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Length and Distance: Do Preschoolers Think That Occlusion Brings Things Together?

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Preschoolers often assert that objects become closer together when part of the distance between them is occluded (occlusion = nearer). Piaget argued that this is due to young children's use of a topological spatial representation. Three studies explored the occlusion = nearer phenomenon. In Study 1, children who asserted that occlusion = nearer nonetheless picked the same stick before and after occlusion as just fitting between 2 points. Study 2 showed that occlusion = nearer is due neither to a belief that all movement alters distance nor to a general misunderstanding about the terms *near* and *far*. In Study 3, children shown separate occluded and unoccluded gaps picked shorter sticks to span occluded gaps, indicating a perceptual basis for the occlusion = nearer phenomenon. Preschool children do not appear to change the geometries they use to represent space, but do show increases in the generality and explicitness with which they map early spatial knowledge onto spatial language.

Formal models of the structure of knowledge have proven to be a fertile source of theories for understanding children's acquisition of knowledge in domains ranging from linguistics (Chomsky, 1965) to conceptual structure (e.g., Quine, 1970; Wittgenstein, 1953). In understanding children's representations of space, it is natural to ask whether children's spatial concepts conform to the same or to a different geometry than do those of adults.

A "Developmental" Geometry

A hierarchical structuring of geometries was described in the Erlanger Program developed by Klein in 1872 (see Klein, 1908/1939). Klein demonstrated that geometries could be defined by describing their automorphic transformations, those transformations that do not produce a different figure. Thus, geometries can be classified according to which transformations produce different objects and which do not. For example, in Euclidean geometry, rotations and other rigid motions do not produce a new object, whereas changes in size do produce a different figure.

Klein's (1908/1939) work produced a set of five groups of transformations, termed *Euclidean, similarity, affine, projective,* and *topological* geometries. These geometries form a hierarchy, ranked according to the properties preserved by the geometry's automorphisms. In this hierarchy, a lower geometry (such as topology) has a broader set of automorphic transformations. Thus, any transformation (such as rotation) that produces an equivalent figure in Euclidean geometry will also produce a topologically equivalent figure, although the reverse does not hold.

This hierarchical structure has seemed a promising way (e.g., Piaget, 1970c) to account for some of the ways that young children's understanding of spatial relations differs from that of adults. Developmental researchers, starting with Piaget, have focused primarily on the endpoints of Klein's hierarchy, Euclidean and topological geometries. Accordingly, the distinctions between Euclidean and topological geometries will be briefly summarized prior to discussing their developmental implications.

Euclidean Geometry

Euclidean geometry stands as the most restrictive member of Klein's hierarchy. Euclidean geometry preserves distances between points, in addition to the features preserved by other Erlanger geometries. Euclidean transformations are those that leave distance invariant, mapping any two points in an object into two others equally far apart in the image resulting from the transformation. They thus include the set of rigid motions (those transformations that correspond to mappings between corresponding points in a rigid object as it moves through space), as well as reflections (transformations that preserve interpoint distances but reverse the sense of angles).

Topological Geometry

Topological transformations consist of any transformation that provides a one–one mapping from object to image, is continuous, and has a continuous inverse (Gans, 1969). Figures

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that can thus be mapped to each other are called *homeomorphic.* Topological transformations do not preserve rectilinearity; thus, lines and curves are homeomorphic to each other, but topological transformations do preserve the features of separation or continuity between points, openness, and linear or cyclic order. Any figures that can be stretched into each other without cutting or joining points are equivalent. Klein (1908/1939, pp. 105–108) suggested that topological transformations of surfaces could be readily visualized by imagining figures inscribed on a rubber sheet or modeled as solid objects. Any transformation of one of these rubber figures (stretching, bending, compressing) that does not involve cutting it or joining two previously unconnected points would produce a new figure that is topologically equivalent to the original. The generality of topological transformations gives rise to the comment that a topologist is someone who cannot distinguish his coffee cup from his donut.

