Physical Similarity and Young Children's Understanding of Scale Models

Judy S. DeLoache, Valerie Kolstad, and Kathy N. Anderson

University of Illinois

DELOACHE, JUDY S.; KOLSTAD, VALERIE; and ANDERSON, KATHY N. *Physical Similarity and Young Children's Understanding of Scale Models.* CHILD DEVELOPMENT, 1991, **62**, 111–126. Young children's understanding of the correspondence between a scale model and a larger space is affected by the degree of physical similarity between the 2 spaces. In 4 studies, children between 2.5 and 3.5 years of age watched as a miniature toy was hidden somewhere in a scale model of a room. They were then asked to find an analogous toy that was hidden in the corresponding place in the room itself. The effects of different levels of 3 types of physical similarity were investigated. In general, the children's retrieval scores increased as a function of increasing similarity, although younger children required a higher degree of similarity to appreciate the model-room correspondence than did older children. Some types of similarity were more important than others: The level of similarity between the objects within the 2 spaces and of the overall size of the spaces both had large effects on the children's performance. Similarity presumably affects accessibility, the likelihood that children's representation of one space will provide access to their representation of the other space.

A hallmark of mature human cognition is its flexibility. Information and skills acquired in one context are readily activated, generalized, and transferred to other appropriate contexts. Lower organisms and developmentally immature humans exhibit less flexibility; skills and knowledge are more tightly welded to the original contexts in which they were acquired (Brown & Campione, 1984). When young or delayed children learn a particular rule or some information in a given situation, they may fail to apply it in related situations in which it would be appropriate to do so. The new situation may fail to activate or provide access to their representation of the rule or the information. Hence, a crucial aspect of early development is increasingly flexible access—the activation of a representation by a variety of contexts or objects related, but not identical to, those involved in its acquisition (Mandler, 1983).

One variable that promotes access is physical similarity: The more two objects or situations resemble one another, the more likely it is that perception of one will activate a person's knowledge representation of the other (Gentner, 1989; Gentner & Landers, 1985; Ross, 1987; Smith, 1989a, 1989b). Thus, similarity is important in any situation in which a person must detect and reason about the relation between two entities. For example, upon hearing a story or being presented with a problem in an analogical reasoning task, people are more likely to think of an analogous story or problem if the new and old ones share numerous surface or perceptual similarities (Gentner & Landers, 1985). Surface similarity between analogues seems to be especially important for young children (Brown & Kane, 1986; Gentner & Toupin, 1986; Holyoak, Junn, & Billman, 1984). Gentner and Toupin (1986) reported that 4– 6-year-old children who first heard a story with a chipmunk, robin, and horse as characters readily transferred the plot to a second story with a set of characters highly similar to the first (squirrel, robin, and zebra) but were much less successful with a set of dissimilar characters (elephant, shark, and cricket).

This article is concerned with the effect of physical similarity on reasoning in young children. A dramatic developmental difference was recently reported in young children's detection and understanding of the relation between a scale model and the larger space it represented (DeLoache, 1987). In this article, we examine the role of physical similarity in this phenomenon.

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In this research, a young child watches as a miniature toy is hidden somewhere in a scale model of a room. Then the child is asked to retrieve a larger, analogous toy concealed in the corresponding place in the room itself. For example, a child observes a tiny toy dog being placed behind the miniature couch in the model and then searches for a larger toy dog that is hidden behind the full-sized couch in the room. (Other children first see the larger toy being hidden in the room and are asked to retrieve the miniature toy from the model. For ease of communication, we shall refer to the situation in which the hiding event occurs in the model.) To succeed in this task, children must: (1) detect the correspondence between the model and the room, (2) map the elements of one space onto those of the other, and (3) use their knowledge of where the miniature toy was hidden to figure out where the larger toy must be.

In the original study using this task, a large difference was found in the retrieval performance of groups of young children only a few months apart in age (DeLoache, 1987). The 3-year-olds who had watched a toy being hidden in the model knew where to find the analogous toy in the room; they went directly to it 77% of the time. In contrast, the 2.5-year-old children's retrieval score (15%) was at chance; they had no idea where to find the hidden toy.

These retrieval results reveal differences in the children's detection of the basic correspondence between the two spaces (DeLoache, 1989a, 1989b, in press). The 3.0-year-olds realized that the model and the room were related, so they transferred what they knew about the model to the room. The 2.5-year-olds, in contrast, seemed unaware that the model and the room had anything to do with each other. Hence, what they learned about the model remained specific to it and was not transferred to the room. Their failure was especially dramatic, given the fact that the correspondence between the two spaces was explicitly described. The experimenter told the children that the two toys were just alike except for size, that the model and the room were alike except for size, and that the two toys would always be hidden in the same places in the model and room.

It is important to note that the large discrepancy in the success of these two age groups was not due to differences in memory for the location of the toy they had originally observed being hidden in the model. When asked to retrieve that toy, both groups were highly successful (88% and 83% for the older and younger children, respectively). This level of memory performance is very similar to that reported for very young children in other location memory tasks (DeLoache, 1985; DeLoache & Brown, 1983, 1984; DeLoache, Cassidy, & Brown, 1985).

Two factors have been hypothesized to be the primary determinants of whether young children detect the model-room correspondence (DeLoache, in press): (1) insight into the representational nature of the model, and (2) perception of the physical similarity between the room and the model. The latter is the main focus of the experiments reported in this article. The former is relevant to this research, so it will also be described here.

Representational insight.—A scale model has the rather peculiar property of being both a salient real object itself and a symbol of something else. To succeed in the model task, children have to adopt a dual orientation to the model; they have to think of it in two different ways at the same time—as what it really is, an object (or set of objects), and as a symbol of something else, the room. When they watch a toy being hidden in the model, they have to think about that toy and its particular hiding place in the model, and they also have to think about the larger toy and the corresponding place in the room. In other words, the children must treat the model both concretely and abstractly, as object and as symbol.

Difficulty in achieving a dual representation of a single reality was hypothesized to be responsible for the extremely poor performance of the 2.5-year-old subjects in the original model study (DeLoache, 1987). It was suggested that very young children might find it difficult to think of one thing in two different ways and that it might be especially hard for them to think of an attractive, complex, real object (such as a model) as a symbol of something else; its salience as an object might lead them to represent it in only one way. This reasoning suggested that young children should be more successful at retrieving a hidden object if they were informed about its location by some means that did not require a dual orientation.

Accordingly, 2.5-year-old children's performance was compared when they were given information about the location of a hidden object via (*a*) a scale model of the room versus (*b*) pictures of the room (DeLoache, 1987, Experiment 2). The pictures represented the various hiding places in the room, just as the model did, but because of their nature, they did not require a dual orientation. The primary function of a picture is to represent something else; its status as a real object is secondary. When one looks at a picture, one normally thinks only of what it represents, not of the picture as an object itself. In agreement with the dual orientation hypothesis, the 2.5-year-old subjects successfully exploited the information in the pictures to retrieve the toy; however, the same children failed to apply the comparable information from the model to the room. Thus, 2.5-year-old children transfer information when they understand that the object providing the information (a picture) represents something else to which that information is applicable. When they do not interpret one object (a model) as a symbol for another, they fail to transfer what they learn about the first to the second.

