaining two SLs, reducing the possible order of SLs from 24 to 8.) Targets were specified randomly for each child at each SL. For each target, the child was asked to point the arrow (set at due north) to where s/he thought the target was and to move the lever to the light that indicated how far away the target was from where s/he was standing. For each child the bearing estimate was recorded in degrees (from north) and the distance estimate recorded as the number of the light adjacent to the final position of the lever. A typical experimental session took approximately 50 min.

Dependent Measures

1. Way-finding task. The average deviation in meters between the three routes walked and the correct routes were computed for each child.

Since the instructions were to take the most direct route, negative deviations, that is, shortcuts from the sidewalk paths, were not counted as errors. Errors were computed if a wrong direction was taken (even if self-corrected) or when a less-than-direct route was taken.

2. *Landmark task.* Accuracy of landmark selection was computed for each route as the percentage of correct identifications of landmarks and decoys for that route. The average percentage of correct responses for the three routes was also computed.

3. *Route-ordering task.* The degree of agreement between the child's ordering of photographs of each route and the correct order for that route was determined by a nonparametric correlation, Kendall's tau. A mean score was also obtained for the three routes for each child.

4. *Route-scaling task.* The accuracy of subjects' placement of photographs relative to their real-world distance was computed as the log of the ratio of estimated to actual distance and averaged across landmarks for each route. This measure has been used successfully by other researchers (Cohen, Baldwin, & Sherman, 1978) to accomplish two purposes: first, the ratio allows for the comparison of intervals of different distances, and second, the log score places over- and underestimates on the same scale. A mean score was also computed for each route.

5. *Configuration.* (a) *Bearing estimates.* The accuracy of bearing estimates was computed as the absolute deviation (in degrees) between the estimated and the actual bearing for each of the six targets from each of the four SLs made by each child. Mean deviations were computed for SL–target locations and a grand mean was also obtained.

(b) *Distance estimates.* Nonparametric correlations (Spearman's rho) were computed between each child's estimated distance and the actual straight-line distances.

RESULTS

Multivariate analyses of variance were performed on the dependent measures to assess the relative effects of grade and familiarity. Since trend analyses have been found to be more satisfactory than overall F analyses for detecting developmental differences when several age groups are present (Hale, 1977), planned trend analyses were performed on the dependent measures to assess grade differences. Preliminary univariate analyses revealed that there were no significant effects for sex, task order, or order of SLs on any measure. These were thus eliminated as variables in subsequent analyses.

The multivariate approach was used to assess the effects of grade and familiarity on performance on all dependent measures except way finding and configuration distance.[1] This test has been recommended for

[1] Way-finding performance was not subjected to a multivariate analysis of repeated measures due to the extremely small number of errors in the total sample. Spearman's rho

use with split-plot or repeated measures designs because it makes no assumptions concerning within group variance–covariance structure (see McCall & Appelbaum, 1973). This procedure analyzes variables created by an orthogonal set of difference contrasts and yields the main effect of the between subject factor (grade), the within subject factor (location) and their interaction.

Three analyses are of interest: (1) performance on the way-finding task; (2) trend analyses and multivariate analyses of variance assessing grade and familiarity differences on the landmark, route ordering and scaling, and configuration tasks; and (3) Guttman scale analysis of the individual subjects' performance patterns on each of the component measures.

Way-Finding Performance

Virtually all children at all grade levels performed without error on the way-finding task. Fourth and seventh graders performed perfectly ($\bar{X}$ = .00, SD = .00). Only three of the 16 first graders' performance was less than perfect and the mean deviation was very near 0 ($\bar{X}$ = 2.97 m of the averaged 171.5 m walk, a deviation of less than 2%). Thus any differences in the cognitive mapping component measures cannot be attributed to grade related differences in way-finding skills. All children in this study were competent way finders.

