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Young Children's Representation of Spatial Information Acquired From Maps

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The early development of the ability to acquire integrated knowledge of a space from a map was investigated in 130 children, 4 to 7 years of age. Experiment 1 demonstrated that all 6- and 7-year-olds and many 4- and 5-year-olds could learn the layout of a large playhouse composed of six adjoined rooms by memorizing a map. Children who learned the map before entering the playhouse more quickly learned a route through it than children who were not exposed to the map, and older children performed significantly better than younger children. In Experiment 2 preschoolers learned a map of a space that contained six spatially separated small rooms within one large room. Children could therefore view the entire configuration of smaller rooms as they traveled around the larger room. Preschoolers performed significantly better in Experiment 2 than in Experiment 1, and the majority of them performed perfectly or almost perfectly. Taken together, the findings help to clarify young children's map-reading abilities in several respects and suggest that preschoolers' abilities are more substantial than has been assumed or demonstrated previously.

The use of maps in research on spatial cognition has waxed and waned. Maps figured in an early wave of investigations when researchers (e.g., Piaget, Inhelder, & Szeminska, 1960) believed that children's construction of maps and model layouts could provide valid replicas of children's mental representations of a space. But the use of maps declined when it became clear that children with equal representations might produce quite different maps because of differences in their ability to draw in general and to construct maps specifically (Kosslyn, Heldmeyer, & Locklear, 1977; Siegel, 1981).

Recently, however, maps have emerged again in research on the development of spatial cognition (e.g., DeLoache, 1987; Landau, 1986; Liben & Downs, 1986; Presson, 1982, 1987). The focus now has shifted to children's ability to understand maps rather than construct them. Two new perspectives motivate this research. First, children's map-reading skills provide important information about one sort of representational competence. Studying when and to what extent children can read and use maps reveals their developing comprehension of concrete, external representational devices and their ability to form mental representations from them (DeLoache, 1987; Flavell, in press). Second, such research addresses a gap in our understanding of the developmental acquisition of spatial knowledge. Research and theory on spatial cognition typically has studied how people acquire spatial information on their own (e.g., Herman, 1980; Siegel & White, 1975; Tolman, 1948). Yet when learning a new environment, newcomers (adults and children) often depend on assistance from others, communicated to them through verbal directions and maps. Researching children's understanding and use of spatial information as provided in maps can provide substantial insights on this topic and on such related topics as spatial egocentrism, children's understanding of spatial communicative conventions, and how information from adults guides children's learning and development more generally (Vygotsky, 1978).

Using a map effectively is a complex task that involves a number of competencies. Describing children's map-reading skills therefore requires investigating many different facets of performance (Liben & Downs, 1986). Prior research on preschoolers' map-reading skills usually has focused either on the ability to understand the aerial perspective from which maps typically are read or to use maps to find hidden objects. For example, Blaut, McCleary, and Blaut (1970) demonstrated that 5-year-olds could identify depicted landmarks on aerial photographs even though they had no previous exposure to aerial photographs. Spencer, Harrison, and Darvizeh (1980) substituted an actual map for the aerial photograph and obtained similar results. Bluestein and Acredolo (1979) found that most 4- and 5-year-olds and some 3-year-olds could use a map to find a hidden object in a real space. Recently, DeLoache (1987) found that most 3-year-olds could use a photograph or a small-scale model to find a hidden object in a represented real space.

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The results accumulated to date are suggestive but not definitive; there is controversy and unclarity with respect to the extent of young children's knowledge and utilization of maps (see Liben & Downs, 1986). The present research was designed to assess two important issues that, among others, remain unaddressed or unresolved. The first issue concerns the relative advantage accrued in learning a space given exposure to a map. For adults, Thorndyke and Hayes-Roth (1982) showed that first learning a map aids navigation and speeds the acquisition of an experience-based representation of the space. But until now no studies have assessed the development of this map-reading advantage in children.

The second issue concerns the nature of children's mental representation of map-acquired information. An unresolved question here is whether and when young children can acquire an integrated mental representation of a space from a map. By integrated representation we mean a representation that captures some essential part of the two-dimensional configuration of spatial relations that corresponding objects exhibit in the world. Previous research has provided ambiguous information about the form and complexity of children's map-acquired representations, because children typically are asked to search for a single target hidden in the space (e.g., Bluestein & Acredolo, 1979; DeLoache, 1987; Presson, 1982, 1987). This is a relatively simple task; children (or adults) need only encode from the map a single landmark that is close to the single hidden object. Once within the space, they could find the object by simply noticing the correct landmark and searching in its vicinity (see Huttenlocher & Newcombe, 1984; Presson, 1982).

In the present research we assessed whether young children's representation of map-acquired information includes the relative positions of several different locations within an integrated representation. Children (4 to 7 years of age) memorized a map of a large space and then were required to navigate through the space itself. The navigation task required more than finding a single object; children learned an extended route through the space.

Experiment 1

In Experiment 1, children learned a map showing the layout of a large playhouse containing six contiguous rooms and then learned to navigate a route through the playhouse. A critical question concerns children's representation of the layout of the playhouse before any navigational experience. If preschoolers demonstrate knowledge of the spatial relations among the several locations at this initial stage, then they must have acquired and encoded configural information from the map. This can be tested on their first trip through the playhouse. Thus, a test of children's ability to identify various unseen locations was incorporated into their first trip through the playhouse. After repeated exposure to the playhouse, children completed inference, pointing, and route-reversal tasks (along the lines of Hazen, Lockman, & Pick, 1978). Successful performance on these postlearning tasks requires some degree of integrated information about the relative location of the animals.

Note that children's actual experience of the playhouse was based on learning a route through it. Some researchers (e.g. Siegel & White, 1975) have suggested that young children's representations of large-scale space often focus on route information. In the extreme, it is possible that from traveling through the playhouse (or perhaps even by reading a map), children might learn the sequence of locations along a specific route but have no sense of the overall integration of the space. We will refer to this simple type of route representation as a "beads-on-a-string" representation and will use it as a baseline hypothesis.