Physical similarity.—The second factor hypothesized to have an important role in determining whether young children detect the correspondence between a model and the larger space it represents is physical similarity—the degree to which the model and the larger space look alike (DeLoache, in press). The 2.5-year-olds' failure in the model task is an accessibility problem; their experience in the room does not gain access to their representation of the model and the hiding event they observed in it. We know they have a good representation of the location of the toy they watched being hidden in the model because they are very good at retrieving the toy later. However, that representation remains isolated from their representation of the room.

Given the evidence that perceptual similarity facilitates access to an analogy or other relations among entities (e.g., Gentner & Landers, 1985; Ross, 1987; Smith, 1989a, 1989b), it seems reasonable to expect that the degree of physical similarity between a scale model and a larger space would affect young children's detection of the correspondence between the two. Thus, the goal of the four studies reported here was to investigate the effects of different types and different levels of physical similarity between a scale model and the larger space it represents.

Experiment 1

In the first study in this series, the effect of two types of physical similarity was examined. One was object similarity—the extent to which the corresponding objects in the two spaces resembled one another. Object similarity has been shown to be important in gaining access to an analogy, that is, seeing the relation between two analogues (Gentner & Landers, 1985). Therefore, it was expected that the degree of surface similarity of the objects in the model and room would affect the children's detection of the correspondence between the two spaces.

The second type of physical similarity that was investigated was of the surrounding walls of the two spaces. It was assumed that the surface appearance of the walls would be a less salient source of similarity than would the objects within the spaces, but that it might still contribute to overall similarity. Hence, this manipulation was included to gauge the extent of the children's sensitivity to similarity. There were two levels of similarity—high and low—for each of the two types, resulting in four conditions. To see how the different levels and types of similarity interact with age, two age groups (2.5- and 3.0-year-olds) received each of the four similarity conditions.

Method

Subjects.—The subjects for Experiment 1 were 70 children (35 females and 35 males), including an older group of 35 3.0-year-old children (36–41 months, M = 38 months) and a younger group of 35 2.5-year-olds (29–33 months, M = 31 months). Approximately equal numbers of older and younger subjects were assigned to each of the four experimental conditions. An additional eight children were eliminated from the study, seven for failing to cooperate sufficiently and one because his mother repeatedly labeled the hiding places for him. Names of potential subjects were obtained from files of newspaper birth announcements and from local day-care centers. Parents were contacted by telephone. The sample was predominantly white and middle class.

In this and all the subsequent studies reported here, half the subjects were assigned to one hiding space condition (hide-in-model/retrieve-in-room), and half were assigned to the opposite (hide-in-room/retrieve-in-model). In addition, half the children received one order of the individual hiding places used for the test trials, and half received the reverse order. To the extent possible in each study, age, experimental condition, gender, hiding space, and order of hiding places were all counterbalanced with each other (in that order).

Apparatus and materials.—In order to manipulate the level of similarity between a larger space and a model representing it, an artificial room and two corresponding models

TABLE 1

CORRESPONDING OBJECTS IN HIGH- AND LOW-OBJECT-SIMILARITY CONDITIONS

	MODEL	
EXPERIMENT 1, ARTIFICIAL ROOM	High Object Similarity	Low Object Similarity
Solid blue chair	Solid blue chair	Solid rust chair
Tan wicker basket	Tan wicker basket	Pink plastic wastecan
Green print floor pillow	Green print floor pillow	Blue corduroy floor pillow
Brown four-drawer dresser	Brown four-drawer dresser	Tan two-drawer dresser
	SMALLER SPACE	
EXPERIMENT 2a, LARGER SPACE	High Object Similarity	Low Object Similarity
Solid grey chair	Solid dark blue chair	Solid rust chair
Brown wicker basket	Brown wicker basket	Tan wicker basket
Solid green floor pillow	Green print floor pillow	Orange checked floor pillow
Brown four-drawer dresser	Brown four-drawer dresser	Blue four-drawer dresser

were constructed. The room measured 2.57 × 1.85 × 1.88 m high and was large enough for a child and an adult to move around in. It was made of a framework of plastic pipes supporting walls of opaque white fabric. An opening in the center of one wall served as the entry, and a clear plastic window flanked by curtains was on a side wall. The artificial room was furnished with a floor pillow, basket, fabric-covered chair, chair pillow, rug, and a dresser and a set of shelves made of heavy cardboard.

The design called for independently manipulating the similarity between the individual hiding places within the two spaces and the similarity of the surrounding walls of the spaces. Two models of the artificial room were constructed. The high similarity of surround model (62.9 × 48.3 × 38.1 cm) was constructed of the same materials as the artificial room—plastic pipes and white fabric walls. The low similarity of surround model (69.9 × 45.7 × 38.1 cm) was a cardboard box covered with white paper. Both models were completely open on the side on which the entryway was located in the room.

For the object-similarity manipulation, the surface appearance of the objects within the model was either made to look as much as possible like their larger counterparts in the room (high object similarity), or their surface appearance was made to be quite different (low object similarity). Table 1 lists the corresponding objects in the two object-similarity conditions.

In all conditions, the artificial room was situated within a much larger room, with the appropriate model resting, in the same spatial orientation, on the floor beside it. Figure 1 shows the layout of the spaces. The child could see the model and the outside of the artificial room at the same time, but it was impossible to view the objects within the two spaces simultaneously.

Procedure.—The following procedure was used, with minor variations, in all the studies reported here.[1] Each child was accompanied to the laboratory by a parent or preschool teacher. Each experimental session began with an extensive orientation phase during which the experimenter explicitly pointed out the correspondence between the model and the room. She began by presenting the two toys that would be hidden, introducing one as "Big Snoopy" (a stuffed dog 15 cm high) and the other as "Little Snoopy" (a plastic dog 2 cm high). She then took the child into the artificial room and pointed out its furnishings: "This is Big Snoopy's big room; Big Snoopy has lots of things in his room." The experimenter named all the items of furniture in the room. The child was then taken out and shown the model: "This is Lit-

[1] There was one exception to the standard procedures. In Experiment 1, the children were given imitation hiding and retrieval trials during the orientation, in addition to the standard orientation described. Comparison among a large number of model studies has shown that different amounts of practice trials during the orientation phase make no difference in children's subsequent retrieval performance (DeLoache, 1989a).