Developmental Implications of Formal Geometries

The Topological Primacy Hypothesis

Piaget (1970c; Piaget & Inhelder, 1967; Piaget, Inhelder, & Szeminska, 1960) suggested that children initially represent only those (topological) features common to all the geometries. With development, they may grasp additional geometric transformations, until they finally master the relations between distance and direction that constitute Euclidean geometry. Piaget (1970c) asserted "It is remarkable that, psychogenetically, topological structures antedate metric and projective structures, that psychogenesis inverts the historical development of geometry" p. 27. The view that children's early spatial thought follows topological principles is called the *topological primacy hypothesis* (Darke, 1982).

There are two ways in which topological relations might be primary in children's conceptions of space. Children might perceive only the topological features of objects, failing to distinguish between different (Euclidean) objects that are topologically equivalent. Children's reasoning about spatial relations might also be bound by topological features. Because distance is not a topological feature, this view implies that children should fail to understand which transformations affect distance and which do not. Piaget asserted that children's early spatial representation was topological in both senses. A number of previous studies addressing the first issue will be reviewed. The current research considers the second sense of topological primacy, the view that young children fail to understand which transformations affect the distance between two points.

Topology and Object Perception

In two books (Piaget & Inhelder, 1967; Piaget et al., 1960), Piaget reported evidence supporting the claim that children initially represent only topological features of space. The task that inspired the most research was one involving haptic perception of a variety of shapes, in which children were asked to feel a variety of shapes and then either draw, describe, or pick them out from a set of drawings. Piaget and Inhelder reported that young children had difficulty distinguishing between what they termed *topological forms,* that is, irregular shapes with holes in them that Piaget and Inhelder felt were topologically equivalent.

Piaget and Inhelder's (1967) research on the geometric basis for object perception has been questioned on both mathematical and empirical grounds. Kapadia (1974), Martin (1976), and Darke (1982) have all questioned Piaget and Inhelder's definition of topological equivalence. Part of the confusion stems from Piaget and Inhelder's use of the terms *topological forms* and *Euclidean forms.* All of the figures have both topological (e.g., containing a hole) and Euclidean (e.g., being rectilinear) properties, and it is only with reference to pairs of figures that one can talk of confusion being based on topological or Euclidean properties. Furthermore, the fact that the Erlanger geometries form a hierarchy implies that any two figures that are equivalent in a Euclidean geometry will necessarily be topologically equivalent. It would therefore be impossible for children to confuse figures that are topologically distinct but equivalent in a Euclidean geometry, for no such objects exist. Empirical evidence has not supported Piaget and Inhelder's claim that children have special difficulties when trying to distinguish topologically equivalent figures (e.g., Lovell, 1959).

Rieser and Edwards (1979) attempted to get around the limitations of the haptic perception task by collecting judgments of perceived similarity among drawings transformed in various ways from an original parallelogram. Multidimensional scaling and clustering analyses indicated that both 5-year-old and adult subjects used metric properties (such as rounded vs. curved) in judging similarity, whereas only adults showed evidence of a category containing figures that were only similar topologically (e.g., all those having continuous surfaces). Thus, on the level of object and figure perception, there is little support for the notion that young children use a topological geometry in representing objects they feel or see.

Topology and Spatial Reasoning

Although it seems clear that children do not perceive objects topologically, tests of haptic perception are of limited use in understanding how children conceive of spatial relations. Despite perceiving the Euclidean features of objects, children may, as Piaget also argued, think of spatial relations in terms of topological features such as containment while failing to represent nontopological relations such as distance. A more direct test of the geometry underlying children's representation of space would involve asking them to judge the consequences of different transformations. If a topologically based geometry provides the basis for children's spatial understanding, then they should have difficulty understanding the metric consequences of spatial transformations.