Experiment 1a

Method

Subjects

The children were 26 four- (M = 54 months) and 24 five-year-olds (M = 66 months) who either attended a university-based preschool or came from a subject pool of healthy children recruited through pediatricians' offices. There were 27 boys and 23 girls approximately evenly divided between the two ages. Equal numbers of children at each age were assigned randomly to map and to no-map groups.

Materials

A large playhouse constructed of six contiguous rooms, as shown in Figure 1, was situated in an empty university classroom. The playhouse rooms were made from 6.5 × 2 ft (1.98 × .61 m) pieces of blue Styrofoam insulation. The Styrofoam pieces were arranged so that they formed two rows of identical 5.5 × 5.5 ft (1.68 × 1.68 m) square rooms. Each room had four identical doors of opaque fabric. A different toy animal was placed in the center of each room. A map that showed the outline of each room and the location of the doors was drawn on white poster board at a scale of 1 in. (2.54 cm) to 1 ft (.30 m). Small photographs of the stuffed animals were placed in the correct positions on the map.

Procedures

Initial training. The child was told that he or she would see several stuffed animals. On entering the larger room, the experimenter pointed to the front of the playhouse and said, "All the animals live in this playhouse right here." The curtain of one of the two front rooms of the playhouse was open at this point. The experimenter then seated the child in front of the open door. In traveling to their seat children could view the front of the playhouse and part of one of the longer sides. Children did not travel around the playhouse, and the playhouse took up approximately two-thirds of the larger classroom. Thus, children's overall view of the playhouse was quite limited.

At their seats, children assigned to the map group first saw and learned the map of the playhouse. They were told, "This is a map of the playhouse. It's a big picture and it shows you where everything is. Here are the doors, and here are all the animals." The experimenter pointed (in random order) to the animals and asked the child to identify each. After correctly identifying all six animals, the child was asked if he or she knew where all the animals lived. The experimenter then said, "let's see" and covered all the animals on the map with index cards. The child was asked to name the animal that lived in each room as the experimenter pointed to the rooms in random order. The experimenter removed each index card when the animal was correctly named and continued to probe misnamed animals until all six cards were removed. The cards were then replaced and the procedure was repeated, except that the cards were removed and then replaced immediately after the child named the animal. This procedure was repeated until all the animals had been named correctly on two successive trials. Then the experimenter reversed the procedure and named an animal and asked the child to point to the correct location on the covered map. When the child pointed, the experimenter said, "let's see" and moved the card. The card was returned immediately after the child saw the animal. Children were again tested until they could point out correctly the location of each animal on two successive trials.

Because the map group learned the animal names and identities as well as their locations, the no-map group was required to memorize the set of animal names. Photographs identical with those shown on the map were attached to cards of the same size as the rooms on the map. No-map subjects were shown the cards one by one and then were asked to name the animals from memory. Children received free recall memory trials until they could recall all six animal names on two successive trials. On these trials, the experimenter held the cards so that the animals could not be seen; then, as children correctly named an animal, they were shown the relevant card, which was placed face down in front of them.

Route navigation. Both groups traveled through the playhouse by following one of two randomly assigned U-shaped routes (either A to B or B to A along the dotted line in Figure 1). The door to the open room was closed, and children wore a baseball cap in case the pattern of lights on the ceiling might have provided some clues about the layout of the space. The first room that the child entered was always opposite the room that had been open. The child was placed at the midpoint of the front section of the playhouse. The experimenter then pointed to the door through which the child would enter and said, "Do you know what animal lives behind that door?". This tested children's knowledge of the identity of a designated, unseen, and unvisited location within the space. If the child was in the no-map group, the experimenter said, "I know you haven't seen it yet, but can you take a guess and tell me what

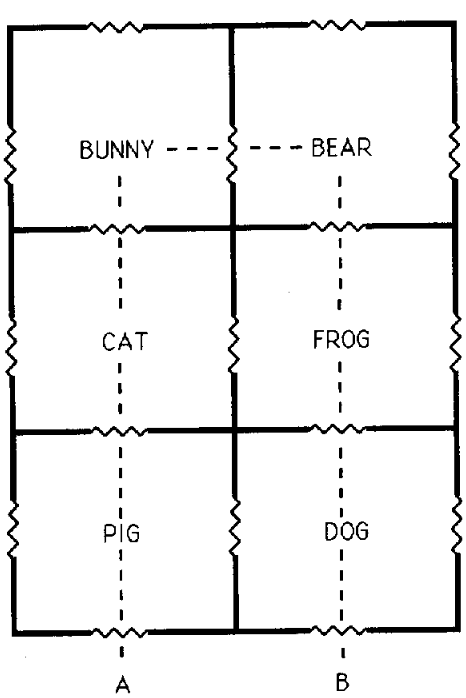

Figure 1. Layout of the playhouse used in Experiment 1 and the U-shaped route. (The map was similar to this figure, except that no dotted line was depicted and photographs of the animals were used instead of written names.)

animal lives there?". After the child responded, the experimenter said "let's see," and opened the door to the room. Incorrect responses were corrected by saying, "This is the _____'s room; the _____ lives here." The child and experimenter then entered that room and moved to its middle. The experimenter pointed to the next door along the route, again asking the child what animal lived behind the door. This procedure was repeated in each room. Children's answers to the first trial location-identification questions constituted the *unseen-location* test.

After completing the first trip through the playhouse, the child was given a pointer and was told that he or she should use it to show the experimenter "the way we go." The experimenter then stood the child in front of the midpoint of the front wall of the playhouse and asked the child to point to the door through which the playhouse had been entered on the previous trial. If the child's answer was incorrect, the experimenter pointed to the correct door and said, "We go *this* way." Then the child was asked, "What animal lives in that room?". After answering this question the child was allowed to enter the room. The child was asked in each successive room to point to the correct door to be entered next and name the animal that lived behind it. This procedure was repeated until the child could follow the correct route through the playhouse twice, making two or fewer errors (i.e., either pointing to an incorrect door or naming an incorrect animal) on both trials. If the child could not reach this criterion within 10 trials, he or she was not tested further. This occurred for 2 children.

