DOCUMENT RESUME

ED 288 785 SO 018 555

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TITLE The Emergence of Route Map Reading Skills in Young Children.
PUB DATE Apr 87
NOTE 45p.; An abbreviated version of this paper was presented at the Biennial Meeting of the Society for Research in Child Development (Baltimore, MD, April 23-26, 1987).
PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *Cognitive Ability; Cognitive Processes; Early Childhood Education; *Map Skills; Metacognition; Social Studies; Spatial Ability; *Young Children

ABSTRACT

There is little agreement about how the ability to read route maps initially emerges and about how it should be stimulated by early childhood educators. This study assessed the route map reading behavior of young children and the basic skills that might contribute to that behavior. In individual videotaped sessions, 120 four, five, and six year olds, assigned to either a mimetic or itinerary map condition, used a series of four route maps (three pretraining; one experimental) to locate animals in a small-scale zoo. Each child's knowledge of basic spatial ability, symbol recognition, and metacognitive skills (thought to underlie map reading performance) was assessed during pretraining. During the experimental task, where and how often children referred back to the map for guidance and contingent route traversal success, was measured. Three questions were asked: (1) What was the initial level of mastery of each skill? (2) What was the level of mastery after explicit instruction? and (3) What was the relationship of possession of these skills to successful map reading performance? Instruction improved the performance of all three age groups on all three map understanding measures. Results indicated that fragile map understanding and usage skills are emerging during the years from 4 to 6 and that the key to this emergence is an increasing capacity to successfully intercoordinate spatial ability, symbolization, and metacognitive skills. (Author/SM)

The Emergence of Route Map Reading Skills in Young Children

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An abbreviated version of this paper was presented at the meeting of the Society for Research in Child Development, Baltimore, Maryland, April 1987.

Abstract

In individual videotaped sessions, 120, four, five, and six year olds, assigned to either a mimetic or itinerary map condition, used a series of four route maps (three pretraining; one experimental) to locate animals in a small-scale zoo.

During pretraining, each child's knowledge of basic spatial ability, symbol recognition, and metacognitive skills thought to underlie map reading performance was assessed. During the experimental task, where and how often children referred back to the map for guidance and contingent route traversal success was measured. Three questions were asked: 1. What was the initial level of mastery of each skill; 2. what was the level of mastery after explicit instruction; and 3. what was the relationship of possession of these skills to successful map reading performance.

Young children came into the experimental situation with less map-related knowledge than older children. Four year olds were disadvantaged relative to five and six year olds in the ability to demonstrate mastery of forward/up equivalence, symbol recognition, and representational correspondence. Five year olds were disadvantaged relative to six year olds in the ability to demonstrate mastery of forward/up equivalence and representational correspondence. Initial symbol recognition performance was equivalent for both older age groups.

Younger children came into the experimental situation less able to use a map than older children. Four year olds were disadvantaged relative to five and six year olds on measures of intentional map referral and on measures of contingent route traversal success. Five and six year old children were initially

equivalent on both these performance measures.

Instruction improved the performance of all three age groups on all three map understanding measures. However, this improvement was not powerful enough to overcome initially observed differences. Only the six year olds benefited from instruction in map usage. Of the basic skills assessed, only representational correspondence correlated with map reading performance during the pretraining trials.

During the experimental task, ANCOVA revealed an interaction of age, map design, and sex. Fours were poor at the route traversal task regardless of map design condition or sex. Five year old boys provided with mimetic maps performed better than all other fives. By six, boys were equally skillful in both map conditions. At that age, girls had achieved mastery of mimetic maps. Of the basic skills assessed, only pretraining route traversal proficiency level, pretraining representational correspondence level, and map referral covaried with map reading performance during the experimental trial.

Results indicate that fragile map understanding and usage skills are emerging during the years from four to six and that the key to this emergence is an an increasing capacity to successfully intercoordinate spatial ability, symbolization, and metacognitive skills.

Although the ability to read route maps is an expected adult accomplishment, there is little agreement about how that ability initially emerges and, consequently, about how it should be stimulated by early childhood educators (Catling, 1979). At one extreme, some theorists believe that map reading is a skill easily and early mastered by young children through informal learning (Blaut, Mc Cleary, & Blaut, 1970). This viewpoint can lead to the conclusion that formal instruction in map reading is superfluous. At the other end of the spectrum, are others who relying exclusively on Piagetian analyses of the development of representational space (Piaget & Inhelder, 1967; Piaget, Inhelder, & Szeminska, 1981), believe that an ability to understand maps is completely constrained by the tacit knowledge about space that one can bring to the task (Towler, 1971; Robinson & Petchenik, 1976). This viewpoint can lead to the conclusion that while formal instruction in map reading might not be superfluous, it is futile until the child has a fully developed understanding of Euclidean and projective spatial concepts (Satterly, 1964).

A way out of this stalemate has been offered by a third perspective. Proponents of this viewpoint (Rushdoony, 1968; Meyer, 1973; Askov & Kamm, 1974, Walker, 1980) redefine the debate by arguing that map reading describes the activation of distinct hierarchies of skills that range across increasing levels of sophistication and that can be brought to bear on an orderly progression of map-related activities and problems. This viewpoint takes the middle ground position that systematic instruction in map reading is valuable and feasible even for very young children if the competencies of children are correctly assessed and tasks are appropriately adjusted to enhance and extend those competencies (Barth, 1986; Downs & Liben, 1986).

Although this latter perspective seems to provide a sensible approach to understanding and fostering map reading acquisition in young children, its suppositions have only recently begun to be worked through and put to systematic empirical test (Downs & Liben, 1986). Consequently, we do not yet have the kind of extensive data base that would allow us to fully understand either the actual skills that are necessary and sufficient for a wide variety of map reading tasks to be accomplished successfully nor do we know which of these potentially important skills young children naturally possess or may be motivated to learn (Bartz, 1971; Carswell, 1971; Downs, 1981).