Landmark Task Performance

Trend analysis of the mean percentage of correct identifications revealed that accuracy increased significantly with grade level ($F_{linear}(1, 37) = 34.2$, $p < .001$). Each group performed quite accurately, with first graders on the average correctly identifying seven of eight photographs ($\bar{X}$ = .87), and fourth and seventh graders responding nearly perfectly ($\bar{X}$ = .98 for both). Multivariate analyses revealed no significant effects due to route location ($F(2, 36) = 2.7$, $p < .08$), nor was there any interaction between grade and location ($F(4, 72) = .98$, $p < .42$).

Visual inspection of a scatterplot of errors made on each photograph by each grade level revealed that not all photographs were equally well identified as landmarks or as decoys. In particular, one decoy photograph on Route 1 was incorrectly selected by almost half of the first graders (44%) and, in comparison, by only 8% of the older two groups. This photograph depicted the playground area in which the younger group frequently played. During the task, many of these children were overheard saying "if you stuck your neck out real far, or looked around the corner, you would see this." In actuality, the scene was about 7 m away and

correlations were computed for all 24 estimates at once and thus did not permit disaggregation by SL and target location.

not visible at any point along the route. While children appeared to understand the instructions to only include those scenes *directly* visible from the route, their previous experiences within the environment may have been more powerful in some instances than the immediate task instructions, especially in the case of the younger grade level. Similar errors occurred for photographs along other routes but to a lesser extent.

Route-Order Task Performance

Trend analysis of mean tau coefficients also indicated that while each grade performed quite accurately, accuracy significantly increased with grade level ($F_{linear}(1, 37) = 7.00$, $p < .01$). The fourth and seventh graders ($\bar{X}$'s = .99) again made nearly perfect responses and first graders were also quite accurate in their responses ($\bar{X} = .93$). As in the landmark task, multivariate analyses revealed no significant effects of route location on performance ($F(2, 36) = 1.63$, $p < .21$) nor was there a significant interaction between the two factors, $F(4, 72) = .64$, $p < .63$).

Route-Scaling Task Performance

Analyses of the route-scaling scores yielded a different pattern of results. There was no significant main effect for grade level on performance ($F(2, 37) = 2.2$, $p < .13$). Multivariate analyses revealed a significant main effect of route location ($F(2, 36) = 4.8$, $p < .01$) as well as a significant interaction of grade and location ($F(4, 72) = 4.0$, $p < .005$). These results are displayed in Fig. 2. To assess grade differences for each route, post hoc analyses were performed by dividing the alpha level by the number of tests (as recommended by Hale, 1977), which in this case resulted in an alpha level of .017. Route 1, which was located entirely within the south side of campus and was relatively unfamiliar to the oldest group, revealed a significant *negative* linear relationship between grade level and accuracy ($F_{linear}(1, 37) = 9.03$, $p < .005$). Seventh graders made less accurate estimates (.32) than either fourth (.21) or first graders (.22). There was no significant grade effect for Route 2, which encompassed both sides of the campus. For Route 3, there was a significant positive linear trend with accuracy increasing by grade level ($F_{linear}(1, 37) = 7.43$, $p < .01$). Seventh graders were more accurate (.24) than fourth (.29) and first graders (.32), when route metric estimates were made within the side of campus in which they had extensive experience, in which fourth graders had previous experience, and in which first graders had only limited experience.

Configuration-Bearing Task Performance

In addition to overall grade related differences, there were two questions of interest regarding performance on the configuration-bearing task: (1) whether there were differences between sightings made entirely within