Further testing. After reaching criterion, children completed three postlearning measures, two of which (inferencing and route reversal) were adapted from Hazen et al. (1978). Each test required a separate trip through the playhouse, following the route that the child had learned originally. In *inferencing,* children were asked to name the animal that lived behind a door that was not part of the learned route. There were four inference questions, as indicated in Figure 2. On an inference trial, the experimenter and child entered and moved to the middle of a room as in the previous tasks. The experimenter pointed to the inference door and asked which animal lived there.

The *pointing* task was counterbalanced (first or second) with the inference task across children. Children were required to identify the location of different animals from different locations in the playhouse. Figure 2 shows the locations and directions for the 12 points; children could not see the animals in question but had to point to their invisible locations. Children were never asked to point to an animal that was located in a room that was either immediately before or after the present room on the route. The experimenter led the child into the room and said "I want you to point to the _____. I know you can't see it right now, but just point to where it lives." Points were coded in terms of the nearest door or corner indicated by the child. If the child's point was ambiguous (i.e., not clearly to a door or corner), the experimenter pointed to both the door and the corner and said "Do you mean here, or do you mean here?". Thus, children's points were coded as one of eight possible directions.

The final test was *route reversal.* The experimenter told the child, "This time we're going to go through backwards." The child was asked to point to the correct doors in reverse order; if the child did not point correctly he or she was shown the correct door. As in the original learning, the child was asked to name the animal that lived behind the correct door.

Results

Preliminary analyses showed no main effects or interactions for sex on any of the dependent variables discussed below. Similar analyses showed no effects for route order except for one uninterpretable effect on the route reversal scores in the postlearning tasks. Therefore, these variables were excluded from further analyses.

Advantage Gained From Exposure to the Map

Was there an advantage gained from first learning the map? One relevant measure of this is the total number of trials needed to reach criterion: completion of two successive trips making two or fewer errors (either naming the wrong animal or pointing to the wrong door) on each trial. A 2 (condition) × 2 (age) analysis of variance (ANOVA) revealed only a main effect for condition, $F(1, 46) = 4.48$, $p < .05$. Map-group children required fewer trials to reach criterion ($M = 4.16$) than no-map children ($M = 5.0$). A minimum of three trials was required to reach criterion because children were not asked to point to doors that delineated the route on the first trip through the playhouse. Thus, the first trial was never included as one of the two needed to reach criterion. Only 3 of the 25 no-map subjects reached criterion in three trials, but 10 of the 25 map subjects did so, $\chi^2(1, N = 50) = 5.09$, $p < .05$.

Children's performance by trials helps clarify the nature of the map-group's advantage. As shown in Figure 3, map-group children performed much better than no-map children on the earlier trials, but the performance of the two groups was nearly identical by the fifth trial. A 2 (condition) × 2 (age) × 5 (trials) ANOVA showed that this interaction between condition and trials was significant, $F(4, 184) = 3.48$, $p < .01$. No other interactions were significant, and the main effects replicated those described above.

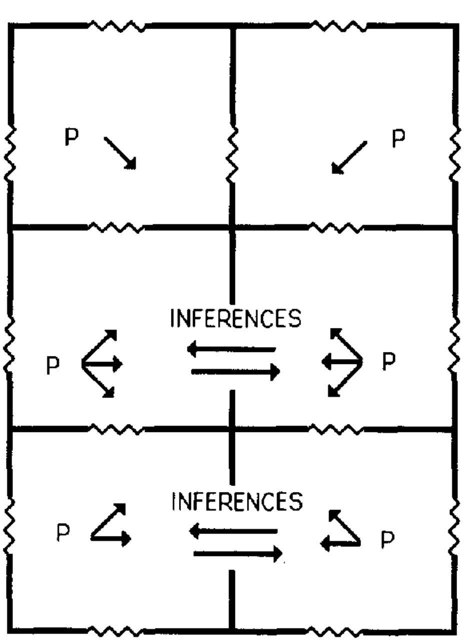

Figure 2. Positions and direction for the inferencing and pointing post-learning measures. (The P represents the position from which children were asked to point; the arrows beginning at the Ps represent the direction of the points. The arrows labeled *Inferences* indicate the directions of the four inference questions.)

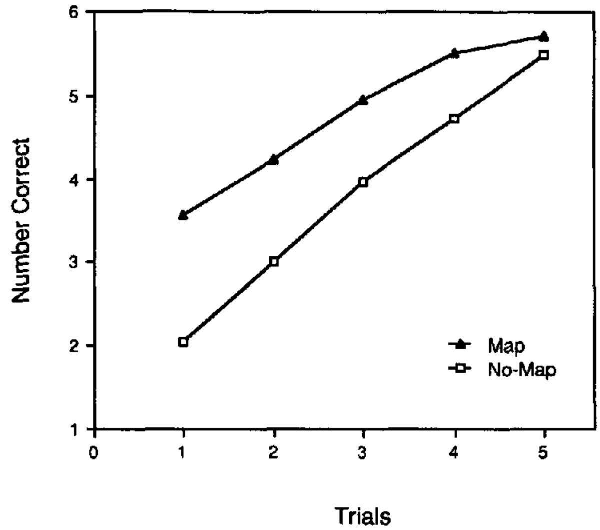

Figure 3. Map and no-map performance on Learning Trials 1 to 5.

Representation of Map-Acquired Information

Did children acquire some integrated knowledge of the playhouse from their exposure to the map? Map-group children's performance on the unseen-location questions during the first learning trial provides information relevant to this issue, because, at this point, map-group children had not yet traveled through the space. If, nevertheless, they could demonstrate knowledge of the relative location of the toy animals, along a route that they had never traveled nor seen specified on the map, then they must have encoded some sort of integrated representation of the space from the map.