Recognition of the need for the development of such a normative data base led to the present study in which both the route map reading behavior of young children and the basic skills that might contribute to that behavior were assessed.

Route map reading was selected as an early estimator of competence because of experience with an earlier study. In this study, Scholnick, Frank, Schwartz, & Fein, 1986 had provided evidence that the ages four through six might be a transitional period for the attainment of early route map reading skill. However, their exclusive reliance on the manipulation of route complexity as a explanatory device had failed to unambiguously explain the documented transition. It therefore seemed appropriate to reexamine this form of map reading expertise within the skill hierarchy framework given above.

The basic skills chosen for analysis were drawn from three skill domains: spatial ability (an understanding of forward/up equivalence and mastery of representational correspondence); symbolic interpretation (an ability to recognize and decode symbolic notation); and metacognition (an ability to consciously self-regulate map reading behavior through strategic map referral).

The first two of these domains were givens. Maps are the means by which spatial relationships are symbolically represented (Olson, 1986). As such, they require both spatial ability and symbolic interpretation skills as prerequisites of use (Levine, Jankovic, & Palij, 1982; Bartz, 1971; Gardner, 1983). The third domain, metacognition, was more speculative. In the adult cartographic and spatial theoretical literature, it has been suggested that the use of a map as a wayfinding tool requires that the user understand the map's function as a symbolic mediator between world and mind and be both willing and able to strategically exploit that function (Chase & Chi, 1981; Keates, 1982; Allen, 1985). From this perspective, "knowing how to know from maps" is potentially as important a predictor of map reading performance as are spatial ability and decoding skills. Including a measure of map referral in the present study allowed a test of this hypothesis.

For each skill, three kinds of information were sought: what was the initial level of mastery of each skill; (2). what was the level of mastery after explicit instruction; and (3.) what was the relationship of possession of these skills to successful map reading performance. Because a transition had already been documented, it was expected that children ages four through six would show variability in both initial level of mastery and in level of mastery after explicit instruction on all assessed skills. It was also expected that proficiency in forward/up equivalence, symbol recognition, representational correspondence, and map referral would covary with map reading performance.

Pilot work and previous research (Bartz, 1971; Walker, 1980; Scholnick, Frank, Schwartz, & Fein, 1986) strongly indicated that demonstration of skill could be both facilitated and disrupted by the adoption of particular map design features. In this regard, the amount of explicit support given for the detection and utilization of the between scale equivalencies that existed between the provided maps and their referent spaces appeared to be especially important. To further explore this issue, two child-accessible schematized maps that varied across the dimension of minimal vs. maximal support for the detection and utilization of these equivalencies were designed and used with the expectation that the most supportive map design would indeed facilitate map reading performance.

A final concern of this research was a test of sex differences. Typically girls have been shown to be at a disadvantage on spatial ability tests that assess maze performance, map reading, and wayfinding, all of which bear some relation to this experimental task (Harris, 1981). This evidence, along with the continuing controversy over the age at which and the tasks on which sex differences in spatial ability

(Linn & Petersen, 1985) first appear, was sufficiently strong to warrant the inclusion of sex as an experimental factor.

Method

Subjects

Twenty girls and twenty boys at each of three age levels, four year olds (M age = 54.4 months), five year olds (M age = 66.2 months), and six year olds (M age = 78.0 months) participated in the study.

These children, whose racial and ethnic backgrounds were heterogenous, attended prekindergarten, kindergarten, and first grade classes at four schools. Two of these schools were research facilities; one was a public elementary school; and one was a privately owned day care center.

Materials

The stimulus materials were 5 1/2" x 8 1/2" route maps that varied along the dimension of amount of explicit structural support provided by the map design. Mimetic maps were experimental space miniaturizations in which an itinerary had been embedded (Figure 1). These maps which were patterned on the type of maps that might be found in such well-organized path-dependent environments as the National Zoo theoretically required the least skill for effective use. Children given these maps could use a perceptual matching strategy to arrive at the correct map-designated location. In addition, if they made an unintentional detour, the explicit correspondences between these maps and the spaces they represented could serve to provide a secure scaffolding from which to recover from error. Itinerary maps patterned upon the informationally improvished sketch maps often distributed among friends in everyday life depicted routes in isolation (Figure 2). These maps purposely required that the children have a more sophisticated grasp of and ability to manipulate the spatial concepts of distance and direction than did their companion mimetic maps.

For both map design variations, routes were represented by narrow red lines, departure points were represented by an arrow contained within a 1/4" x 1/4" square, intersections at which a change of direction was required were preceded by a pair of 1/8" x 5/16" rectangles representing gates, and correct destinations were signalled by miniature 5/16" x 5/16" black and white reproductions of animal facial profiles.

Each map in a given map design group showed the way to a particular animal house in a small-scale zoo. This zoo, through which subjects moved a toy figure, was represented by four (three for pretraining; one for the experimental task) masonite models. On each pretraining model, measuring 24" x 31", one path composed of three intersections was represented. On the experimental model, measuring 48" x 31", one path composed of seven intersections was represented.

All paths were constructed so that the miniature figure could be secured on them and moved to all available locations. Miniature wooden gates marked intersections which required changes in direction. At all possible locations, a 2" neutral-colored cube representing an animal house at the zoo was available. All these houses were secured by a hinge. Incorrect houses were empty. Correct houses revealed a color photograph of an animal figure when lifted by a child.

Procedure

In a single session, each child, randomly assigned to either a mimetic or itinerary map design condition, participated in a series of map reading exercises.