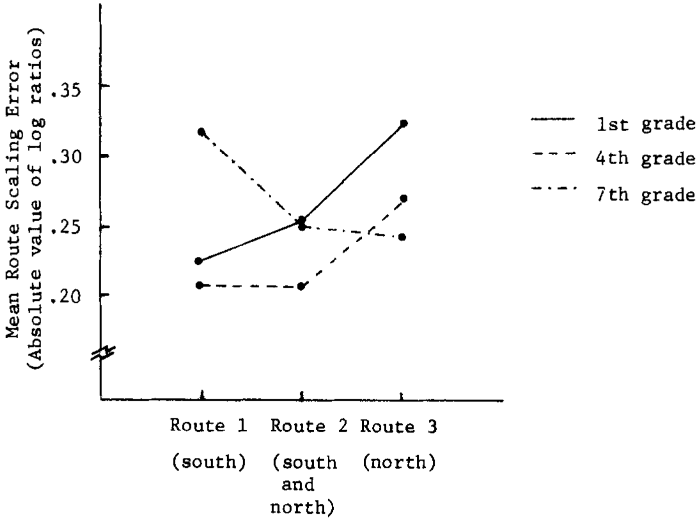

FIG. 2. Mean route-scaling scores (log ratios) as a function of grade and route location.

either side of the campus versus those made across the street "barrier" from one side of campus to the other (see Kosslyn, Pick, & Fariello, 1974); and (2) whether degree of experience within the two sides of the campus affected performance. Deviation scores (in degrees) of estimated bearing from actual bearing from each SL to each target were thus grouped into four mean categories: south SLs to south targets (S—s), north SLs to north targets (N—n), south SLs to north targets (S—n), and north SLs to south targets (N—s). Each of the four means included was based on six bearing estimates.

Multivariate analysis of variance on these four measures revealed a significant main effect for grade ($F(2, 37) = 4.82$, $p < .014$), but more importantly, a significant interaction of grade and SL–target location ($F(6, 70) = 2.49$, $p < .03$). There was no significant main effect of location ($F(3, 35) = 1.6$, $p < .20$). These results are presented in Fig. 3.

Post hoc analyses were performed on each of the four SL–target conditions to assess grade differences at each location, with alpha again divided by the number of tests ($\alpha = .0125$). When bearing estimates were made entirely within the south side of campus (S—s), accuracy increased significantly with grade level, $F_{\text{linear}}(1, 37) = 9.94$, $p < .003$. In spite of the fact that seventh graders had only limited experience within that area, their estimates were more accurate ($\bar{X} = 16.6°$) than either fourth ($\bar{X} = 19.3°$) or first grade estimates ($\bar{X} = 29.1°$). When estimates were made entirely within the north side of campus (N—n), accuracy was positively but not significantly related to grade level

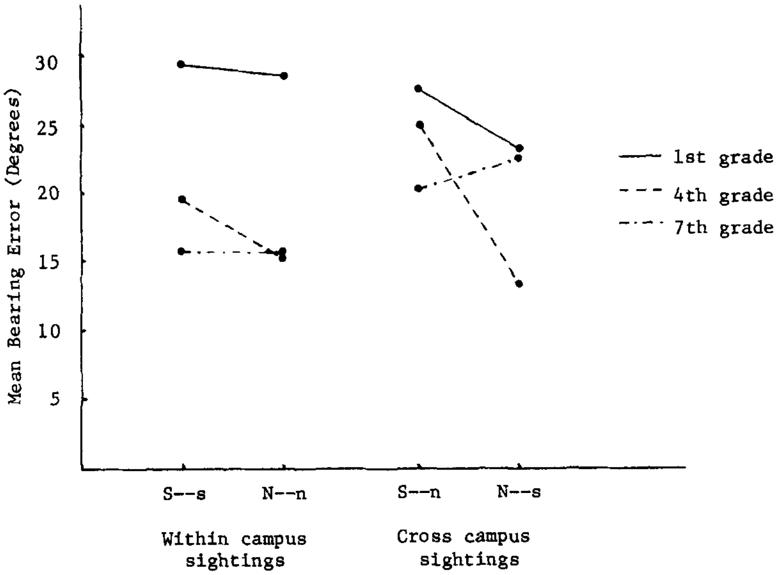

FIG. 3. Mean deviations of bearing estimates as a function of grade and sighting location—target positions.