Piaget et al. (1960) looked at children's understanding of the metric consequences of a simple transformation, occlusion, that does not alter distance. Piaget et al. argued that for children using a topological representational system, occluding part of a distance can function as cutting, disrupting the connection between points and thereby altering a topologically based distance relation between them. To test children's understanding of distance, Piaget et al. showed young children two objects (such as toy soldiers or trees) and asked them whether the objects were near one another or far apart. Then, some kind of obstacle (such as a cardboard screen or a cube) was placed between the objects (which were not moved), and the child was asked whether the objects were still as near or far apart (depending on the prior answer). Preschool children generally asserted that the objects became closer together when part of the distance between them was occluded. Piaget et al. concluded that preschoolers do not understand that there is a correspondence between length (or filled space) and distance (or empty space), due to the use by preschoolers of a topological rather than Euclidean frame of reference. Because topological geometries represent distance only in terms of whether or not points are connected, a child representing only topological features of space such as being *together* or *apart* would have no means of relating connected points (and their corresponding lengths) to unconnected points (and the distances between them). As Piaget et al. concluded,

> It may be that common usage makes no sharp distinction between the concept of distance and that of length. But psychologically they point to two quite different situations which become interdependent only as a result of a gradual development. . . . The building up of notions of distance enables children to pass from elementary topological relations to those of Euclidean space. (p. 69)

The basic phenomenon, that young children believe occluding part of the distance between two points shortens that distance, has been replicated by Lovell, Healey, and Rowland (1962) and by Shantz and Smock (1966). Lovell et al. found that only one third of 9-year-old children realized that distance was preserved across such an occlusion. Shantz and Smock found somewhat better performance, with one third of a group of 6-year-olds meeting a criterion of four out of five correct answers on this task. Shantz and Smock reported that modifying the task so that it involved choosing matching pictures from drawings varying in total and occluded distance led to somewhat increased performance. Both of these replications support Piaget's general conclusion that young children fail to realize that occluding part of a distance between two points does not affect the total distance between them.

The possibility that young children use a topologically based geometry in judging spatial relations is a radical suggestion, and one that deserves further scrutiny. An alternative view, explored in this research, is that children may in fact possess an early understanding of the Euclidean relation between length and distance and still have difficulty accessing this knowledge explicitly and mapping it onto the linguistic terms used to describe spatial relations. To test the robustness of children's belief that occlusion affects distance, we looked for a task that might reveal early understanding of the relation between length and distance.

If early knowledge of the relation between length and distance exists, where might one find it? One situation in which it is possible to observe children apparently making use of this relation is the context of building bridges out of blocks. Building rudimentary bridges is a ubiquitous activity in preschools, and the ability to copy a simple bridge was placed on the 3-year mental-age level of the Stanford-Binet Intelligence Scale (Terman & Merrill, 1972). Placing blocks so that a spanning segment will just fit between them would seem to require exactly the knowledge that children appear to lack on Piaget's task. Whether a block will fit across a gap formed between two others is obviously a function of the relation between the length of the block and the distance it needs to span. Although this ability might rely on perceptual processes of the sort Piaget (1970a) described as figurative knowledge, the ability to *reason* about the effects of occlusion on the relation between length and distance clearly requires understanding of the relation between length and distance.

Study 1 was designed to explore the limits of children's confusion about the relation between length and distance. The screening transformation used by Piaget was presented to children in two tasks. The first (Piagetian task) was a replication of the procedure used by Piaget et al. (1960) and described earlier, in which children were asked whether screening meant that objects were closer together. The second (bridge task) used the same objects, distances, and screens to ask about the same relation, but asked children whether screening would affect the length of stick required to span the gap between the two points. In the second condition, we were interested in whether children believe that occluding some of the distance between two points implies that a different stick is required to span the gap between them. If preschoolers are bound by a topological geometry in reasoning about length and distance, they should show poor performance on both tasks. On the other hand, if children possess an early but context-bound understanding of length and distance, one might expect children to believe that screening does not affect the length of stick required to fit between two points, while asserting that the same objects become closer together after screening. Both tasks assess children's understanding of the relation between length and distance, because each looks at children's beliefs about how interposing a screen (a *length* in Piaget's terminology) affects the distance between two points. The tasks differ in whether children are queried directly on whether occlusion affects distance (in the Piagetian task) or asked to determine whether occlusion has altered the length of stick required to span a gap (in the bridge task).