During the first of three pretraining exercises, each child demonstrated the map-related knowledge that was brought to the testing situation. Demonstrations of map understanding required the child indicate mastery of the principle of forward/up equivalence, identify map symbols, and indicate locations and landmarks on the represented space that corresponded to selected map symbols. Demonstration of map usage required the child to use the provided map to help a toy figure arrive at a particular animal house located at a small-scale zoo. In this latter task, actual route traversal performance and instances of intentional map referral were monitored. No assistance was provided during this first exercise. During the second pretraining exercise, each child was given performance feedback and provided with explicit instruction when needed. During the third and final pretraining exercise, the procedure used in the first exercise was repeated. Differences in performance between exercises one and three provided the means by which each child's sensitivity to instruction could be assessed.

At the conclusion of the pretraining exercises, each child was introduced to a final experimental map reading exercise. This exercise required the child to help the toy figure use a map to locate an animal house that was located in a different part of the zoo. The path to this house was longer and more complex than the paths encountered in pretraining. In this last exercise, assessment was restricted to actual route traversal performance and instances of intentional map referral; and, once again, no assistance was provided.

As the children worked, their actions were videotaped. Examination of these tapes provided data for error location and map referral analyses. One coder extracted data from all tapes. A second coder reexamined 30 tapes (10 per age group) in order that reliability estimates could be made. Agreement between coders for error location (pretest, posttest, and experimental task combined) was .99. Agreement for location of map referral was .93. The technique used for assessing reliability (Hartmann, 1982) included order and number as well as location information.

Results

Skill Assessment During Pretraining Activities

In order to assess initial levels of skill mastery and levels of mastery after receipt of instruction, pretraining forward/up equivalence, symbol recognition, representational correspondence, route traversal, and map referral scores were evaluated in a series of mixed design ANOVA's. Age (four year olds, five year olds, six year olds), map design (itinerary, mimetic), and sex (males, females) were between subject factors in each analysis to be reported. Time (pretest, posttest) was a within subject factor for each analysis. The representational correspondence analysis had an additional within subject factor of question type (route, landmark). Only differences at $<.05$ will be reported. Significant factors were followed up by Newman-Keuls test for ordered means.

Forward/Up Equivalence

At the beginning of each trial, children were asked to demonstrate they understood the principle of forward/up equivalence by aligning a map with the space it represented. If the child performed this task accurately, a score of one was recorded. No credit was given for inaccurate responses.

In this analysis, age and time yielded significant main effects. Both these factors interacting with map design provided two additional sources of variance as noted below.

Table 1

Forward/Up Equivalence Analysis: Means and Standard Deviations for the Age x Map Design Interaction

	Map Design			
	Itinerary		Mimetic	
Age	M	SD	M	SD
Four	1.35	.49	1.10	.55
Five	1.20	.41	1.45	.51
Six	1.45	.51	1.70	.47

Note: Maximum score = 2.

Age x map design interaction. A main effect of age, $F(2, 108) = 5.34$, was qualified by a significant age x map design interaction, $F(2, 108) = 3.42$. In the itinerary map condition, forward/up equivalence skill was similar for all age groups. However, in the mimetic map condition, forward/up equivalence skill improved with age such that the five year olds demonstrated better skills than the four year olds and the six year olds demonstrated better skills than both younger groups (Table 1). Only for the six year olds was the difference between performance on the mimetic vs. itinerary maps statistically significant.

Time factor. Performance improved from pretest (M = .40; SD = .49) to posttest (M = .98; SD = .16), $F(1, 108) = 155.81$.

Time x map design interaction. Map design created a difference in performance during the pretest, but not during the posttest $F(1, 108) = 3.96$ (Table 2).

Table 2

Forward/Up Equivalence Analysis: Means and Standard Deviations for the Time x Map Design Interaction

	Map Design			
	Itinerary		Mimetic	
Time	M	SD	M	SD
Pretest	.33	.48	.47	.50
Posttest	1.00	.00	.95	.22

Note: Maximum score = 1.

Symbol Recognition

During each trial, children were asked to point to four map symbols. These were, in order, an animal house, a directional sign, a path, and a gate. A score of one was recorded for each correct response. No credit was given for inaccurate responses.

In this analysis, age, $F(2, 108) = 22.73$, map design, $F(1, 108) = 8.23$, and time, $F(1, 108) = 48.60$, were significant main effects while time x age and time x map design interactions provided additional sources of variance.

Time x age interaction. During the pretest, the scores of the four year old children were lower than those of the five and six year old children. The scores of the two older age groups were equivalent. Although children at each age level significantly improved their performance during posttesting, the four year olds still were at a disadvantage relative to both the five and six year olds. These latter two groups continued to perform comparably.

Table 3

Symbol Recognition Analysis: Means and Standard Deviations for the Time x Age Interaction

	Time			
	Pretest		Posttest	
Age	M	SD	M	SD
Four	2.12	1.34	3.48	.78
Five	3.10	.93	3.88	.33
Six	3.38	.81	3.95	.22

Note: Maximum score = 4.

The observed time x age interaction, $F(2, 108) = 5.89$, consequently, did not indicate that the relative position of the age groups had changed as a function of time (Table 3). What it did indicate was that training had brought the youngest children up to the level of performance at which the older children had entered the experimental situation. Specifically, the four year olds at the time of posttest had improved to the level of the five and six year olds at the time of pretest. In addition, the five year olds at the time of posttest outperformed the six year olds at the time of pretest.

Table 4

Symbol Recognition Analysis: Means and Standard Deviations for the Time x Map Design Interaction

	Map Design			
	Itinerary		Mimetic	
Time	M	SD	M	SD
Pretest	3.13	1.04	2.60	1.24
Posttest	3.82	.54	3.72	.56

Note: Maximum score = 4.

Time x map design interaction. At the time of the pretest, the children who had been assigned to the itinerary map condition identified more symbols than those children who had been assigned to the mimetic map condition, $F(1, 108) = 5.12$. During training, children in both conditions improved their performances such that at the time of the posttest, map design differences had dissipated (Table 4).