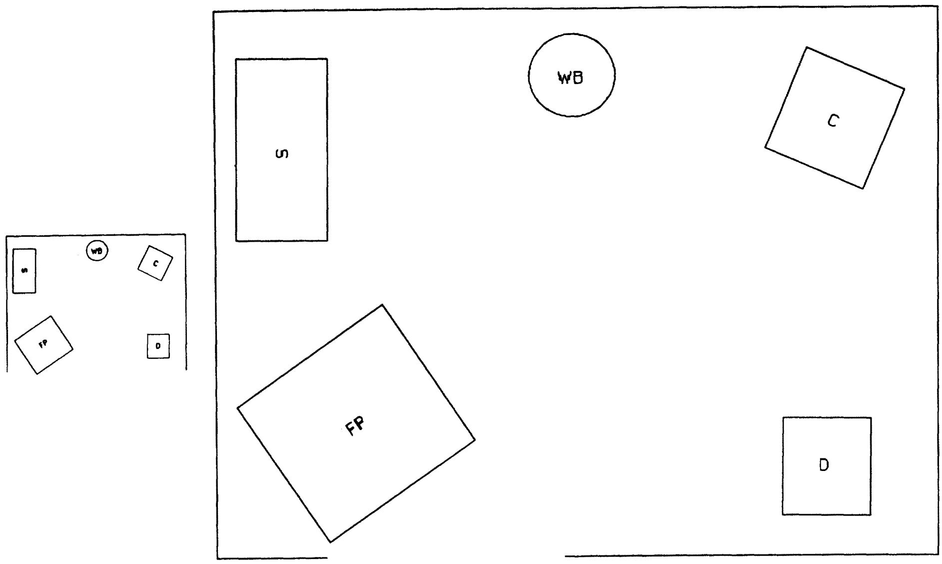

FIG. 1.—Layout of the model and artificial room

tle Snoopy's little room. He has all the same things in his room that Big Snoopy has." The experimenter again labeled each object within the space. She then demonstrated the correspondence between the pieces of furniture in the two spaces by carrying each item of furniture from the model into the room, holding it up to its counterpart, and remarking upon the relation between them: "See Little Snoopy's chair; Big Snoopy's chair is just like it, only it's a lot bigger."

Next, the experimenter tried to convey the idea that actions within one space corresponded to actions in the other space. For this part of the orientation, as well as for the subsequent trials, space was counterbalanced; the experimenter placed and hid the large toy in the room for half the subjects and the miniature toy in the model for the other half. (For ease of communication, we will continue to describe and use examples from the hide-in-model/retrieve-in-room condition.) The experimenter explained to the child that "Big and Little Snoopy like to do the same things. Whatever Little Snoopy does in his room, Big Snoopy likes to do in his room too." She put the small toy on the shelf in the model and tried to get the subject to imitate her placement by putting the larger toy in the corresponding location in the room. "Little Snoopy is sitting here; can you put Big Snoopy in the same place in his room?" If necessary, the child was prompted—"Remember, Little Snoopy is on his shelf. Big Snoopy wants to sit on his shelf too. Can you put him there?"[2] The motivation for this extensive orientation sequence was to provide the children with substantial, explicit information about the room-model correspondence.

[2] Although the children's performance on the placement trial(s) during the orientation was not a focus of his research, it resembled their retrieval 1 performance on the experimental trials (reported in the Results section). The two older groups that were successful on the retrieval trials were reasonably successful at imitating the experimenter's placement of the toy during the orientation (high-high, 67%; high-low, 71%); the other two older groups were less successful on the imitation trials (low-high, 58%; low-low, 38%), just as they were on the subsequent retrieval trials. The younger subjects were generally unsuccessful on the imitation trials (high-high, 25%; high-low, 29%; low-high, 29%; low-low, 21%). These results are consistent with those in an earlier study (DeLoache, 1989b, Experiment 2) in which 2.5- and 3-year-old children were given a series of four placement imitation trials just like those used in the orientation phase here. The 3-year-olds successfully imitated (75% correct) the experimenter's placements of the toys (i.e., after watching the experimenter put Little Snoopy on the miniature table in the model, they placed Big Snoopy on the full-sized table in the room), whereas the 2.5-year-old children did not imitate (16%). These results lend further credence to the claim that the crucial factor underlying children's performance in the model task is their realization of the correspondence between the two spaces. If children are unaware of the correspondence, it does not matter whether they are asked to place or retrieve a toy; they have no basis for doing either. If they are aware of the model-room correspondence, they can readily carry out either of these simple acts.

Immediately following the orientation phase, each child received four test trials, each of which involved three parts. (*a*) *Hiding Event:* The child watched the experimenter hide the miniature toy somewhere in the model, with a different hiding place used for each trial. The experimenter always called the child's attention to the act of hiding, but she never referred to the hiding place by name. "Look, Little Snoopy is going to hide here." The experimenter then told the child that she would hide the large toy "in the same place in his big room." The same four hiding places (in two orders) were used for all subjects. (*b*) *Retrieval 1—Analogous Object:* Without retrieving the toy he or she had seen being hidden, the child was led into the adjoining room and asked to find the analogous toy. On every trial, before permitting the child to search, the experimenter provided a reminder: "Remember, Big Snoopy is hiding in the same place as Little Snoopy." If the toy was not found on the first search, the child was encouraged to continue searching other locations, and the experimenter reiterated that the large toy was in the "same place" as the small one. If this failed to elicit a correct search, the experimenter provided increasingly explicit prompts (without ever naming the hiding place) until the child found the object. ("Remember, Little Snoopy is hiding behind his chair; Big Snoopy is in the same place." Then, if the child had still not retrieved the toy, "I think Big Snoopy is hiding somewhere over here," gesturing in the direction of the hiding place.) The point of the sequence of prompts was to maintain the child's motivation for the task; however, only the child's first search counted as retrieval data. After retrieving the large toy, either on the first or a prompted search, the child was taken back to the model. (*c*) *Retrieval 2—Original Object:* Next, the child was asked to retrieve the miniature toy that he or she had observed being hidden in the model at the beginning of the trial. Retrieval 2 was thus a standard memory trial. The child was again prompted to continue searching if the first search was incorrect, and the trial always concluded with the child's retrieving the toy. Retrieval 2 was crucial for interpreting the data. If the child could find the original toy on Retrieval 2, then poor performance on Retrieval 1 could not be due to simple forgetting or lack of motivation.

Results

Figure 2 shows the proportion of errorless retrievals achieved by the two age groups in each of the four experimental conditions. To count as an errorless retrieval, the subject's *first* search had to be correct. To summarize the results shown in Figure 2, the expected high level of retrieval 2 performance was found for all groups, but there was substantial variation in the retrieval 1 results. The level of perceptual similarity between the artificial room and the model affected the children's performance. Retrieval 1 was better with higher levels of similarity and poorer with lower similarity. Similarity of the individual hiding places (objects) was more important than similarity of the surrounding walls. The older group was more successful than the younger on retrieval 1.