The map-group's first trial performance on the unseen-location questions was compared with that of the no-map group, a comparison that provides baseline information as to children's correct guessing. A 2 (condition) × 2 (age) ANOVA on the number of animals anticipated correctly (out of six possible) on the first navigation trial revealed a main effect for condition, $F(1, 46) = 18.78$, $p < .001$. Map-group children anticipated more animals correctly ($M = 59\%$) than did no-map children ($M = 34\%$). Neither the main effect for age nor the interaction was significant.[1]

Two aspects of these data require further consideration: (a) No-map children were correct a third of the time, and (b) map children, although significantly better than no-map children, were far from perfect. The no-map group knew the animal names before entering the playhouse. No-map children could use this knowledge to make logical guesses and, as they traveled through the playhouse on their first trip, they could be increas-

[1] As a validity check, if learning the map benefits map-group children, and performance on the first trial unseen-location questions indexes children's learning of the map, then first trial performance should predict number of trials to criterion for the map group. It did, $r(24) = -.48$, $p < .05$; children who anticipated more animals required fewer trials to reach criterion. For no-map children, $r(24) = -.17$, *ns*.

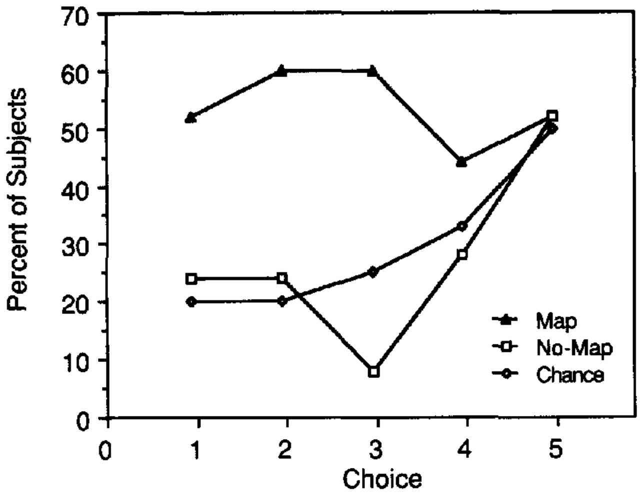

Figure 4. Map, no-map, and chance performance on the first five choices.

ingly correct by keeping track of the names of animals already seen and not guessing these. Their performance, then, might reflect sampling *without* replacement from the list of animal names that they memorized initially.

To test this possibility we compared the performance of both groups with a sampling-without-replacement probability model. Children's first guess occurred when they were asked to name the animal that lived behind the first door on the route. The predicted probability of guessing correctly at this location was .20, because there were five animals that the child had not yet seen. Although there were six animals in the playhouse, we did not include the animal that was behind the open door, which children saw on initial exposure to the playhouse. We did, however, count this animal as a possible guess for all other choices. Thus, the chance performance level for the second choice was again .20. The predicted and observed proportion levels for the first five choices on the first trip through the playhouse are shown in Figure 4. Only the first five choices were included, because children had seen the last animal through its open door on original exposure to the experimental situation.

The no-map group's performance did not differ significantly from the predicted model of performance: Hotelling's $T^2 = 10.891$, $F(5, 20) = 1.8152$, $p = .1556$; $\chi^2(4, N = 125) = 3.50$, $p > .50$. However, the map group performed much better than this prediction: $T^2 = 31.191$, $F(5, 20) = 6.37$, $p < .001$; $\chi^2(4, N = 125) = 34.55$, $p < .001$.[2] That the no-map group took advantage of the information that they acquired before entering the playhouse demonstrates both that the task was engaging to young children and that the no-map group's performance provides a conservative baseline for comparisons with the map group.

Consider next why map children were not more correct. This seems to be the result of variation in children's use of the map. Scores for the 25 map-group children were distributed across the possible range but were more skewed toward correct responding: 0, 2, 5, 7, 3, 4, and 4 children got 0, 1, 2, 3, 4, 5, or 6 answers correct, respectively. Scores for the 25 no-map children were skewed toward incorrect responding: 1, 3, 16, 4, 1, 0, and 0 children got 0, 1, 2, 3, 4, 5, or 6 responses correct. If we use the no-map group's modal response as a cutoff, then more than two-thirds of the map group children benefited from the prior exposure to the map, but some did not.

Postlearning Measures

Many map-group children acquired a representation that included at least some information about the relative location of the animals from the map; otherwise they could not have anticipated the locations of unseen animals as well as they did on their first trip through the space. However, by the time they reached criterion, both groups had learned the space in the sense of learning a route through it. The postlearning tasks assessed whether the knowledge of the map and no-map groups was equal at the end of learning. If the no-map group's knowledge was limited to something like a "beads-on-a-string" representation, then they should perform worse than the map group on the postlearning tasks. On the other hand, if the no-map group had integrated their exposures to the playhouse, they too could have some knowledge of the relative location of the animals (see Hazen et al., 1978; Thorndyke & Hayes-Roth, 1982).

The inference task required children to name animals that were concealed behind doors that were not part of the route. This task, therefore, was similar to children's anticipation of unseen animals on their first trip through the playhouse; both tasks required identifying unseen animals concealed behind doors through which children had never traveled. There were five possible choices for each inference (the five animals excluding the one in the room from which the inference was made). Thus, chance performance was 20% correct. Both map (M = 57%) and no-map children (M = 49%) exceeded the chance level, $ts(24) > 3.58$, $ps < .001$. A 2(condition) × 2(age) ANOVA showed that no effects for condition were significant, $F < 1.0$, but that the main effect for age was, $F(1, 46) = 7.94$, $p < .01$. The map-group's overall performance on this task was nearly identical with their performance on the analogous anticipation task on their first trip through the playhouse (59% correct, first trip; 57% correct, inference).

Results were very similar for the pointing task in which children were required to identify a correct location for a named but unseen animal. Because children could point in only one of eight directions, chance was calculated as 12.5%. Both map (M = 65%) and no-map children (M = 53%) exceeded this chance level and indeed exceeded a more conservative 25% estimate, $ts(24) > 4.63$, $ps < .001$. A 2(condition) × 2(age) ANOVA was conducted to compare the performance of the map and no-

[2] Two inferential statistics are reported because neither is completely appropriate for the data. Hotelling's T^2 assumes that the data are normally distributed; however, the data here are proportions, and the variance of a proportion is related to its level (Fleiss, 1981). The chi-square test assumes that each observation is independent of all others. This is not true here because the data are repeated measures on the same subject. Although neither test is completely appropriate, the similarity of findings from the two quite different tests provides the needed confidence in the results.

map groups further. As on the inference task, only the main effect for age was significant, $F(1, 46) = 10.09, p < .01$.