Representational Correspondence

During each trial, children were asked to demonstrate they understood the exact relationship between a map and the space it represented by pointing to four locations at the imaginary zoo. These locations included two landmark targets (the sign that pointed the way to an animal house and the first set of gates on the zoo path) and two route targets (a spot on the second path segment and the third intersection) targets. A score of one was given for each correct response. No credit was given for incorrect responses.

Preliminary analyses of the data revealed that the route and landmark questions had grouped together as anticipated. For this reason, in the analysis to be reported, the question within subject factor was collapsed from four levels to two.

Age factor. Scores improved from 4.00 (SD = 2.09) to 5.75 (SD= 1.46) to 6.55 (SD = 1.40) in the four year old, five year old, and six year old groups, respectively, $F(2, 108) = 26.09$. All differences among groups were significant.

Time x question x map design interaction. Main effects of question, $F(1, 108) = 71.21$, and of time, $F(1, 108) = 69.88$, were qualified by a significant time x question x map design interaction, $F(1, 108) = 7.00$.

During the pretest, children were able to accurately answer more landmark correspondence questions than route correspondence questions. The ability to answer landmark questions was unaffected by map design. On the other hand, map design was a factor in the ability to answer route correspondence questions. The ability to answer these more difficult questions was facilitated by mimetic map design features (Table 5).

During the posttest, although scores on both types of questions had significantly improved and map design was no longer creating a performance difference, route representational correspondence questions still remained more difficult to answer correctly than landmark correspondence questions.

Table 5

Representational Correspondence Analysis: Means and Standard Deviations for the Time x Question x Map Design Interaction

	Time			
	Pretest		Posttest	
Map Design	M	SD	M	SD
Itinerary				
Route	.62	.74	1.37	.71
Landmark	1.48	.68	1.73	.58
Mimetic				
Route	1.07	.82	1.38	.78
Landmark	1.43	.77	1.78	.52

Note: Maximum score = 2.

Location of Error Analysis

At the conclusion of both the pretest and posttest activities, children were asked to use the map they had been working with to help a toy figure locate a prespecified animal house. Engaging in these map reading analogue tasks gave the children an opportunity to demonstrate that they could translate map provided knowledge into successful route traversal.

Success was evaluated in terms of whether or not the children were constrained by map information to localize their movement of the toy figure to particular sectors of the zoo path. Four sectors were defined. The two detour branches at intersection one comprised the first sector. The detour branch at intersection two comprised the second sector. The two detour branches at intersection three comprised the third sector. The correct destination branch at intersection three comprised the fourth and final sector.

Each child's route traversal pattern was assigned a location of error score ranging from one to four. A score of one indicated that the child lifted at least one incorrect house in each of the three sectors in which it was possible to make an erroneous decision before finally arriving at sector four. A score of two indicated that the child lifted at least one incorrect house in two of the three sectors in which it was possible to make an erroneous decision before arriving at sector four. A score of three indicated that the child lifted at least one incorrect house in one of the three sectors in which it was possible to make an erroneous decision before arriving at sector four. A score of four was given to those children who restricted the movement of the toy figure to the fourth sector.

In this analysis, age, map design and sex were the source of main effects. A time x age interaction created an additional source of variance.

<u>Age factor</u>. Throughout pretraining, younger children explored a greater number of sectors than did the older children, $\underline{F}(2, 108) = 22.94$.

The pattern of relationships between the three tested age groups varied as a function of time, $\underline{F}(2, 108) = 3.86$. During the pretest, the four year olds tended to investigate more sectors than either the five or six year olds. The latter two groups performed comparably. However, this profile changed during the posttest. At this time, while four year old and five year old performance remained stable, six year old performance improved. The fact that the six year olds evidently benefited from practice while the four and five year olds did not created a significant difference between five and six year olds on the posttest (Table 6).

Table 6

Location of Error Analysis: Means and Standard Deviations for the Time x Age Group Interaction

	Time			
	Pretest		Posttest	
Age	M	SD	M	SD
Four	2.52	1.09	2.18	1.11
Five	3.05	1.04	3.05	.88
Six	3.32	.92	3.68	.73

Note: Maximum score = 4.

Map design factor. Fewer sectors were investigated when children were using a mimetic map (M = 6.28; SD = 1.95) as opposed to an itinerary one (M = 5.58; SD = 1.65), $F(1, 108) = 6.28$.

Sex factor. Girls (M = 5.58; SD = 1.97) searched more sectors than did boys (M = 6.28; SD = 1.63), $F(1, 108) = 6.28$.

Map Referral

The map that showed the way to each animal house remained in place as the children moved the toy figure to its correct destination. Children were free to refer to each map as they worked.

One point was given the children for each map referral. A map referral was defined as a deliberate effort to glance at the map for guidance. Each referral could include one or more glances. All glances that occurred prior to the continued movement of the toy figure were grouped into a single referral. Once movement of the toy figure had been resumed, credit for additional map referrals was possible. Since the map check score was intended as a record of the children's independent actions, the experimenter-directed tracing of the route on each map prior to route traversal was not counted as a map referral.

For the map referral analysis, each of the three main intersections on the maps were considered to be separate sectors. These sectors were coded serially from one to three beginning from the start of each route. Referrals that occurred at or before a given intersection were assigned to that intersection's sector number. Referrals that occurred immediately after an intersection had been passed were assigned to the following intersection's sector number.

The sector partition of each map was used to create a location of map referral score that recorded every sector the child used as a vantage point for glancing back at the map before reaching the correct map-designated goal. This score ranged from one to four. A one indicated that the map was never referred to during route traversal. A two indicated that the map was referred to one or more times in one sector. A three indicated that the map was referred to one or more times in two sectors. A score of four indicated the map was referred to at least once in all three possible sectors.