The retrieval 1 data were analyzed in a 2 (object similarity: high, low) × 2 (surround similarity: high, low) × 2 (age: 2.5, 3.0) × 2 (hiding space: hide-in-model, hide-in-room) ANOVA. Preliminary analyses indicated no effect of gender (female $M = 61\%$, male $M = 60\%$) nor any interactions with it, so it was not included in the analysis.[3] Two main effects were significant: object similarity, $F(1,54) = 25.43$, $p < .001$; and age, $F(1,54) = 11.15$, $p < .01$. Retrieval 1 was better with high object similarity (56%) than with low object similarity (21%), and the older group was more successful on retrieval 1 (49%) than the younger group was (29%). The two-way interaction between these variables was also significant, $F(1,54) = 8.83$, $p < .01$. Post hoc tests showed that the older subjects performed better in the high- (77%) than in the low-object-similarity condition (21%), $t(33) = 6.04$, $p < .001$. This difference for the younger group (36% vs. 20%) was in the same direction but was not significant. The main effect for surround similarity (high = 45%, low =

[3] Preliminary analyses of gender effects were done in all the subsequent studies reported here. As this variable never had any effect, it was eliminated from all the analyses. An alternative way of analyzing the data from Experiment 1 would be to perform a MANOVA with the same between-subjects variables as in the reported analysis, but with retrieval 1 versus retrieval 2 as a within-subjects variable. That analysis was conducted for the Experiment 1 data, with the same results as those reported, plus a highly significant main effect for retrieval. However, in some of the experiments reported here, the primary question was whether there was a significant difference between groups on retrieval 1. A conservative approach was taken of analyzing retrieval 1 and retrieval 2 separately so that any differences on retrieval 2 could not affect the retrieval 1 comparison. To be consistent across the four studies reported here and to facilitate cross-study comparisons, the two retrieval scores were always analyzed separately.

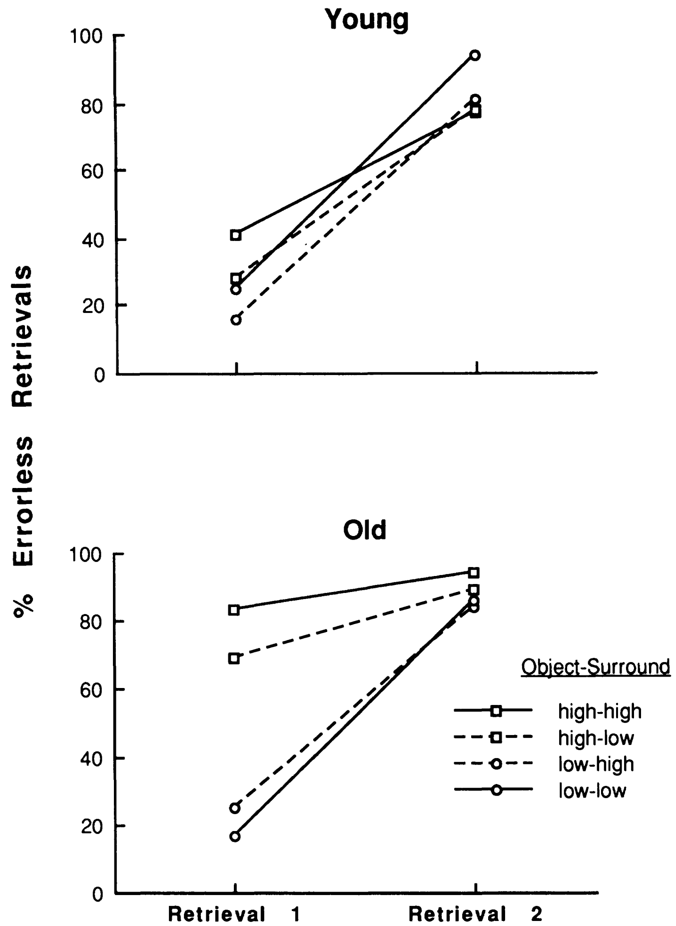

FIG. 2.—Retrieval performance as a function of age and similarity condition

33%) did not approach significance ($p = .16$), nor did any interactions with it. The lack of an effect or hiding space is consistent with the earlier studies (DeLoache, 1987, 1989a).

The same analysis performed on the retrieval 2 data produced no significant effects. All the retrieval 2 scores were equivalent.

The individual retrieval 1 scores were examined to see if they corresponded to the pattern found in earlier studies in which performance seemed to be all or none (DeLoache, 1987, 1989a); that is, almost all children were either highly successful or markedly unsuccessful. In the present study, 24 of the 70 subjects had retrieval 1 scores of 0; they never found the analogous toy on their first search. A nearly equal number (20) were highly successful; 11 of these children had perfect performance, and another nine made only one search error. The remaining 26 children were in between, with 12 of them succeeding 50% of the time. Thus, the individual data from the present study do not reveal strongly dichotomous performance; a substantial percentage of the children performed at an intermediate level.

Discussion

The results of this experiment clearly established that perceptual similarity influences young children's ability to reason from a scale model to a larger space (or vice versa). Such a finding was expected based on the analogical reasoning literature, where it has been shown that a high degree of surface similarity between two analogues helps children gain access to the analogy (e.g., Brown & Kane, 1986; Gentner & Landers, 1985).

In the present experiment, two different aspects of physical similarity were manipulated—the surface appearance of the objects (furniture) within the two spaces and the surface appearance of the surrounding walls of the spaces. Object similarity had a pronounced effect on retrieval 1 performance.

The children were much more successful at applying what they knew about the model to the room (and vice versa) when the objects in the two spaces looked very much alike than when they were dissimilar in appearance. This effect was substantially larger for the older subjects than for the younger ones. Surround similarity did not have a significant effect, although retrieval 1 performance was somewhat better in the high-surround-similarity than in the low-surround-similarity condition.

It must be stressed that the children who did poorly were deficient in only one aspect of the experimental task—using their knowledge to draw an appropriate inference. They understood that there were toys hidden in the spaces and that they were supposed to search for the toys. They used their memory for where they had seen one of the toys being hidden to find it, and they cheerfully searched for the other one as well. However, they simply did not realize they had any way of knowing where it was.

The most dramatic results of this experiment came from the older children—the extreme deterioration in their performance with low levels of object similarity (only 21% in the low-object-similarity condition). The conceptual equivalence of two spaces is, for 3.0-year-old children, still very much rooted in perceptual similarity.

In contrast to the retrieval 1 results, neither similarity manipulation affected the children's retrieval 2 performance; they were equally good at remembering where they had seen a toy hidden, regardless of similarity condition. The uniformly high level of retrieval 2 performance is consistent with previous model studies with these same age groups (DeLoache, 1987, 1989b), and it is also the level reported for very young children in regular memory for location tasks (DeLoache, 1985).

It makes sense that similarity affects retrieval 1 but not retrieval 2 performance. Similarity is a characteristic of the *relation* between the two spaces. Hence, it affects the measure of the children's performance that reflects their understanding of that relation —retrieval 1—but has no effect on the measure that is independent of the relation—retrieval 2.

One difference between the present results and those obtained in previous model studies is the fact that performance was not strongly all or none; a substantial number of subjects achieved intermediate retrieval 1 scores (i.e., 25%–50% correct). It may be that similarity affected the children's performance in two different ways. (1) It may have helped some subjects to catch on to the overall relation between the model and room, leading to a high level of success. (2) High similarity may also have helped some children to note the relation between individual objects (e.g., miniature and full-sized dressers) without being aware of the overall relation between the two spaces. In this second case, the child might make one or two successful retrievals without fully understanding the task.