The final postlearning task required children to anticipate the sequence of doors and animals when the original route was reversed. If children's knowledge of the space was limited primarily to a "beads-on-a-string" representation, they might be expected to have difficulty reversing the route (see Kuipers, 1982). However, children were good at this task. A 2(condition) × 2(age) ANOVA showed that only the main effect for age was significant, $F(1, 46) = 9.30, p < .01$. The difference between the map (M = 78.33% correct) and no-map groups (M = 71.67%) was not significant.

The map group outperformed the no-map group on all three postlearning tasks, but these differences were not significant. Thus, after reaching criterion the two groups' knowledge of the space was relatively equal, and information gained from the map no longer provided an advantage. Note, however, that the map group acquired this knowledge earlier, taking fewer trials to reach criterion; the no-map group had to rely solely on information acquired by traveling through the space.

Experiment 1b

We believe that the first trial unseen-location task provides the same sort of test of children's representation as that provided by the later inference task. Specifically, to be correct in either task, children had to identify unseen animals even though they had never traveled between the two locations (i.e., their current position and the position of the unseen animal). Still, these two tests do not incorporate the exact same questions. The first trial unseen-location test asked children about animals that would be straight ahead on the to-be-traveled route; the inference test asked children about animals sideways to that route (compare Figures 1 and 2). Of course, on the first trial children had never yet traveled the route, so in that sense the tests seem conceptually identical. However, if children somehow fortuitously acquired a beads-on-a-string representation of the to-be-traveled route, just from learning the map, the two tests would be different. In Experiment 1b we took the simple precaution of asking children, on their first trial, to answer all the unseen-location questions and all the inference questions used in Experiment 1a. This then made the first trial unseen-location test a comprehensive assessment of all possible configural adjacencies in the large playhouse, thereby testing more adequately children's representation of the total integrated layout.

That map-group children's performance was far from perfect in Experiment 1a raises the question of when near-perfect performance would be attained. Therefore, we also included a group of older children (6- and 7-year-olds).

Method

Subjects

Twenty-one preschoolers (4- and 5-year-olds, 51 to 70 months of age, M = 61) and 14 elementary-school children (6- and 7-year-olds, 79 to 91 months of age, M = 84) participated. Children were recruited from the same sources used in Experiment 1a.

Materials and Procedure

Because we had obtained findings for a no-map group in Experiment 1a and had demonstrated that no-map children's performance could be accounted for by the sampling-without-replacement guessing model, all children in Experiment 1b learned the map. Additionally, because of our focus on first trial performance, after learning the map children took a single trip through the playhouse. On this trip, they were asked 10 unseen-location questions, both the ahead questions shown in Figure 1 and the sideways (or inferences) questions shown in Figure 2.

Children learned the map in the same way as subjects in Experiment 1a, and on their subsequent trip through the playhouse, questions were posed in the same way as in that experiment. In rooms where children were asked both an ahead and a sideways question (e.g., in the frog's room in Figure 2), the order of these questions was randomized.

Results

For preschoolers, performance on the 10 unseen-location questions for Experiment 1b (M = 60%) was almost identical with that for the 6 unseen-location questions in Experiment 1a (M = 59%). In addition, in Experiment 1b preschoolers performed comparably on both the straight ahead and sideways unseen-location questions (Ahead M = 62%; Sideways M = 56%), $t(1, 42) < 1$, *ns*. Moreover, performance on the straight ahead and sideways questions was correlated, $r(19) = .64, p < .01$. Finally, preschoolers' performance on the sideways unseen-location questions (M = 56%) was almost identical with children's performance on the postlearning inference questions in Experiment 1a (M = 57%), $t < 1$, *ns*. Thus, the ahead and sideways unseen-location questions seem to access the same, integrated representation.

We compared the performance of these map-group preschoolers on the straight ahead unseen-location questions with the no-map group's performance in Experiment 1a and with the sampling-without-replacement guessing model validated for that no-map group. Map-group preschoolers in Experiment 1b (M = 62%) performed significantly better than the no-map preschoolers in Experiment 1a (M = 34%), $F(1, 44) = 20.934$, $p < .001$. Preschoolers in Experiment 1b performed significantly better than the predicted sampling-without-replacement probability model: Hotelling's $T^2 = 77.00$, $F(5, 16) = 12.32$, $p < .001$; $\chi^2(4, N = 105) = 59.60, p < .001$.

All the elementary-school children correctly answered 9 or 10 of the 10 unseen-location questions. Consequently they were more correct on unseen-location questions (M = 97%) than were the preschoolers (M = 60%), $F(1, 33) = 22.57, p < 001$.

Discussion

The results indicate that learning a map can significantly aid preschoolers in learning the spatial layout of a large-scale space. Children who learned the map in Experiment 1a required fewer trials to reach a route-learning criterion than children who did not learn the map. Moreover, the map groups in both Experiments 1a and 1b performed significantly better than the no-map children on the very first navigation trial. This difference is impressive because it demonstrates a unique advantage of learning a map—the map provides spatial information about relative locations. Note that no-map children also engaged in prior learning (specifically of the animal names) and no-map children used the information acquired initially as they answered the unseen-location questions. Nevertheless, they performed significantly worse than the map-group children.

Experiment 1a also shows that children can learn the spatial layout without a map, if given substantial first-hand exposure to the space. This conclusion is corroborated by the lack of difference in the performance of the map and no-map groups on any of the postlearning tasks; both groups had traveled through the space several times before completing these tasks. However, the no-map group took significantly more trials to acquire a representation that was comparable with the map group's. This finding replicates with young children similar findings with adults. Thorndyke and Hayes-Roth (1982) showed that, initially, adults who learn the layout of a large building from maps have significantly more adequate configural representations than adults who learn the layout from navigation. After repeated exposure to the layout, however, the differences between the two groups diminish.