Study 1: Understanding Length and Distance

Method

Subjects

Subjects were 64 children, 16 (8 boys and 8 girls) at each of ages 3 years ($M = 3.5$; range = 3.25–4.0), 4 years ($M = 4.5$; range = 4.25–5.0), 5 years ($M = 5.6$; range = 5.25–6.0), and 6 years ($M = 6.4$; range = 6.1–7.0), drawn from a preschool and a private elementary school in downtown Philadelphia serving a largely middle-class population. One 3-year-old girl dropped out of the study and was replaced by a girl of the same age from the subject pool used for Studies 2 and 3.

Stimuli and Apparatus

The basic apparatus used in both tasks consisted of two wooden posts set on a series of bases of varying length. After children made an initial distance judgment, screens varying in size and orientation were interposed between the two posts. For the bridge-building task only, there were also sets of dowels of varying length from which children chose a stick judged to just fit between the posts. Figure 1 shows the apparatus with the screen interposed, as seen by children during the posttransformation phase of the bridge-building task. The apparatus used for the

Piagetian task differs from that shown in Figure 1 only in the absence of the set of sticks.

Each of the endposts shown in Figure 1 was a 3⅞-in. (9.84-cm) high piece of 33-in. (8.57-cm) × 1½-in. (3.81-cm) pine lumber. Each post had a 3-in. (0.95 cm) groove cut in the top so that with a ½-in. diameter rod inserted the height of the block–rod combination would be 4 in. (10.16 cm) tall. Distances were coded by the distance between the centers of the blocks, which will be referred to as the (nominal) span between the blocks. Because of the thickness of the blocks (1½ in. [3.81 cm] each), the shortest distance between the two blocks for a given span (e.g., 12 in.) was 1½ in. less (e.g., 10½ in.), and the distance between the outside edges of the blocks was 1½ in. more (e.g., 13½ in.).

Four cardboard bases were constructed so that when the posts were placed on them, the distances between the centers of the posts (along the long axis of Figure 1) were 12 in. [30.5 cm], 18 in. [45.7 cm], 24 in. [60.96 cm], and 36 in. [91.5 cm]. For each distance, four sticks were constructed in varying lengths from 0.5 in. [1.27 cm] diameter dowels; each stick was painted a different color. The correct dowel was always either the second or third longest in the series. The dowel lengths employed for the distances used were as follows: For the 12-in. base, the sticks were 8 in. [20.32 cm], 10 in. [25.40 cm], 12 in. [30.48 cm], and 14 in. [35.56 cm] long. For the 18-in. base, the sticks were 14 in. [35.56 cm], 16 in. [40.64 cm], 18 in. [45.72 cm], and 20 in. [50.80 cm] long. For the 24-in. base, the dowel lengths used were 22 in. [55.88 cm], 24 in. [60.96 cm], 26 in. [66.04 cm], and 28 in. [71.12 cm] long. Sticks for the 36-in. base were 30 in. [76.20 cm], 34 in. [86.36 cm], 36 in. [91.44 cm], and 40 in. [101.60 cm] long. The 36-in. distance varied from the regular 2 in. [5.08 cm] progression of distances because pilot testing indicated that some children showed a tendency to simply pick the largest stick from the set for this distance.