One might expect that, with development, children would be less reliant on perceptual similarity. Gentner (1988) asserts this in her relational shift hypothesis. She claims that young children (and novices in any domain) rely on "mere appearance" or surface similarity among objects in making various kinds of judgments more than do older subjects (and experts). For example, given a metaphor such as "a cloud is like a sponge," younger children (5-year-olds) tend to offer interpretations based on matching surface attributes of objects—"they're both round and fluffy." Older children (8-year-olds) interpret the same metaphor in terms of similarity of underlying relational structure—"they both hold water and give it back." Thus, the younger and more inexperienced the subjects, the greater the effect of surface similarity.

The interaction of age and similarity in Experiment 1 was the opposite of this pattern—similarity had a greater effect on the performance of the older subjects than the younger ones. However, almost none of the younger children, other than in the high-high condition, showed any sign of recognizing the room-model correspondence. The similarity manipulation may have been ineffective because these subjects were so far from understanding the task that it was irrelevant. However, the predicted pattern of increasing performance with increasing similarity should appear at the other end of the continuum. If children older than the older group (the 3.0-year-olds) in Experiment 1 were tested, one would expect them to be less dependent on surface similarity in the model task. In other words, children older than 3 years of age should be able to detect the underlying structural correspondence between the model and room even when the objects within them are quite dissimilar in appearance. In Experiment 1a, a group of 3.5-year-old children was tested in the low-low condition of Experiment 1 to see if their performance would be superior to that of the 3.0-year-olds in that study.

Experiment 1a

Method

Subjects.—The subjects for Experiment 1a were eight 3.5-year-old children (four females and four males, 42 to 46 months, M = 44 months). No subjects were eliminated.

Materials and apparatus.—The artificial room and the low object–low surround similarity model from the first experiment were used in this study. The same toy dogs served as the hidden objects.

Procedure.—The procedure for Experiment 1a was the same as that for Experiment 1.

Results

The 3.5-year-old sample scored 84% for retrieval 1 and 94% for retrieval 2. This level of retrieval 1 performance was clearly superior to the 17% achieved by the 3.0-year-olds (the older group) in the low-low condition in Experiment 1. Six of the eight children in the 3.5-year-old group succeeded in the task (scored 75% or better on retrieval 1), compared to only one of the nine children in the 3.0-year-old group, a significant difference by Fisher's exact test ($p < .05$).

Discussion

Combining the results of Experiments 1 and 1a, a pattern of decreasing dependence on physical similarity emerges. The 3.5-year-olds tested in Experiment 1a were successful with a level of similarity that produced chance performance in children a few months younger. This oldest group appreciated the correspondence between the two spaces even when both the objects and walls looked different, whereas the 3.0-year-olds seemed unaware of the room-model correspondence in the low-object-similarity condition. These children were very successful so long as the objects—the hiding places—within the two spaces looked alike. The 2.5-year-olds were even more restricted; only with the highest level of physical similarity (both objects and surround) did the youngest group perform above chance on retrieval 1. Thus, as has been observed in other domains (Gentner, 1988), there was a clear decrease with age in the children's reliance on perceptual similarity in relational reasoning.

Experiment 2

Experiment 1a extended the results of Experiment 1 by testing an older group of children with a very low level of similarity. Experiment 2 extends the results of the first study in the opposite direction. The fact that the 2.5-year-olds' performance was elevated somewhat in the high-high condition of Experiment 1 is interesting, since the performance of this age group has been extremely poor (i.e., 15%–20% on retrieval 1) in previously published reports (DeLoache, 1987, 1989b), as well as in the other three conditions of Experiment 1. The presence of this relatively small but positive effect suggests that if the level of physical similarity between the room and model were further increased, 2.5-year-olds might do better; they might understand that the model and the room correspond to each other and that what happens in one has implications for the other.

A dimension on which the room and model have differed substantially in all the previous studies is scale or size. In the earlier research (DeLoache, 1987, 1989b), the room and model differed markedly in overall size; the size ratio of model to room was approximately 1 to 7. They were also different kinds of spaces. The model was a small-scale space; it was surveyable—the whole thing could be seen at once—and it did not surround a viewer (even a very short one). The room, in contrast, was a relatively large-scale space; it was not surveyable at one time, and a viewer was surrounded by it. With respect to the artificial room and models used in Experiments 1 and 1a, the size difference was smaller (an approximate ratio of 1 to 4), but the model was still a small-scale surveyable space and the artificial room a surrounding space.

The degree of size disparity between the two spaces might very well influence how easy or hard it is to realize the correspondence between the two. For one thing, spatial cognition researchers have warned that some processes or behaviors might be different in large- versus small-scale spaces (Acredolo, 1977; Siegel, Herman, Allen, & Kirasic, 1979). In addition, in terms of overall similarity, a model closer in size to the larger space it represents would probably just simply look more like it.

Experiment 2 was designed to investigate the effect of size similarity on 2.5-year-old children's performance in the model task. In Experiment 2, the question was whether 2.5-year-old children's retrieval 1 performance would be affected by the degree of size difference between the model and room. To examine this issue, two groups of children were given a model task in which, for both

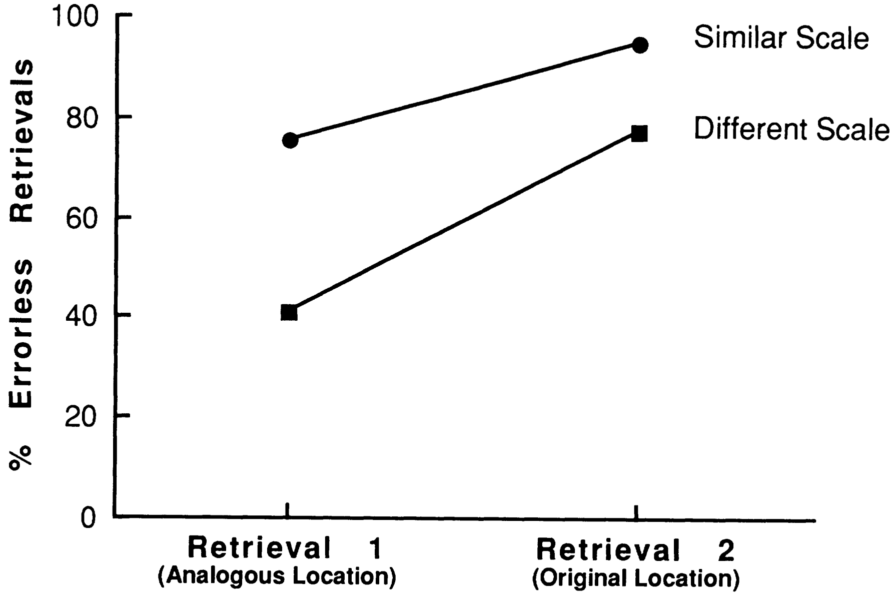

FIG. 3.—Retrieval performance of 2.5-year-old children as a function of size similarity. For the similar-scale condition, the corresponding spaces were both small-scale. For the different-scale condition, there was one large- and one small-scale space.

groups, there were high levels of similarity of objects and of surround. The only difference between the groups was that for one group the model and corresponding larger space were very similar in size, and for the other group, the spaces were of very different sizes.