In this analysis, age was a significant main effect, $\underline{F}(2, 108) = 11.77$. Four year olds (M = 3.18; SD = 1.28) were less likely than either the five year olds (M = 4.48; SD = 1.55) or six year olds (M = 4.70; SD = 1.77) to refer back to the map for guidance. This failure to use the map is especially striking when you realize it is this age group that was having the most trouble getting to the correct destination during both of the map reading exercises. The performance of the older two groups were comparable. This finding when considered with the route traversal results given above indicates that although both older age groups were equally willing to refer back to the map for guidance, the six year olds at the end of pretraining were using the information they retrieved from their maps more effectively.

<u>Relationship between route traversal performance and forward/up equivalence, symbol recognition, representational correspondence, and map referral</u>. Partial correlations controlling for age were calculated to test the relationship between possession of the skills hypothesized to underlie map reading performance and location of error scores. These correlations are reported in Table 7.

Forward/up equivalence, symbol recognition, and map referral were not significantly correlated with route traversal performance at either time of test. However, representational correspondence was significantly correlated with location of error scores during both pretraining trials.

Table 7

Partial Correlations: Relationships between Location of Error Scores and Basic Skill Scores Controlling for Age

	Basic Skill			
Location of Error Score	Forward/ Up	Symbol Recognition	Representational Correspondence	Map Referral
Pretest	.01	.12	.32*	-.03
Posttest	-.03	.15	.37*	.02

Note: df = 117. Significant correlations are marked with an asterisk.

Experimental Task

Location of Error Analysis

During the experimental task, children were asked to help the toy figure use a map to find one more animal house. Route traversal instructions and location of error scoring procedures replicated those used in pretraining except that sectors were now defined by larger units. (Sector one included the three detour branches at intersections one and two. Sector two included the four detour branches at intersections two and three. Sector three included the five detour branches at intersections five, six, and seven. Sector four included the correct destination branch at intersection six.)

An analysis of covariance was carried out on the resulting data in order to determine the effects of the experimental factors and evaluate the relative contributions of basic map-related skills to performance. Age (four year olds, five year olds, six year olds), map design (itinerary, mimetic), and sex (males, females) were between subject factors. Covariates included experimental task map map referral score, pretraining alignment proficiency level, pretraining symbol recognition proficiency level, pretraining representational correspondence proficiency level, and pretraining route traversal proficiency level.

The location of map referral score chosen for use as a covariate paralleled the score used in pretraining and was calculated in the same manner except that now each sector included more than one intersection. For this analysis, the first sector included intersections one and two. The second sector included intersections three and four. The third and final sector included intersections five, six, and seven.

The proficiency level scores used as covariates were extrapolated from the pretraining data by the following method:

For each covariate, there were four levels. The first level (Score = four points) indicated a high level of skill during both the pretest and the posttest portions of pretraining. (For the forward/up equivalence covariate, high level was defined as correctly aligning the map with the space it represented at each time of test. For the symbol recognition covariate and the representational correspondence covariate, high level was defined as being correct on three out of four possible questions at each time of test. For the route traversal covariate, high level was defined as making one error or less before finding the correct animal house at each time of test.)

The second level (Score = three points) indicated a high level of knowledge and skill (as defined above) only on the posttest. The third level (Score = two points) indicated a deterioration in performance from the time of pretest to the time of posttest. The fourth and final level (Score = one point) indicated a failure to meet the criteria set for high level of performance at each time of test.

Only differences significant at <.05 will be reported. Significant factors were followed up by Newman-Keuls test for ordered means. Significant between subject factors have been adjusted for the effects of every other factor. Significant covariates have been adjusted for the effects of all factors and every other covariate. This sequential analysis allows a determination of what each factor and every covariate alone significantly contributed to performance.

In this experimental task location of error score analysis, age and map design were significant main effects. An age x map design x sex interaction created an additional source of variance. Significant covariates included experimental task location of map referral scores, pretraining route traversal proficiency level, and pretraining representational correspondence proficiency level.

Age factor. As children grew older, they were able to localize their search for the correct map-designated animal house to a smaller area of the experimental space. Location of error scores, consequently, increased from 1.55 (SD = .81) to 2.25 (SD = 1.13) to 2.90 (SD = 1.13) in the four year old, five year old, and six year old groups, respectively, $F(2, 103) = 32.46$. All differences between groups were significant.

Map design factor. Errors were limited to fewer sectors when the children were asked to read mimetic maps (M = 2.50; SD = 1.19) as opposed to itinerary maps (M = 1.97; SD = 1.09), $F(1, 103) = 15.19$.

Age x map design x sex interaction. The reported main effects of age and of map design were qualified by a three-way interaction of age, map design, and sex, $F(2, 103) = 6.46$. This interaction suggests that boys are mastering the skills necessary for effective map reading at an earlier age than girls.

Looking at the data in Table 8, the following pattern of male performance emerges. At four years of age, boys in both map design conditions are performing comparably. At five years of age, boys in the highly structured mimetic map condition are outperforming boys in the less detailed itinerary map condition. At six years of age, boys in the itinerary map condition catch up; and, consequently, at that age, significant map differences among boys disappear.

The pattern for girls differs. In contrast to the boys, the performance of the girls is not facilitated by the use of mimetic maps until six years of age. Furthermore, at that age, while boys are performing comparably with maps of either map design, girls in the itinerary map condition remain at a disadvantage relative to girls in the mimetic map condition.