For each span, six screens were constructed from 1/16-in. [0.15-cm] thick posterboard for the posttransformation phase. The six screens varied screen height (short or tall), width (narrow or wide), and orientation (along the long axis in the picture plane, as shown in Figure 1 [*along* orientation] or intersecting this line [*across* orientation]). Short screens were 2 in. [5.08 cm] tall, which was too short to occlude a line between the tops of the blocks. Tall screens were 7½ in. [19.05 cm] tall, which would cover a line between the tops of the blocks. Both short and tall screens were constructed for both narrow and wide widths. Wide screens were 3 in. [7.62 cm] less than the span between the centers of each block, leaving a 1½-in. [3.81-cm] gap between the posts. Narrow screens for a span were one third of the span. Wide and narrow screens were placed in the along orientation shown in Figure 1. In addition, a tall (7½ in. [19.05 cm] × 4 in. [5.08 cm]) and a short (2 in. [5.08 cm] × 4 in. [5.08 cm]) screen were constructed to be placed in the across orientation. Each screen had a small wooden base (1½ in. [3.81 cm] thick) glued to its back so that it could remain upright.

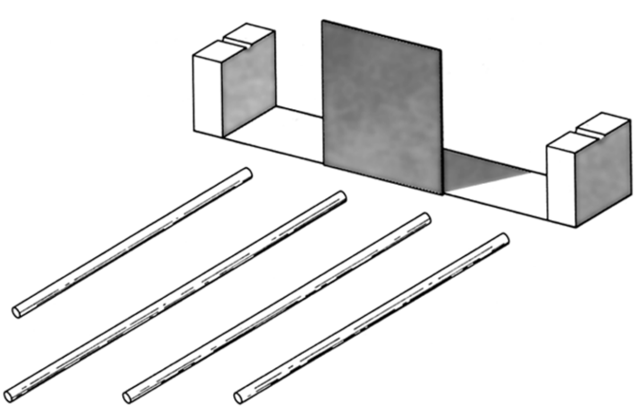

Figure 1. Apparatus used in length and distance studies.

Procedure

The experimenter spent several hours in the children's classrooms prior to testing in order to become familiar with them. Children were tested individually in a single 20-min session in a room within their school. Two tasks were administered to all of the subjects, with order of presentation counterbalanced within each Age × Sex group. To make the tasks as similar as possible, the same objects, distances, and screens were used in both tasks.

Bridge-building task. The bridge-building task required the child to choose a stick that would just fit between the two blocks. To explain the task, the child was first given a practice task with the blocks at one of the four spans (12 in., 18 in., 24 in., or 36 in.). This span was then not used for either the Piagetian or bridge-building tasks. The four sticks used for that span were placed in a random order in front of the child, as shown in Figure 1. The child was asked to choose from the set of sticks one that would make the best bridge between the two blocks. The child was informed that if the stick was too short, it would fall down, and that if it was too long, it would stick out the end of the block. If the initial choice was incorrect, the child was permitted to continue choosing sticks until one was found that would just fit between the two blocks. Then the experimenter demonstrated with the incorrect sticks that a stick that was too small would fall down, and one that was too long would protrude. Because the purpose of the pretraining was simply to familiarize children with the question to be asked, no screens were interposed between the objects in this pretraining task.

Following this pretraining, children were presented with the blocks placed at the remaining three spans. For each span, the apparatus was first presented without a screen interposed, and the child was asked to pick a stick from a set of four that would just fit between the blocks. The child was not permitted to check whether the stick would fit. Because we were interested in children's reasoning about the effect of screen interposition, rather than their ability to estimate distance, the experimenter responded positively to whatever choice was made for the unscreened distance. Following this initial choice, five screens (narrow–short, wide–short, narrow–tall, wide–tall, and across–short) were interposed in a random order for each span, for a total of 15 screened trials across the three spans. Before each screen was interposed, the child was reminded which stick had been chosen for the unscreened distance. The across–tall screen was not used for this task, out of concern that children might be confused because it is not possible to place a stick between the posts in this condition. The order in which the screens were interposed was varied randomly across spans. After each screen was interposed, the child was asked, "And now which stick will just fit between the two blocks?" The experimenter continued to respond positively, noted previously, as to whatever choice the subject made.