That all 6- and 7-year-olds performed almost perfectly on the comprehensive unseen-location task of Experiment 1b suggests that the acquisition of an integrated representation of space from a map is a relatively well-established skill by the early school years. Moreover, even preschoolers seem to be able to acquire a reasonable sense of the layout of locations from a map. Nevertheless, many preschoolers were also substantially wrong in identifying locations on their first trial. Thus, in Experiment 2 we further investigated preschoolers' ability to acquire and represent information about the relative relations among several locations.

Experiment 2

In Experiment 2 we used a somewhat simplified space to explore young children's abilities. We disconnected the six rooms of the playhouse and placed them in a large room as shown in Figure 5. This made all six of the locations visible once inside the larger room, but the animals remained invisible within their smaller rooms. Thus, in comparison to Experiment 1 children had more immediate visual access to the configuration of the rooms themselves. Therefore, the space in Experiment 2 was a small-scale one, in the sense that it could be viewed in its entirety from a single vantage point (see Acredolo, 1981). The space in Experiment 1 was large-scale, although the measurements of the space in the two experiments were identical.

Increased visual access to the actual space could affect children's performance in two ways. First, if children have such visual access to the space *as they learn the map*, then it could enhance their understanding of exactly how the map (and its configuration of symbols) represents the space and its configuration. Without such access, preschoolers might have some difficulty realizing how the map represents an unseen space and the locations within it. However, even with such visual access, children must still acquire from the map an integrated representation of which animals could be found at which locations. Second, even if children had no such visual access while learning the map, visual access to the entire space could help children keep their bearings on their first trip through it. In Experiment 1, once within the playhouse children could only view the interior of a single room at a time, and all six rooms were identical except for the single identifying animal. This could make it relatively difficult for children to keep track of where they are in the space as they travel through it. Successful use of a map-acquired representation requires keeping track of one's orientation within a space, no matter how detailed and adequate the mental representation itself (Levine, 1982; Presson & Hazelrigg, 1984). In short, the space used in Experiment 2 might lead to enhanced performance because it (a) aids children's understanding of the map as a representation of the specific space or (b) aids use of the map-acquired information during navigation by helping children maintain their sense of where they are within the space.

To test these possibilities we compared children's performance in three conditions. *Map-inside* children learned a map of the space while seated in the larger room at a point giving visual access to the configuration of the smaller rooms. *Map-outside* children also learned a map of the space, but they did so while seated in the hall outside the larger room, with no visual access to the space itself while learning the map. *No-map* children did not learn a map; they learned the animal names. All children then received an unseen-location test as in Experiment 1.

Method

Subjects

Forty-five preschoolers (29 boys and 16 girls) participated. Their ages ranged from 48 to 71 months ($M = 60$). They were recruited from the same sources as Experiment 1. The number of children tested in the map-inside, map-outside, and no-map conditions was 18, 15, and 12, respectively.

Materials

Six large boxes (6.5 × 2 × 2 ft., or 1.98 × .61 × .61 m), much like large, free-standing closets, were constructed using the same Styrofoam insulation used in Experiment 1. These "rooms" were placed in a large, empty classroom as in Figure 5. Each room had a single curtain-door on one side; a stuffed animal was hidden in the room behind the curtain. The map was constructed in the same manner as in Experiment 1, except that the six separate rooms were shown instead of the interconnected playhouse. A photograph of the appropriate, hidden toy animal was placed in each room on the map.

Procedures

Initial training. Children were randomly assigned to one of three conditions. Inside-map children learned the map while seated in the larger room, at the position marked X in Figure 5. As in Experiment 1 the curtain to one of the nearest rooms was open, and children could see the animal in that room while they learned the map. The map-learning procedure was identical with that in Experiment 1a. Map-group children were told that they would first learn the map and then go around the room to see what animals were in the boxes. The entire learning procedure was timed.

The no-map condition was analogous to the no-map condition in Experiment 1a. Children saw one open room. They were seated at position X in Figure 5 and then learned the animal names using photographs.

The name learning procedures were identical with those used in Experiment 1a.

In the outside-map condition, children entered the larger room and briefly saw the single open room and its animal. They then immediately left the larger room and learned the map outside in the hallway. While learning the map, children were oriented in the same direction as children in the map-inside and no-map groups. During this learning children were behind a small screen; not only could they not see inside the larger classroom itself, they could not see the door of the classroom. The map-learning procedure was identical with the inside-map condition and with the map group of Experiment 1a.

Testing. The testing procedure was identical for all three conditions and was analogous to the first trial testing in Experiment 1a. However, there were no pointing or inferencing trials in Experiment 2, because children could view the entire layout of the rooms. After learning the map, the open room was closed, and children were asked to identify the animal that lived in the rooms on the U-shaped route (from A to B or B to A in Figure 5). As in Experiment 1a, the experimenter always began the unseen-location questions at the room opposite the one that was open initially. For example, if the child had seen the dog's room before learning the map, he or she began the trip around the larger room at the pig's room (see Figure 5). As in Experiment 1, the experimenter then followed a U-shaped route around the larger room, stopping before entering each room and asking the child to identify the hidden animal that lived there. This procedure was repeated at each room. When the child correctly anticipated an animal, the experimenter asked, "how do you know," before opening the curtain. Children's responses were recorded on tape for analysis.

Results

Learning the Map or Names

We chose the map- and name-learning criteria in Experiment 1a to ensure that both the map and no-map groups learned the materials and that the two groups had comparable exposure to the materials. To test whether exposure was comparable, we recorded learning time in Experiment 2. A one-way ANOVA showed that children in the three conditions required approximately the same time to learn the map or the animal names, $F(2, 42) < 1$, *ns*. Children in the map-inside, map-outside, and no-map groups required 6.43, 6.06, and 6.97 min, respectively, to learn the map or the cards.