Method

Subjects.—The subjects in the similar-scale group were 10 2.5-year-old children (five boys and five girls, 29 to 32 months, M = 31 months). The different-scale group comprised the 11 children (five boys and six girls) of the same age (M = 31 months) who had served in the high-high similarity condition of Experiment 1. No subjects were eliminated.

Apparatus and materials.—For the similar-scale condition, two small-scale spaces were used, that is, two nonsurrounding spaces. In both cases, even if a child knelt down to retrieve an object, he or she could see over the walls. One space (the high-high similarity model from Experiment 1) measured 62.9 × 48.3 × 38.1 cm, and the second was approximately twice as large as the first, measuring 92 × 70 × 61 cm. The external walls of both spaces were constructed of opaque white fabric supported by plastic pipes (high surround similarity). The two spaces were situated in the same spatial orientation approximately 1 m apart within a much larger room. A tall partition separated them, so the child could see only one at a time.

The furnishings of the spaces were of the same general nature as those in Experiment 1. The corresponding objects were made to be as perceptually similar as possible (the same fabrics and contact paper were used on the surfaces of corresponding objects, and so forth) (high object similarity). The hidden objects were two toy dogs—the miniature plastic dog (2 cm) from Experiment 1 and a small stuffed dog (5 cm).

The different-scale data came from the subjects who had the artificial room and the high-high similarity model in Experiment 1.

Procedure.—The procedure was essentially the same as that followed in the preceding studies.

Results and Discussion

As Figure 3 shows, size similarity had a dramatic effect on the children's performance. The children in the similar-scale group had a much higher retrieval 1 score (75%) than did the children in the different-scale group (41%). In 2 (scale similarity) × 2 (hiding space) ANOVAs performed on the retrieval data, there was a significant main effect of scale similarity on retrieval 1, $F(1,17) = 7.14$, $p < .05$, as well as retrieval 2, $F(1,17) = 7.02$, $p < .05$.

Although it had been expected that the retrieval 1 performance of the 2.5-year-olds in this study would be facilitated by high size similarity, the absolute level (75%) was unexpectedly high. Eight of the 10 subjects scored 75% or better. (One child had 50% correct, and another had 25%.) In previous published (DeLoache, 1987, 1989b) and unpublished studies with this age group, their performance has consistently been extremely poor, in spite of various manipulations designed to make the model task easier for them. For example, in one study the hiding places were labeled, but with absolutely no effect (DeLoache, 1989b, Experiment 3). Thus, the high level of success in the present study suggests that the degree of size difference between a scale model and a larger space is an especially important factor in young children's understanding of the correspondence between the two. It is apparently much easier for 2.5-year-olds to appreciate the correspondence between two small-scale spaces than between a small-scale and a large-scale space.

There are at least three factors that may have contributed to the unusually high retrieval 1 performance of the 2.5-year-olds in Experiment 2. (1) Overall similarity is presumably much greater with two similar-scale spaces: they just simply look very much alike. (2) The fact that the children could see all of each similar-scale space at once may have facilitated their detection of the correspondence between the two. In contrast, in a large-scale space, a child has to scan actively around the room to sequentially take in all the objects within it. This difference in how small-scale and large-scale spaces are viewed may have contributed to the children's difficulty with perceiving the similarity of two different-scale spaces. This suggests that two similar, but both large-scale spaces, might not facilitate performance as much as the two small-scale spaces in Experiment 2 did. (3) It is possible that there is also a categorization effect. When young children believe that two objects are from the same category, they use what they know about one of them to infer what is probably true about the second (Gelman & Markman, 1986). Perhaps something like that happened here. The 2.5-year-olds may have thought of the two similar-scale models as the same kind of thing (e.g., toy or pretend rooms), and this may have encouraged them to use what they knew about one of them to draw an inference about the other. This again suggests that two large-scale spaces might not be as facilitative as two small-scale ones.

An additional aspect of the Experiment 2 findings deserve comment. The children's retrieval 2 performance was higher in the similar-scale than in the different-scale condition. (This 95% score was also relatively high compared to the typical retrieval 2 levels in other model studies; although retrieval 2 scores have ranged from 70% to 100%, approximately 75%–85% is most common.) It may be that with two spaces so similar in appearance, the child's memory for where he or she saw the first toy being hidden is strengthened or refreshed by finding the analogous toy on retrieval 1 (whether by a single correct search or with prompting).

The results of Experiment 2 agree with those of Experiment 1 in showing that retrieval 1 performance increases as physical similarity between two spaces increases. With surround similarity held constant, the 2.5-year-olds in Experiment 2 performed very successfully with the combination of high object and size similarity.

It thus appears that these two sources of perceptual similarity may combine in a more or less additive fashion, while interacting with age. The goal of the next experiment was to examine further the combined effect of size and object similarity at the two ages.

Experiment 2a

In Experiment 2a, the combined effect of size and object similarity was investigated (with high surround similarity held constant). Two age groups of children were asked to reason from one small-scale space to another (the same small-scale spaces used in Experiment 2) with either high (as in Experiment 2) or low levels of object similarity. It was expected that the retrieval 1 scores would be related to both age and object similarity, but it was not clear what absolute levels of performance to expect. We were particularly concerned with assessing the extent to which high size similarity might be adequate by itself to support successful retrieval 1 performance.

Method

Subjects.—The subjects for Experiment 2a were 48 children, 24 (12 boys and 12 girls) 2.5-year-olds in the younger age group (29–32 months, M = 31 months), and 24 (12 boys and 12 girls) 3.0-year-olds in the older group (36–39 months, M = 38 months). No subjects were eliminated from the study.

Apparatus and materials.—The two small-scale spaces from Experiment 2 were used in this study. As shown in Table 1, the corresponding furnishings within the two spaces were of the same general categories, but their surface appearance was either quite different or highly similar.

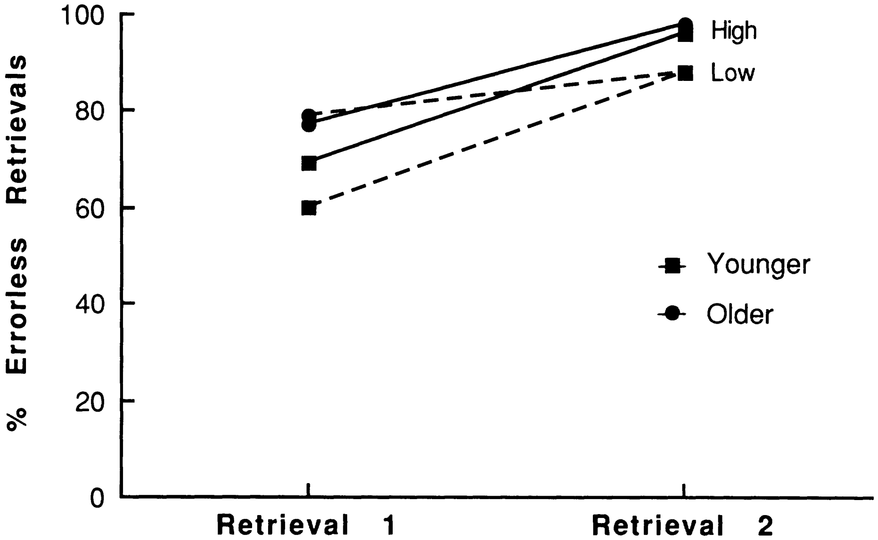

FIG. 4—Retrieval performance in similar-scale spaces as a function of age and object similarity

Procedure.—The procedure was the same as in the preceding studies.