Piagetian task. The Piagetian task was essentially a replication of the procedure used by Piaget et al. (1960) to assess children's understanding of the relation between length and distance. Children saw the apparatus shown in Figure 1 without the screen interposed and without the set of sticks, and were asked whether the blocks were near together or far apart. As in the bridge-building task, the experimenter reinforced the initial choice. A screen was placed over part of the distance between the blocks, as with the bridge-building task, and children were asked whether the blocks were now nearer together, farther apart, or still the same distance apart. As with the bridge task, children were reminded of their initial judgment before each screen was interposed. This process was repeated for all six screens (narrow–short, wide–short, narrow–tall, wide–tall, across–short, and across–tall) at each of three spans, for a total of 18 screened trials across the three spans. As with the bridge task, the order in which the alternatives were presented to children was varied across trials; the order in which the screens were interposed was varied randomly across children.

Results and Discussion

Because we were primarily interested in children's *reasoning* about the relations between length and distance, the main variable of interest was whether children changed their judgment of distance or choice of stick when a screen was interposed between the posts from their initial, unscreened choice. Therefore children were coded as being correct if they chose the same stick after screening as they did before the screen was interposed, without concern for whether the stick chosen would actually fit between the two points.[1] Children were coded as being correct on the Piagetian task if they judged the blocks to be still the same distance apart after screening. Figure 2 shows the average percentage correct responses for the posttransformation distance judgment by age across the two tasks. Although the materials and transformations used were the same in each task, there was a lag of approximately 2 years between equivalent levels of performance on the two procedures for assessing children's understanding of the relation between length and distance.

Preliminary Analyses

Use of different sizes of screens permitted us to evaluate several possible explanations for why screening affects children's judgments of distance. If the critical issue is the ability to perceive a continuous line between the endpoints, then there should be an effect of screen height, with short screens affecting judgments less than tall screens. If children at some age level are subtracting filled space from empty space (as Piaget et al., 1960, have suggested), then screen width should affect judgments. Possible effects of the type of screen used were evaluated in four separate analyses, evaluating effects of span (3: short, middle, or long distance between the posts), screen height (2: short or tall screen), screen width (2: narrow or wide screens), and screen orientation (2: screen placement across or between the line connecting the two blocks) on the percentage of correct judgments. In order to counteract the problem of statistical biases in the assessment of within-subjects factors (e.g., McCall & Appelbaum, 1973), multivariate analyses of variance (MANOVAS) were used.

Each of the various screen factors was evaluated in turn in a separate MANOVA of correct responses with between-subjects factors of age (4: 3, 4, 5, & 6 years), sex (2: male, female), order (2: bridge first, Piagetian task first), and within-subject factors of task (2: bridge, Piagetian) and one of the screen variables (screen height, screen width, screen orientation, and screen span). The separate MANOVAS were conducted because screen width, screen orientation, and span were not fully crossed (not all widths were used in the across orientation, and the tall screen was not used in the across orientation in the bridge task). In each MANOVA, the only significant effects obtained were for age, sex, and task, with no significant interactions between these variables and no significant effects or interactions involving span, screen height, screen width, or screen orientation. Thus, the kind of screen used did not have a significant effect on children's judgments. Whatever effect occlusion has, it appears not to matter whether the screen in question blocks a line of sight between the endpoints, is long or short, or is oriented along or across the line between the endpoints. Because the kind of screen shown did not seem to affect responding, an overall dependent variable was obtained by calculating the percentage of consistent responses for each task, across span, orientation, screen height, and screen width. This measure was based on 15 separate responses for the bridge-building task (5 screens × 3 spans), and 18 responses for the Piagetian task (6 screens × 3 spans).