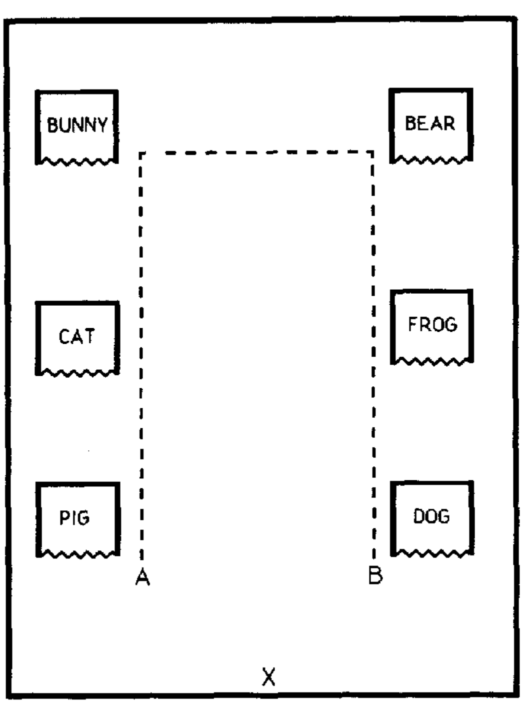

Figure 5. Layout of the space used in Experiment 2 and the U-shaped route. (The *X* represents the position at which the map-inside and no-map groups learned the map or the picture cards.)

Unseen-Location Performance

A one-way ANOVA on the number of animals correctly identified out of six revealed a main effect for condition, $F(2, 44) = 10.202$, $p < .001$. Scheffé post hoc contrasts showed that children who learned the map either in the room ($M = 84\%$) or outside the room ($M = 82\%$) anticipated significantly more animals correctly than did children in the no-map group ($M = 51\%$), $Fs(1, 43) > 14.35$, $ps < .01$. The performance of the two map groups did not differ significantly, and these groups therefore were combined in further analyses. A one-way ANOVA showed that the map groups in Experiment 2 ($M = 83\%$) performed significantly better than the combined map-group preschoolers in Experiments 1a and 1b ($M = 60\%$), $F(1, 77) = 16.45$, $p < .001$.

In Experiment 2, map-group children's responses were decidedly skewed toward correct performance: 0, 0, 1, 6, 3, 5, and 18 of the 33 map-group subjects answered 0, 1, 2, 3, 4, 5, or 6 unseen-locations questions correctly; 0, 0, 5, 2, 4, 1, and 0 of the 12 no-map children answered 0, 1, 2, 3, 4, 5, or 6 of the questions correctly. Note that in this experiment over 70% of the map-group subjects were near perfect, answering five or six of the questions correctly. Only 32% of the map-group children in Experiment 1a performed this well.

In Experiment 1a we found that the no-map group's performance conformed to a sampling-without-replacement model of guessing. In Experiment 2 the no-map group's performance again did not differ from the predicted sampling-without-replacement probability model: Hotelling's $T^2 = 14.54$, $F(5, 7) = 1.85$ $p = .22$; $\chi^2(4, N = 60) = 5.27$, $p > .05$. The map-group's performance in Experiment 2 was clearly superior to this model: $T^2 = 286.95$, $F(5, 28) = 50.22$, $p < .001$; $\chi^2(4, N = 165) = 169.00$, $p < .001$.

Children's Verbal Comments

During the unseen-location test, children were asked how they knew the correct answer when they answered correctly. Different patterns of response between the map and no-map groups revealed differences in the type and form of information available to them. The dependent variable for these comparisons was the proportion of each type of response. That is, for each child we divided the number of responses in each category by the number of total responses. Two-thirds of all map-group responses made reference to the map or to knowledge of the directional relation between animals as depicted on the map; not one no-map child gave this type of response, $F(1, 40) = 26.63$, $p < .001$. Some no-map group responses revealed evidence of the sampling-without-replacement guessing strategy;

14.89% of no-map group responses showed evidence of eliminating other animals, but only 2% of the map group responses showed evidence of this strategy, $F(1, 40) = 6.99$, $p < .05$. No-map children (33% of total responses) were also more likely than map-group children (7.7%) to say that they guessed, $F(1, 41) = 6.98$, $p < .05$.

Discussion

The results indicate that preschoolers' map-acquired representation of a space can support quite accurate identification of a configuration of hidden objects in that space on their very first trip through it. The perfect or near-perfect performance of over 70% of the children in the map-outside group is especially important in this regard. These children could not see the space while they learned the map and only briefly viewed the space initially. Most of them proceeded to identify correctly the location of five or six of the six hidden animals within the space. Children's map-acquired representations must have included the identities of what hidden animals were in which of the small rooms, and the clue to which room was which was the relative position of a room within the configuration of rooms. This task is somewhat simplified compared with that used in Experiment 1 because we used a small-scale space; nevertheless, map-group children's near-perfect performance seems to demonstrate the acquisition and use of an integrated mental representation.

Both the map-inside and map-outside groups in Experiment 2 performed better than the map groups in Experiment 1. Thus, continuous visual exposure to the space while learning the map does not seem necessary to ensure that preschoolers understand the map as a representation of a specified space. However, visual access to the space while using a map-acquired representation does seem helpful. This seems reasonable, because using a map to assist navigation through a space requires knowing not only (a) that and how the map represents the space, but also (b) where one is in the space in order to use the information available from the map relevant to one's current position (Levine, 1982; Vesely, 1985). Experiment 2 suggests that relative to 6- and 7-year-olds, preschoolers have trouble with the second requirement rather than with the first.

Research indicates that even adults often have trouble keeping track of where they are while using a map to navigate through a space. Adults can quickly lose their way when using maps that are improperly aligned with the represented space (see Levine, 1982; Presson & Hazelrigg, 1984). Map-reading manuals, such as the *Boy Scout Fieldbook* (see Levine, 1982), therefore, suggest that map readers establish orientation by comparing visible landmarks with their represented symbols on the map before using the map to navigate. The sole visible animal in any playhouse room in Experiment 1 was sufficient for older children to maintain an orientation, but apparently was insufficient for many of the younger children to do so. In Experiment 2, however, children could use the entire configuration of locations to help them maintain the orientation between their map-acquired representation and their current position in space. This developmental finding is thus consistent with research on children's ability to locate their current position on a map. Vesely (1985) showed that preschoolers were much worse than older children at establishing their current position on a map and that they were better in spatial environments that provided visual access to the configuration of locations (analogous to the Experiment 2 space) than in environments that did not (analogous to the Experiment 1 space).