Results and Discussion

The results are shown in Figure 4. The retrieval 1 performance of the younger children in the high-object-similarity group (70%) replicated the performance of the comparable group in Experiment 2 (75%). There were no significant main effects or interactions in a 2 (age: 2.5, 3.0) × 2 (object similarity: high, low) × 2 (hiding space: hide-in model, hide-in-room) ANOVA performed on the retrieval 1 data. The same analysis of the retrieval 2 data revealed a significant main effect for condition, $F(1,40) = 6.64$, $p < .05$. As was also found for Experiment 2, retrieval 2 performance was better in the high-similarity (97%) than in the low-similarity (88%) condition.

These results indicate that high similarity of scale was sufficient to support successful performance in the model task, even when the objects within the two spaces were dissimilar in appearance. The fact that the younger children's performance in the low-object-similarity condition (60%) was not significantly lower than that of the same age group in the high-object-similarity condition (70%) suggests that scale may be an especially important dimension of similarity.

General Discussion

The series of experiments reported here clearly established an effect of perceptual similarity on young children's understanding of the relation between a scale model and the larger space it represents. In general, the more physically similar a model is to the corresponding larger space, the more likely it is that young children will use what they know about one of them to figure out the other.

The effects of three different sources of physical similarity—object, size, and surround—were examined in the four studies reported here. Although there was not a full factorial investigation of all the combinations of the different types of similarity with different ages, the results are nevertheless highly consistent and reveal a clear pattern. Figure 5 summarizes the retrieval 1 performance for the two primary age groups in the present series of studies.

Four general effects are apparent. (1) Retrieval 1 scores increase as a function of increasing physical similarity. Performance is poorest when there is low similarity on all three sources, and it is best when there is high similarity on all three. Note that this generalization is qualified by ceiling and floor effects at the extreme levels of similarity. Some similarity manipulations do not raise the older children's performance because of ceiling effects. For example, the 3.0-year-olds have excellent retrieval 1 scores with high levels of either object or size similarity; hence, one could not expect to enhance their performance substantially by adding another source of high similarity. Conversely, because of floor effects, some manipulations do not have much effect on the performance of the younger age group. Subtracting a source of similarity has no impact when performance is

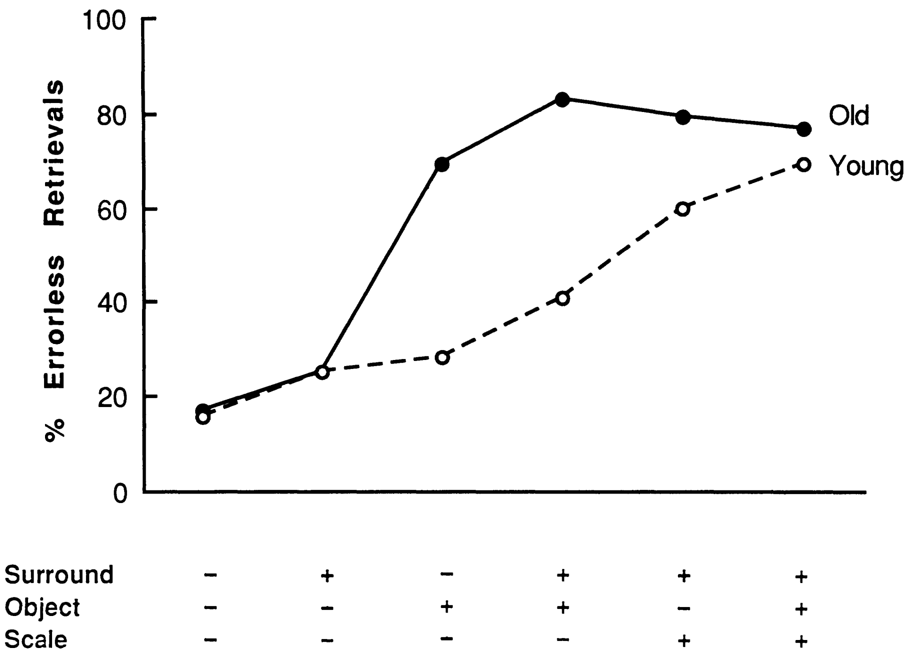

FIG. 5.—Retrieval performance of 2.5- and 3.0-year-old children as a function of three types of physical similarity. A "+" means high similarity for that similarity type, and a "−" means low similarity. Data for the first four points come from Experiment 1 (low-low, low-high, high-low, high-high), the fifth and sixth from Experiment 2a.

already at chance. (2) Overall, the older children have higher retrieval 1 scores than do the younger ones. At most levels of similarity, their performance is better, although at both extremes, the scores of the two age groups converge. (3) The younger children require a higher degree of similarity to appreciate the model-room correspondence than do the older children. The younger children reach near-ceiling performance only with high levels of size, object, and surround similarity combined, whereas the older children achieve comparably high scores with object similarity alone. (4) Some sources of similarity are more important than others. Whether the surrounding walls of the two spaces are of the same material has the smallest (a nonsignificant) effect. Object similarity had a much larger effect. Similarity of scale seemed to have the most potent effect. Even the younger group was successful when two small-scale spaces were used. (As mentioned earlier, it is not clear that the same result would occur for two large-scale spaces.)

The studies reported here clarify the nature of the deficit shown by the 2.5-year-old children in previous model studies (DeLoache, 1987, 1989b). The extremely poor performance of the younger children in the original study led to the inference that 2.5-year-olds might be incapable of understanding the correspondence between a model and a larger space (DeLoache, 1987). This conclusion was also supported by the insensitivity of this age group to a variety of manipulations designed to elevate their performance (DeLoache, 1989a, 1989b).

Any time young children fail a task, however, there are at least two possible explanations: (1) an absolute lack of ability, or (2) a fragile ability that is manifested only under certain conditions. The similarity studies summarized here support the second of these possibilities: 2.5-year-old children are capable of understanding that one space stands for another space, but they achieve it only under optimal conditions. Only when there was a very high degree of physical similarity between the model and the larger space did most children in this age group detect the correspondence between them. With lower levels of similarity, they treated the two spaces as unrelated entities. Older children displayed the same capacity under a wider range of circumstances: 3.0-year-olds detected the room-model correspondence with moderate levels of similarity, and 3.5-year-olds detected it with low similarity.