($F_{\text{linear}}(1, 37) = 4.4$, $p < .04$). Seventh ($\bar{X} = 15.9°$) and fourth graders ($\bar{X} = 15.1°$) performed only slightly differently and first graders made an average 28.5° bearing estimate error.

In contrast to the two within-campus SL—target location categories where positive linear relationships were found between grade and accuracy, analyses of deviation scores in the two cross-campus conditions revealed a different pattern of results. In the S—n condition, the accuracy of estimates from south SLs to north targets also were positively but not significantly related to grade level, ($F_{\text{linear}}(1, 37) = 4.9$, $p < .05$), with seventh, fourth, and first graders averaging deviations of 20, 25, and 28°, respectively. However, there was no linear trend for performance in the N—s condition ($F_{\text{linear}}(1, 37) = .08$; $F_{\text{nonlinear}}(1, 37) = 4.4$, $p < .04$). Seventh graders ($\bar{X} = 22°$) averaged nearly the same amount of error in their estimates as did first graders ($\bar{X} = 23°$), when estimates were made from the more to the less familiar side of campus, while fourth graders made an average 13° error in bearing estimates in this condition.

Configuration-Distance Task Performance

The test of linear trend on the rho coefficients indicated a significant increase as a function of age ($F_{\text{linear}}(1, 37) = 4.5$, $p < .04$), with seventh (.71) and fourth (.72) graders' scores again nearly equal and more accurate than first graders' scores (.59).

Guttman Scale Analysis

Guttman scale analysis was performed on the mean scores of each component measure to assess the degree to which individual performance patterns conformed to the patterns predicted by the proposed model (Siegel & White, 1975). Guttman scale analysis is a statistical procedure that seems uniquely suited for assessing the basic claim of the model: that the components in the development of cognitive mapping are attained in a cumulative unidirectional manner. Specifically, the scale analysis assesses the extent to which the components form a hierarchical set by determining how well each individual's performance on each measure of the model's components agrees with the perfect unidirectional, cumulative pattern predicted by the model. In this pattern, the measures of components proposed to develop later (e.g., configurational knowledge) should not be performed successfully (i.e., above a criterion level of accuracy) unless measures of developmentally earlier components (e.g., landmark and route knowledge) were also above criterion levels. Each deviation from the expected pattern is counted as an error and standardized coefficients of reproducibility and scalability are statistically derived from the accumulation of errors (Goodenough, 1944).

Criterion levels for assigning subjects' performances to either passing or failing were established on the basis of accuracy percentages when scores were direct accuracy measures: way finding ($<10\%$ deviation), landmark ($\geq 80\%$ correct responses), and configuration-bearing scores ($<|15|^\circ$ bearing deviation); and on the basis of score distributions for those tasks where scores were the result of statistical computations: route-order tau coefficients (tau $\geq .85$), route-scaling log ratios ($<.26$), and the configuration-distance rho scores (rho $\geq .80$). The criterion for the overall configuration measures was determined by criterion levels on both bearing and distance scores. Whereas it may be argued that a posteriori setting of criterion levels could be contrived so as to inflate scale analysis coefficients, there was little, if any, practical feasibility of determining each of these apriori. Criteria were determined on the basis of what the authors agreed were reasonable levels of accuracy for the direct measures, and upon the distribution of scores for the total sample of subjects as a whole for the statistical measures. Obtaining acceptable scalogram coefficients, given reasonable criterion levels is not possible, moreover, unless individual (not group) performance levels on each task reflect the pattern of scalability predicted.