Table 8

Location of Error Analysis: Means and Standard Deviations for the Age x Map Design x Sex Interaction

	Map Design			
	Itinerary		Mimetic	
Age	M	SD	M	SD
Four				
Boys	1.40	.70	1.60	.97
Girls	1.70	.95	1.50	.71
Five				
Boys	1.80	1.14	3.30	.82
Girls	2.10	1.10	1.80	.79
Six				
Boys	2.60	1.07	3.30	.67
Girls	2.20	1.32	3.50	.97

Note. Maximum score = 4.

Covariates. Pretraining representational correspondence proficiency level, _F_(1,103) = 4.51, location of map referral, _F_(1,103) = 4.50, and pretraining route traversal proficiency level, _F_, (1, 103) = 10.60 created additional sources of variance in this analysis. The regression coefficients for each tested covariate are given in Table 9.

Table 9

Location of Error Analysis: Regression Coefficients

Covariate	Regression Coefficient
Route Traversal	.28*
Representational Correspondence	.20*
Location of Map Referral	.19*
Symbol Recognition	-.02
Forward/Up Equivalence	-.17

Note: Significant covariates are indicated by an asterisk.

Further Analysis of Map Referral

To more completely understand the impact of map referral on route traversal performance, the location of map referral score used as a covariate in the analysis reported above was analyzed in an ANOVA in which age, sex, and map design were between subject factors. In this analysis, age was shown to be a main effect, F (2, 108) = 13.76. Four year olds (M = 2.17; SD =.84) were significantly less likely to refer to the map than were children in the two older groups. Five year olds (M = 2.95; SD = 1.11) and six year olds (M = 3.32; SD = 1.00) performed comparably. This finding replicated the pretraining results.

Discussion

Awareness of the tentative nature of current knowledge about map reading led to the present exploratory research project in which the route map reading behavior of young children and the basic skills that might contribute to that behavior were assessed. Underlying these assessments was the expectation that these children would be in a transitional period of map reading acquisition and that, consequently, there would be age-related variability in both initial skill levels and in level of mastery after explicit instruction. It was also expected that pcssession of basic skills would covary with actual map reading performance. Each of these expectations will now be discussed in turn. For clarity of discussion, map-related understanding (forward/up equivalence, symbol recognition, and representational correspondence) and actual map usage (route traversal and map referral) will be discussed separately before issues of relationship are addressed.

As anticipated, age-related variability in ability to indicate mastery of map-related understanding was documented. Four year old children came into the experimental situation less able to correctly answer questions about these skills than either their five or six year old counterparts. Five year olds came into the experimental situation performing equivalently to the six year olds in the domain of symbol recognition, but showing less skill relative to the six year olds in both the demonstration of command of the principle of forward-up equivalence and in the demonstration of command of representational correspondence. While instructed practice did improve the performance of all three age groups, this practice was not powerful enough to overcome initially observed differences. At the end of pretraining, the position of each group relative to both other groups had not changed. No sex differences were observed.

Researchers have speculated that the symbolic understandings that would necessarily have to predate map literacy are emerging during the preschool years (Gardner, 1983). The data supports this claim to the extent that, if simple and supportive materials are used and instruction is very explicit, even four year olds are prepared to learn about maps. Although these children came into the experimental situation less able to answer questions about forward/up equivalence, symbol recognition, and representational correspondence than five and six year olds, during the course of pretraining, they were able to show an improvement in comprehension. In fact, in relation to symbol recognition questions, they were able to boost their performance to that of naive five and six year olds. One suspects that an ability to improve with standardized, brief instruction during an experimental manipulation indicates that longer and more individualized practice within the natural context of the classroom would be even more effective.

However, along with a sense of early emergence of skills, comes an equally strong sense of their tenuousness and of a developmental course that for even these minimal demonstrations of knowledge extends beyond the age range of the children in this sample. Three findings contribute to this assertion.

First of all, learning was apparent in all three age groups and in all three question domains. Even for the six year olds, there existed possibilities for improvement.

Second of all, there appeared to be an hierarchical relationship between and within question domains. Symbol recognition was shown to be an easier task than the identification of representational correspondences. While five year olds came into the experimental situation performing comparably to six year olds in the former domain, they were disadvantaged relative to the six year olds in the latter. Furthermore, in addition to the overall age difference in the ability to successfully identify correspondence relationships in general, route correspondences remained more difficult than landmark correspondences to identify even among the oldest children tested and even after explicit training had been provided. This pattern of performance indicates that it was not a generalized lack of understanding of the concept of correspondence that was impeding performance but perhaps a more specific inability to coordinate the order and directionality information provided by the map with the order and directionality information embedded in the experimental spaces.

Finally, during the pretest, map design effects differed by question type. Initially, the additional information provided by mimetic maps hampered children in their efforts to answer symbol recognition questions, but aided children in their efforts to answer the forward/up equivalence and representational correspondence questions. This finding was intuitively rational. The symbol recognition questions required the children to match a verbal symbol with a pictorial one. For novice map readers, less pictorial choices would be expected to make the selection task easier. It did. Consequently, for symbol recognition, the informationally sparse itinerary maps gave an initial advantage. In contrast, t. ɔrward/up equivalence and representational correspondence questions required the children to recognize the identities between the map and the space it represented. For novice map readers, the key to successful performance would presumably be in the amount of support given to aid in that recognition. For these questions, consequently, the mimetic maps that were created as exact replications of the represented spaces should have bolstered performance; and, in actuality, they did.

To summarize, the map understanding data show the emergence of a fragile understanding of map-related principles and conventions. Subject in limited ways to modifiability through learning and capable of being disrupted by contextual task factors, this understanding is neither completely nor firmly established.

As predicted, the children in this study demonstrated age-related variability in their ability to translate map provided knowledge into successful route traversal. Four year olds experienced the most difficulty with these tasks. They came into the experimental situation with less skill than both the five and six year old children and were not significantly helped by instructed practice. Consequently, during all trials, these youngest children made errors earlier in the route and in more overall locations than did children in either of the two older groups.