Examination of the error data from these experiments highlights the extent to which children who failed various model tasks treated the two spaces as unrelated. The universally high levels of retrieval 2 performance indicate that these children almost always correctly remembered where they had observed the toy being hidden. On the relatively rare occasions on which they failed to retrieve that toy, they typically searched incorrectly at the location where it had been hidden on the previous trial (i.e., on trial n, they searched at the $n - 1$ hiding place). This shows that these children remembered their last retrieval experience in that space.

Retrieval 1 errors were of the same type: Not knowing where the analogous toy was, the unsuccessful children most frequently used a fall-back strategy of searching where they remembered finding it the last time they were in that space. For example, suppose the child had watched as the miniature toy was hidden under the tiny pillow on trial n. On retrieval 1, the child had no idea where to search, but thanks to the experimenter's prompting, eventually "retrieved" the toy from under the large pillow in the room. On trial $n + 1$, the miniature toy was hidden behind the model couch. On that retrieval 1, the child, again not understanding where the larger toy was actually hidden, went back to the pillow where he or she had last found the toy in the room.

What the error patterns thus reveal is that these children remembered, *separately*, what they had experienced in each of the two spaces. In some sense, one could say that the children who did poorly in the model task were working harder, remembering more, than were the children who succeeded.

The effect of similarity on children's understanding of the relation between the model and the room is presumably an accessibility effect, like those found for analogical reasoning (Gentner & Landers, 1985), memory (Ross, 1987), and other domains. There are at least three ways in which similarity might affect accessibility. First, high similarity may increase the probability that the children detect the overall correspondence between the model and the larger space. In many model studies, the main factor underlying differences in performance for different conditions and age groups is the children's awareness of the relation between the two spaces (DeLoache, 1987, 1989b).

The second possibility is that similarity facilitates mapping the objects from one space onto the other. Given that the child has detected the overall correspondence between the two spaces, high object similarity could make it easier to establish the object-to-object correspondences. A mapping effect might occur for both retrieval 1 and retrieval 2, as the child goes back and forth between the two spaces. Retrieval 2 seemed to be enhanced in the highest similarity conditions in this series of studies (i.e., the conditions with high object and size similarity in Experiments 2 and 2a).

A third possibility is that high similarity makes it easier for children to detect the correspondence between individual objects, without necessarily realizing the overall correspondence between the spaces as a whole. Thus, high object similarity may help the children equate the miniature chair and the full-sized chair. On a given trial with that particular hiding place, they might succeed while failing with other ones. As mentioned before, this individual objects account receives support from the fact that intermediate levels of performance were found in some of the experiments reported here (see Fig. 5).

Similarity probably has all these effects. It probably helps some children get the odd retrieval 1 correct without recognizing the overall correspondence between the spaces. It may also lead some children to detect the overall correspondence between the two spaces that they would miss with lower similarity. In addition, it may facilitate mapping the objects in one space onto those in the other, once the overall correspondence is detected.

As mentioned in the introduction, it is hypothesized that young children's understanding of scale models results from the interaction of two factors—perception of physical similarity and representational insight (DeLoache, in press). Representational insight refers to the child's readiness to notice a symbolic relation, a predisposition that is influenced by, among other things, the extent of the child's previous experience with various symbol systems. It is proposed that these two intervening variables interact to influence the likelihood that a young child will become aware of the representational relation between a scale model and the larger space it represents. Both variables are always important: The less symbolically sophisticated young children are, the more important similarity will be.

The interaction of these two variables to determine performance means that high levels of one can compensate for low levels of the other. Consider, for example, the picture task described in the introduction (DeLoache, 1987): 2.5-year-old children who failed the model task could find the hidden toy when its location was communicated to them via pictures rather than a model. The degree of physical similarity between a two-dimensional picture and a three-dimensional space is presumably less than that between a scale model and a room. However, because a picture does not require a dual orientation, it is easier for young children to become aware of its symbolic potential than it is for them to realize the symbolic potential of a three-dimensional, real-object model. In this case, the greater ease of achieving representational insight compensates for a lower level of physical similarity.

The fact that similarity becomes less important with age reveals the same interaction of perception of physical similarity and representational insight. The necessity for physical similarity does wane, as shown by the results of Experiment 1a: The 3.5-year-old children in that study achieved very high retrieval 1 scores with the lowest level of similarity represented in Figure 5 (i.e., low similarity of size, object, and surround). Presumably, if even older children were tested, they could succeed with increasingly little physical resemblance (e.g, a model with simple blocks representing various features of the room) and even with competing physical appearance (e.g., a coffee cup standing for the chair, a stapler for the couch, etc.). This decreasing reliance on physical similarity is consistent with Gentner's (1988) view that children's relational reasoning becomes increasingly less dependent on surface similarity with age and experience.

Physical similarity becomes less essential with development, in part because symbolic experience increases with age: Any given 3-year-old is likely to have had more experience with symbols than any given 2.5-year-old. For example, one common source of such experience for young children in this culture is picturebooks. In middle-class families (like those in our sample), mothers and their infants and toddlers typically spend substantial amounts of time in joint picturebook "reading" (DeLoache & DeMendoza, 1987; Ninio & Bruner, 1978). At a very early age, children start to learn that pictured objects are not real objects, that books are not to be treated like other objects, and eventually that pictures can represent real, existing states in the world (DeLoache & Burns, 1989).

The decrease with age in dependence on physical similarity for success in the model task is thus due in part to young children's increasing experience and skill with other symbol systems. As a function of their experience with other symbolic relations, they more readily entertain the hypothesis that our model is a symbolic representation of the larger space. In other words, experience with symbols in general helps children to adopt a more abstract stance to a scale model. This more abstract orientation enables them to avoid being captivated by the model as object and to appreciate its potential as symbol.

Clear predictions can be derived about individual and group differences in performance in the model task as a function of symbolic experience. Comparisons among different cultural groups (Kolstad, 1988) suggest the importance of general symbolic experience. Support has also been obtained from experimental manipulations of children's immediate symbolic experience. For example, 2.5-year-old children (who would normally be expected to fail the standard model task) were first given a picture task that they understood. These children were much more successful in a subsequent model task (DeLoache, 1989a) than were children who had not experienced the picture task first. Using a symbol-referent system that they understood—pictures—helped them interpret one they did not initially understand—models.

With respect to the interaction of similarity and representational insight, we can predict, for example, that successful experience with a high-similarity model task should facilitate children's subsequent performance on a low-similarity task that they would otherwise be expected to fail. Again, the reasoning is that success in the model task indicates that the young child has overcome the lure of the model as object to interpret it as a symbol. Having, with the help of similarity, understood that one model is a symbol of something else, the child should more readily detect the symbolic potential of a second.

The fact that the effect of similarity decreases with age is not to say that it ever becomes irrelevant (Smith, 1989a, 1989b). At *any* age, it will be easier to reason from a model to room or vice versa when the two look more alike than when they look less alike; however, as children get older, they become increasingly proficient at detecting and reasoning with lower levels of physical similarity. As adults, we can reason about the relations between completely abstract entities—

"let $x_1 = y_1$ and $x_2 = y_2$." However, we will still find it easier to reason about corresponding entities that resemble one another—"let this red circle represent an apple and this yellow oval stand for a banana."

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