Results of the Guttman scale analysis revealed the observed performance patterns for all subjects presented in Table 1. Each component measure is given with order of difficulty ascending from left to right. Under each component task is the number of subjects passing or failing that item. Any task which should have been passed or failed by an individual given performance on all other items is noted under the error

TABLE 1
RESULTS OF GUTTMAN SCALE ANALYSIS

Component measure	1 Way finding		2 Landmark		3 Route order		4 Route scaling		5 Configuration		Total
	Fail	Pass	Fail	Pass	Fail	Pass	Fail	Pass	Fail	Pass	
	Error		Error		Error		Error		Error		
5	0	5	0	5	0	5	0	5	0	5	5
										Error	
4	0	16	0	16	0	16	0	16	16	0	16
								Error			
3	0	14	0	14	0	14	14	0	14	0	14
						Error					
2	0	5	3	2	3	(2)	4	(1)	5	0	5
				Error							
1	0	0	0	0	0	0	0	0	0	0	0
Sums	0	40	3	37	3	37	18	22	35	5	40
Percent	0	100	8	93	3	93	45	55	88	13	
Errors	0	0	0	3	0	(2)	0	(1)	0	0	6

Note. Coefficient of reproducibility = .97; coefficient of scalability = .79.

column for that task. Each error appears twice: first under the column of the failed easier item (the developmentally earlier task), and again under the corresponding more difficult item (the developmentally later task), given in parentheses. Thirty-seven of the forty children's response patterns conformed to the pattern predicted by the model. That is, 93% of the subjects tested performed in the manner predicted. The strength of this prediction is indicated by a very high coefficient of reproducibility (.97), measuring the extent to which a subject's score is a predictor of one's response pattern. (A coefficient of reproducibility higher than .90 is generally considered to indicate a valid scale.) The coefficient of scalability (.79) assesses the extent to which the scale is truly unidirectional and cumulative, and generally should be .60 or greater (Anderson, 1966). Also given in the table is the number and percentage of subjects who passed or failed each item. No children failed or passed only the way-finding task, two children passed only the way-finding and landmark tasks, 14 children passed only those tasks up to and including the route-order task, 16 children passed those tasks preceding and including the route-metric task, and five children passed all tasks. Three children's performance patterns did not fit the proposed sequence: two failed the landmark task yet passed the route-order task, and one failed the landmark task yet passed both route tasks. It should be noted that way-finding was not originally included as a component in the Siegel and White model (1975), but was included in this analysis as a means of testing our hypothesis regarding way finding and representational competence.

DISCUSSION

Nearly all children in this study performed perfectly on the way-finding task. That is, almost every child at each grade level exhibited rather sophisticated spatial knowledge by navigating novel and efficient routes within their environment. Yet, performance on the other cognitive mapping tasks varied significantly with grade level and, in some cases, with degree of familiarity with the environment. Few children's performances on these tasks could be characterized as perfect. This pattern of results supports the conventional wisdom regarding children's ability to navigate successfully within their environments and also confirms previous findings that older children are more skilled in cognitive mapping than younger ones. The difference in performance found between a measure of spatial knowledge in action (way finding) and the measures of spatial representational knowledge also support the notion of a competence-load tradeoff (Siegel, 1981; White & Siegel, 1976). It has become increasingly apparent in a variety of developmental studies that variations in the nature of assessment and experimental procedure result in variations in subjects' performance. In particular, variations which introduce load factors, (e.g., representational demands), "noise," confusion regarding instructions, or the presentation of novel or unusual tasks, appear to decrease cognitive performance. These variations are particularly problematic for investigations which attempt to equate cognitive performance with some underlying cognitive competence (e.g., cognitive maps). In the present study, although most children appeared to understand task instructions after their first presentation, the number, novelty, and memory requirements of the experimental tasks suggest the presence of numerous load factors. That even the younger subjects were able to remember target locations from the way-finding task to the later configuration task reinforces the picture of competence presented by their way-finding performance. The present findings indicate the importance of increased sensitivity to load factors in future research.