Since five year olds and six year olds performed comparably during the first pretraining trial it appears as if these two oldest groups came into the experimental situation with equivalent skill in traversing short routes. This initial similarity no longer was evident during the latter two trials.

While five year old performance remained stable during the posttest, six year old performance improved such that six year olds on the average outperformed five year year olds on this latter test. This overall age advantage of the older group was maintained during the more demanding experimental trial. These differences seem to indicate that instructed practice of the type provided by the experimental context was more beneficial for the six year olds than for the five year olds.

Map design and sex as well as age affected route traversal performance. Children were assigned to one of two route map reading conditions, mimetic and itinerary, with the expectation that mimetic maps would facilitate performance. This prediction proved accurate. Mimetic maps produced the highest levels of route traversal performance throughout the experiment. During the pretraining trials, the mimetic map advantage was an overall main effect. During the the more difficult experimental trial, the overall main effect of the mimetic map design variation was qualified by interactions with both age and sex. It appears that during that last trial mimetic maps as opposed to itinerary maps did not facilitate the route traversal performance of four year old children of either sex, facilitated the route traveral performance of five year old boys to such an extent that their scores were equivalent to that of six year old boys assigned to the same map reading condition, and facilitated the route traversal performance of six year old girls.

The mimetic map advantage serves to support the notion expressed above in regards to map-related understanding that these children were able to demonstrate extremely fragile map reading capabilities even when asked to utilize simple and supportive materials. In this regard it should be specifically noted that even children in the oldest age group tested had relatively more difficulty during pretraining interacting with itinerary maps than with mimetic maps and it was only the six year old boys who were able to close the gap between mimetic and itinerary map performance during the experimental task.

Sex had been considered as a legitimate variable in this research because existing spatial ability literature raised a suspicion that girls might have more difficulty than boys performing the criterial tasks. This suspicion was born out in the obtained results of this research. As noted above, the performance of the girls during the experimental trial was not as advanced as that of the boys. This relative disadvantage had also been apparent during the pretraining trials. During those trials, sex was a significant main effect. Girls came into the experimental situation less able to perform the criterial tasks than their male counterparts and were not able to benefit from instructed practice to the extent that they could overcome that disadvantage.

As reported in the map understanding section of this discussion, sex was not a significant factor in any analysis. Girls were not disadvantaged relative to boys in terms of forward/up equivalence skill, symbol recognition skill, or representational correspondence skill. Furthermore, no differences in map referral were attributable to sex. These results would seem to indicate that girls did not differ from boys in terms of awareness of map conventions and principles, in terms of knowledge of map functions, nor in terms of willingness to use a map as a referent. The observed difference appears to be strictly confined to the accurate translation of the route information provided by the map onto the referent space.

Granting that the observed sex difference is essentially one of spatial translation, the question becomes one of whether or not the source of difference may be located more explicitly. Fortunately, it can be. In addition to the total score route traversal analysis reported in the results section, a supplementary analysis was carried out on a score that focused on the children's performance up to the first house check. That score, that by definition eliminated the necessity of reorienting, indicated no sex difference either during pretraining or during the experimental task. If these two analyses are considered together the indication is that boys and girls differ on the dimension of reorientation after error rather than on a more global dimension of overall spatial translation. This finding is congruent with Linn & Petersen's (1985) assertion that differences in mental rotation ability favoring males are found at the earliest ages that can be tested.

In consonance with map understanding and route traversal findings, children in this study demonstrated age-related variability in their willingness to refer back to the map at strategic locations. During pretraining, four year olds were shown to be less likely than either five or six year olds to visibly refer back to the map at strategic locations. Five year olds displayed an increase in willingness to use the map for guidance over their younger counterparts. Although five year olds were arguably more willing to refer back to the map, they were not necessarily equipped to do so with great success. Although they looked at their maps as often as six year olds did during the final pretraining trial, they were not as able to convert reliance on the map into correct route traversal choices. In this regard, six year olds clearly had an advantage, however, their skill was still far from perfect. Their route traversal performance was never at ceiling.

In this study the relationship of the basic skills discussed above to actual route map reading behavior was also of interest. It was expected that possession of each skill would be necessary to map reading performance and thus would covary with it. Tests of this hypothesis were made using data from both the pretraining and the experimental trials. The pattern of results from each test were not identical. During pretraining, only possession of representational correspondence correlated with map reading performance. During the experimental task, map referral, representational correspondence, and route traversal performance during the pretraining trials covaried with map reading performance. Two aspects of these findings require explanation. First of all, the differential impact of the three map understanding skills on map reading performance is of interest. Second of all, the differential pattern of relationship between representational correspondence and map referral to performance during pretraining and during the experimental trial invites speculation.

It was expected that all three aspects of map-related understanding, forward/up equivalence, symbol recognition, and representational correspondence, would affect map reading performance. This expectation was not met. Of these three assessed skills, only representational correspondence was influential. This finding indicated that that latter skill was fundamentally different from the two former ones. Reexamination of the skill assessment procedure isolated a potential source of this difference. Forward/up equivalence and symbol recognition questions had been posed as "identification" queries on the assumption that possession of factual knowledge of mapping conventions was a sufficent condition for being able to use maps. No explicit information was provided that indicated how to convert this knowledge into workable map-related problem solving strategies. On the other hand, representational correspondence questions, although theoretically posed in the same way, had the practical effect of assisting those children who were capable of doing so to understand the linkage between the route on the map and the route on the represented space. In essence, these latter questions provided the children with an essential clue to map usage that the former ones did not. This assistance proved to be of critical importance and leads to the conclusion that young map readers need to be helped to understand not only map-related conventions but the functional significance of these conventions as well.