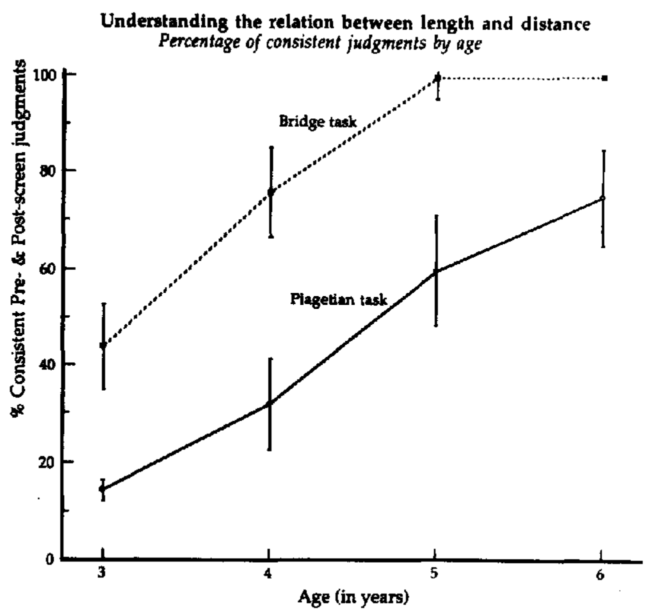

Figure 2. Percentage of correct judgments on two tasks measuring children's understanding of relations between length and distance. (Vertical bars show the standard error for each Age × Task mean.)

Analysis of Consistent Responses

A task (2: bridge, Piagetian) × age (4: 3, 4, 5, and 6 years) × sex (2: males, females) × order (2: bridge first, Piagetian first) MANOVA (with task as a within-subjects factor) of the percentage of correct answers (picking the same stick after screen interposition in the bridge task, and making a same-distance judgment after the same transformation in the Piagetian task) revealed no interactions among these variables, but significant main effects for task, $F(1, 48) = 38.27, p < .001$; age, $F(3, 48) = 24.21, p < .001$; and sex, $F(1, 48) = 6.84, p < .05$, as well an interaction between sex and task, $F(1, 48) = 4.96, p < .05$. As Figure 2 indicates and tests of simple effects confirmed, the bridge-building task was easier at each age level. Improvement with age was seen in both tasks until the 5- and 6-year-olds reached ceiling on the bridge-building task. The sex effect, which was not predicted, favored boys, and post hoc tests (using

[1] Overall accuracy of judgments was fairly low, ranging from a low of 21% correct choices for the 4-year-olds to a high of 35% correct choices for the 6-year-olds; at no age level were children reliably better than chance (25%) in picking the correct stick.

Table 1
Number of Children Passing Each Length Task by Age and Sex

	Bridge task		Piagetian task	
Age group	Boys	Girls	Boys	Girls
3-year-olds	4	0	0	0
4-year-olds	8	3	1	1
5-year-olds	8	7	4	4
6-year-olds	8	8	6	5

Note. There were 8 children in each Age × Sex group for each task. Criterion for passing was 15 of 15 consistent stick choices for bridge task, 18 of 18 "same distance" responses for Piagetian task.

Tukey's honestly significant difference [HSD] procedure with $\alpha = .05$ for this and other post hoc tests reported here) indicated that there was a significant sex difference for the bridge task but not for the conservation task. We will not attempt to provide a substantive interpretation of this effect because sex differences were not found for the tasks used in Studies 2 and 3, and are not generally found in studies of spatial abilities in subjects of this age (see review by Maccoby & Jacklin, 1974).

Classification of Children

Analysis of correct responses across the two tasks indicates that children are more likely to assert that interposing a screen does not require a longer stick to reach between two points than to realize that the same transformation does not mean the two points are closer together. To look at consistency of responding, children were classified as passing a task if they correctly answered all questions concerning the effect of screens on distance. The number of children in each age and sex group meeting this criterion for the two tasks is shown in Table 1, which reflects the same pattern that emerged from analyzing the number of correct answers. The same 2-year gap between equivalent levels of performance emerged when one looked at the number of children passing each task. Two thirds of the 4-year-olds (69%) passed the bridge-building task, whereas it was not until the 6-year-old group that the same level of performance was achieved for the Piagetian task. No child passed the Piagetian task who did not also pass the bridge-building task.