General Discussion

The results of Experiments 1 and 2 shed new light on how young children represent information acquired from maps. Specifically, we claim that young children's map-acquired information can take the form of an integrated representation of the space. By integrated representation we mean a representation that captures the two-dimensional pattern or layout of spatial relations that corresponding objects exhibit in the environment. One alternative unidimensional representation would be to encode the location of a set of objects solely in terms of their proximity to or distance from a single landmark (Huttenlocher & Newcombe, 1984). This sort of representation would be unidimensional in that the single relation specified is each object's proximity to the landmark. Another alternative is a beads-on-a-string representation; here the single relation specified is each object's order, first to last, in a linear sequence.

The various map-groups' performances are unlikely to have been based on a simple encoding of information relative to a single landmark. Our map in Experiment 1 showed only the outline of the playhouse, and each of the rooms was depicted identically except for the presence of a unique animal. In Experiment 2 the map showed only the configuration of the six identical rooms. Neither map is easily construed in terms of "prototypical" landmarks, such as windows, doors, or chairs (i.e., prominent, distinctive items that are typically found in a room; see Huttenlocher & Newcombe, 1984), or in terms of an obvious single landmark. More important, map-group children performed much better than predicted by a contrasting guessing model and better than the no-map groups in anticipating the locations of the animals on their first trip through the larger spaces. Thus, the map groups demonstrated a significant amount of knowledge of the layout of the different animals, and some children were quite accurate. Indeed in Experiment 2, most children performed perfectly or near perfectly. Children could have represented the different animals as a network of landmarks, but representing a two-dimensional network of landmarks would constitute an integrated representation of the spatial layout.

It is similarly unlikely that map-group children acquired a beads-on-a-string representation because the maps specified no routes, and no route-like depictions such as roads, sidewalks, or hallways. In addition, in both Experiments 1 and 2, unless map-group children coincidentally acquired from the map the exact route that they would travel, a beads-on-a-string representation would not allow them to make the relational judgments needed to anticipate correctly the animals' locations on their first trip along the actual route through the space. Consistent acquisition of just the right ordered representation seems especially unlikely because children were taken on one of two different routes, and this difference had no effect on children's performance on their first trip through the playhouse. Moreover, in

Experiment 1b acquisition of a beads-on-a-string representation would not account for correct performance on sideways unseen-location questions, but children performed equally on the ahead and sideways questions in that experiment.

Given the characteristics of our maps, spaces, and procedures, the map group's ability to identify the location of unseen objects implicates an integrated representation. The exact nature and variety of integrated representations is a topic of much debate (see Anderson, 1983; McNamara, 1986). A strong and precise form of integrated knowledge might be survey knowledge. At least as some authors use the term (Levine, Jankovic, and Palij, 1982; Siegel & White, 1975), survey knowledge is literally map-like—representing the locations of all encompassed points in a two-dimensional configuration and capturing exact distance and angle relations as well. In such a representation, distances in a real space could be read off or computed from one's survey representation (McNamara, 1986). We have not shown that young children's map-acquired representations are this precise. Thus, our results represent a middle ground. We do not claim that preschoolers can acquire precise metric notions of space from maps (Landau, 1986), but they do acquire more than single landmark-based representations (Presson, 1982). Acquiring some sense of spatial layout from a map is an important ability, because communicating information about the relative spatial relations among several locations is a key feature of real maps (see Robinson & Petchenik, 1976). Our results show that even preschoolers can take advantage of this sort of spatial information available in maps.

We agree, however, with other researchers (e.g., Liben & Downs, 1986; Presson, 1987) who suggest that the acquisition of full competence in map reading is an extended developmental achievement. The map-group's performance in Experiment 1 was significantly better than the no-map-group's performance but significantly worse than that of 6- and 7-year-olds. Moreover, our maps were relatively simple ones, and few symbolic map conventions were used (e.g., the map showed photographs of the represented objects). Furthermore, map-group children did not just view the maps, they memorized them.

Finally, our subjects received some exposure to the space itself before or while learning the map. In exposing children to the space itself our procedures parallel those of other research on preschoolers' use of maps (Bluestein & Acredolo, 1979; Presson, 1982) and mimic many everyday map-reading experiences in which a person uses a map while within the represented space. If anything, our procedures provide preschoolers with considerably less initial exposure than in prior studies. For example, in Bluestein and Acredolo's (1979) research, children always were oriented to the map while inside the represented space before attempting more difficult conditions, such as reading the map outside the space. In our studies the map groups of Experiment 1 could see the interior of only a single room and could not see the configuration of the rooms of the playhouse while learning the map, and the map-outside group of Experiment 2 had only a brief initial glance at the space. In these ways our findings substantially reduce the estimate of what sort of prior information about the space preschoolers might need in order to comprehend and use a map of it. However, we have not addressed whether or to what extent preschoolers can understand an unknown space simply by seeing a map of it. This is an intriguing question for future research.

Because our results reveal impressive map-reading abilities in preschoolers, we believe that maps may be more useful to young children in their acquisition of spatial information than previously suspected. Children learned our map with no specific instruction on how the information would be used and subsequently accessed their map-acquired information to apply it to a novel task. This suggests that young children can and do readily acquire a significant amount of information about a space from a map. Other studies of children's map-reading abilities (Bluestein & Acredolo, 1979; Presson, 1982) have used much more intensive instruction and familiarization experiences to identify the correspondence between map and space, and children were told explicitly that the map would help them find desired objects. Although we required memorization of the map, we provided no instruction about map use. Nevertheless, preschoolers demonstrated sufficient competence with simplified maps to represent integrated information contained in such maps and to apply that information spontaneously to novel navigation tasks.

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