Map referral was evaluated as a tangible indicator of intentional self regulation of map reading performance on the assumption that such self regulation was an essential component in the transition from novice to expert map reader. In this evaluation, location of map referral scores was expected to covary with location of error scores because if the map was used effectively at every available location, the translation of map provided information into successful route traversal should of necessity been excellent; and, conversely, if the map was ignored or misused, the translation of map provided knowledge into successful route traversal should have been poor. During the experimental task, this expectation was met. However, during the pretraining trials, it was not. Clearly, if the relationship between map referral and route traversal success was a truly necessary one, then the size of the space to be traversed should not have affected its expression. Furthermore, as indicated above, while map referral did not correlate with route traversal success during pretraining, representational correspondence did. It thus appeared that the ability to recognize representational correspondences could substitute for systematic map referral when the space to be traversed was compact enough to be encoded as a simultaneously perceived structural unit, but not when the space was to be viewed segmentally and sequentially as was the case with the experimental task miniaturized space and would be the case in real world map reading. In that latter situation, both a mastery of representational correspondence and a willingness to be guided by the map when there was a felt need to do so appeared to be required.

These relationship findings led to a reconsideration of the nature of using maps for wayfinding purposes and some suggestions for the behavioral prerequisites that must accompany that use:

During wayfinding, maps function as external memory aids. Referrals are made to maps when introspectively one feels that the information being held in spatial storage is not sufficient for continuing along a designated route. Success at map reading depends upon how accurately these introspective judgments are made, upon how accurately the map's symbolic notation is interpreted, and upon how accurately that interpretation is translated into real world practical activity. Given that these statements are true, key elements in learning to use a map in wayfinding activities are (1) the development of an awareness of the relationship between internal spatial representations, the symbolic information provided by a map, and the real world that map depicts, (2) the development of a perceived need to consciously exploit that relationship, and (3) the development of the capability of making that exploitation successful. These elements are assumed to be hierachically organized such that each successive element presupposes those that went before. Although awareness and perceived need are unitary dimensions, capability is not. This dimension involves the intercoordination of metacognitive control, spatial ability, and map interpretation skills. These skills, in turn, may be facilitated or hindered by variation in task demands.

If maps and map reading are conceptualized in this manner, the behavior of the children in this sample becomes more readily interpretable. Being map reading novices, they were fluctuating between awareness, perceived need, and capacity. Four year olds appeared to be just entering a stage of awareness. Consequently, on the uncomplicated pretraining maps, some of them were able to arrive at the map-designated location if their initial glance at the provided map had allowed them to obtain a complete veridical internal representation of the to-be-traversed space. However, they were in general not at the level of perceived need or capacity to consciously exploit that awareness. During the experimental task, when the length and complexity of the route demanded the children coordinate accurate judgments of how much of the route could be held in spatial storage with active attempts to refer to the map, these children proved to be at a serious disadvantage. They did not have the resources to consciously control and regulate this necessary goal-oriented strategy. Instead the evidence suggests these young children did the next best thing. They used a skill they had already developed and searched the space until they by luck arrived at the correct destination.

Five and six year olds presented a different picture. Pretraining and experimental task map referral data suggest that the children in both these groups had been able to grasp the functional significance of the map's availability as an external memory aid. However, six year children demonstrated superior ability in successfully exploiting this knowledge. By outperforming five year olds in both the posttest and experimental measures of route traversal success, they demonstrated a greater awareness of their own qualities as map readers and a greater awareness of how to use those qualities to effectively meet task demands.

Despite the very real skills shown by these most sophisticated subjects, it is well to remember they were still novices. As evidenced by map design effects and sex effects, their ability to manipulate symbolically provided spatial information had not yet become perfectly intercoordinated with their willingness to be guided by the map. They performed more skillfully than the five year olds but the assigned map reading tasks, especially on the more extended experimental space, were still challenging for them.

The accumulated evidence in this paper suggests that there are separate developmental progressions in the skills that underlie map understanding and map use and that these progressions are only beginning to tenuously emerge and become coordinated in the early childhood years. Educators may support this emergence and coordination by providing mapping tasks and materials that respect the fragile nature of the skills the children are exhibiting and that specifically emphasize "knowing how to know" from maps. This kind of curriculum will not and certainly can not turn young children into mature map readers in the adult sense but it will provide a necessary first step in helping them to understand and begin to be able to manipulate the essential relationship that exists between world, map, and mind.

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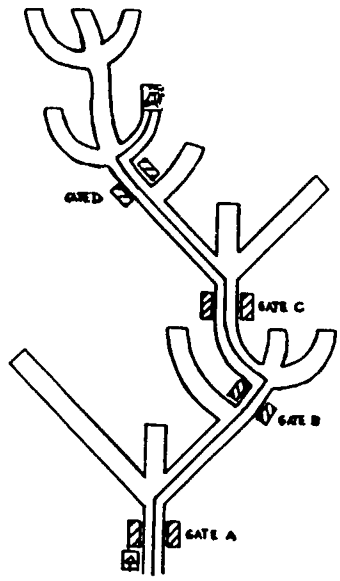

Figure 1
Experimental Task Mimetic Map

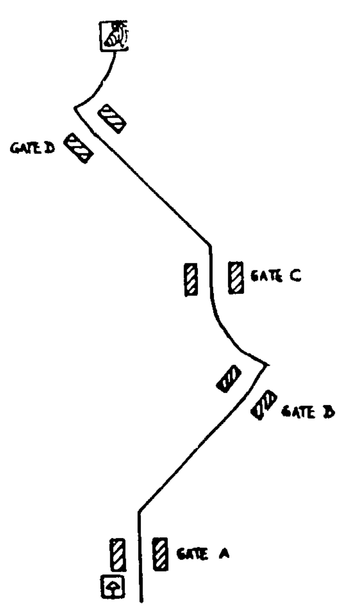

Figure 2
Experimental Task Itinerary Map