The results of the Guttman scale analysis provide strong support for the developmental sequence of cognitive mapping proposed by Siegel and White (1975). Scale analysis indicated that performance patterns on the four component measures of 37 of the 40 children tested were consistent with the hierarchical pattern specified by the model. Thus, almost every child's performance, regardless of grade level, reached a criterion level of accuracy on each component measure in the manner predicted, from landmark to route order to route scaling to configuration. Further support of the developmental model was found in grade level differences on the cognitive mapping measures. These results are consistent with previous research findings which indicate that accuracy increases as a function of age. Seventh and fourth graders were consistently more accurate than first graders on measures of landmark and route-order knowledge, and in most conditions of the route scaling and configuration measures. Reversals in this developmental sequence occurred in the route-scaling and configuration-bearing measures where performance differences appeared to be a function of degree of familiarity with the environment. An editorial reviewer has pointed out that results of the scalogram analysis may appear unlikely given the effects of familiarity upon performance and the resulting lack of consistent grade level differences on measures of route-metric and configuration-bearing knowledge. That these results indicate criterion levels of accuracy for 93% of each individual's mean performance on each task suggests that familiarity, as well as grade level, affected performance on each task in a rather consistent manner.

Familiarity and grade level interacted to predict performance on the route-scaling task. The expected relationship between grade level and accuracy was found only for the route within the side of campus experienced extensively throughout the year by seventh graders, previously by fourth graders, and limitedly by first graders. Yet, when seventh graders were asked to make metric judgments of a route within the side of campus within which they had only limited experience, their judgments were less accurate than the judgments of either the fourth or the first graders, who had more extensive experience within that area. Familiarity also influenced the accuracy of bearing estimates made from one side of campus to the other. For each group tested, accuracy appeared to be greater when estimates were made from the less familiar side of campus to targets within the more familiar side of campus.

These results are consistent with the findings of other researchers (Herman & Siegel, 1978; Allen et al., 1979) who found that a certain level of experience within the environment is necessary to construct an accurate representation of its features. The results are also consistent with the proposal that older children and adults with minimal experience within an area are able to construct configuration-like clusters of that environment before they are able to integrate all of its features into a total configuration (Hardwick et al., 1976; Siegel & White, 1975). If the development of these clusters precedes the development of configurations, it would be expected that both fourth and seventh graders, who had less than extensive (or recent) experience within one side of campus, would be able to make accurate bearing estimates within the less familiar side or from the less familiar to the more familiar side. They should not be able to make accurate estimates of the less familiar features when doing so required the integration of those features with the larger environment. Fourth graders in particular showed a large difference in accuracy between S—n and N—s estimates. It is not clear from this data, however, whether this is attributable to grade level or to their relocation from one side of the campus to the other prior to the time of testing. The apparent lack of effect of familiarity on performance of landmark and route-order tasks, and the high levels of accuracy achieved by each grade level on these tasks, suggest that even limited experience was sufficient for the acquisition of these types of representations.

This study represented an initial investigation of individual children's patterns of performance on measures of cognitive mapping components. Previous research has well documented the existence of developmental differences on cognitive mapping components between groups of children, but the present results warrant further research on within subject differences. The results of the scalogram present evidence that at one point in time nearly all children tested exhibited the predicted pattern of performance. This study did not assess the developmental sequence in each child across different time periods, that is, it was not longitudinal. The present study also attempted an exploratory analysis of the relationship between age and familiarity in a natural environment, and the results indicate the need for further investigation of this relationship. Previous research has typically confounded age and familiarity (Curtis et al., 1981) or has tended to minimize the effect of familiarity (Annoshian & Young, 1981). The present findings indicate the type and extent of experience the individual has within the environment, for example, whether it is long term or short term, extensive or limited, previous or recent, significantly affects the accuracy of at least route and configuration knowledge and that these effects may differ developmentally. Cognitive maps exist as dynamic, functional representations of the individual's environment and, as such, reflect and differ according to the needs and agenda of the individual. Further developmental studies are needed which will address such individual differences as the extent and nature of the individual's experiences within the environment, as well as developmental differences in cognitive mapping of large-scale environments.

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