Where children asserted that distance was changed, or picked a different stick, they were somewhat more likely to pick a shorter stick or to say the objects were closer than to pick a longer stick or say the objects were farther apart. Table 2 shows the percentage of trials for which children at each age picked sticks that were shorter, longer, or the same length after screening as their original (unscreened) choice, and the percentage of children saying that screening caused the endpoints to be closer together, farther apart, or the same distance apart. Wilcoxon signed-rank tests of the likelihood of closer versus farther judgments were calculated for each task (looking at the number of each type of judgment, excluding trials on which the same stick was chosen or children asserted that distance was conserved). For the Piagetian task, children were more likely to assert that the objects were closer together than that they were farther apart, $T(38) = 194.5, p < .05$. Testing judgments on the Piagetian task separately for each age, there were significant effects only at ages 4 and 5 years. Three-year-olds gave nearer and farther responses about equally often, $T(15) = 55.5$, *ns*. Four-year-olds were more likely to give nearer than farther responses, $T(12) = 16.0, p < .05$, as were 5-year-olds, $T(8) = 0.0, p < .05$. Six-year-olds tended to assert that distance was the same after screening, which resulted in few nontied cases for the analysis, $T(3) = 3$, *ns*. Children passed the bridge task at an earlier age than they did the Piagetian task, which meant that it was possible to test for an asymmetry in judgments only at ages 3 and 4 years. Overall, 9 of the 15 children who showed any preference picked a shorter stick more often than a longer one after occlusion, but this effect did not reach significance overall, $T(15) = 32.5$, *ns*, or in any age group. Three-year-olds were about as likely to pick a longer stick as a shorter one, $T(10) = 16.5$, *ns*. Most four-year-olds passed the bridge task (thus showing no preference for longer vs. shorter sticks), but the children who failed that task showed a marginally significant preference for shorter sticks after screening, $T(4) = 0, .05 < p < .10$. Because 5- and 6-year-olds were at ceiling on the bridge task, analysis of their errors is not meaningful.

Analysis of error patterns provides some support for the possibility that children who fail to realize that screening does not affect distance view occlusion as shortening the distance between the two endpoints. Because this analysis relies on children's errors, it is limited in statistical power. This is particularly a problem for the bridge task, which children master well before the Piagetian task. The idea that there is a perceptual effect of screening, causing occluded spans to be seen as smaller than unoccluded spans may provide an explanation for this asymmetry in choices among children who fail the bridge and Piagetian tasks. Study 3 followed up this explanation for children's failure, providing a more direct test of the idea that children might perceive a screened distance as being shorter than an equivalent unscreened span.

The main finding of Study 1 is the large time-lag in performance between two tasks assessing children's understanding of the relation between length and distance. Two apparently similar ways of asking children about the relation between length

Table 2
Effects of Screen Interposition on Perceived Distance in Two Tasks in Study 1

	Bridge-task stick choices			Piagetian-task judgments		
Age group	Shorter	Longer	Same	Nearer	Farther	Same distance
3-year-olds	31.3	22.9	45.8	42.0	43.8	14.2
4-year-olds	15.0	9.2	75.8	42.7	25.5	31.8
5-year-olds	0.0	0.4	99.6	38.9	1.7	59.4
6-year-olds	0.0	0.0	100.0	14.9	10.8	74.3

Note. Percentage of responses after screen interposition indicating that the distance between the endpoints was shorter, longer, or the same as prior to screening. Bridge results are based on 240 judgments at each grade level; Piagetian task responses are based on 288 judgments at each grade level.

and distance produce dramatically different results. Children do appear to possess some early tacit understanding of the relations between length and distance that is not tapped by the apparently more direct procedure of asking them whether occluding distance affects length.

Study 1 contradicts the notion that young children use a different (topological) geometry than older children in reasoning about length and distance. In the same session, using the same materials, a substantial proportion of 4- to 6-year-old children asserted that interposing a screen between two points does not affect the length of stick need to bridge them, while saying that the points became closer together. It appears that reasoning about the terms used to describe length and distance is governed by different features than is reasoning about a particular consequence of that relation—that screening does not mean there is less space between two points.

Two results from Study 1 suggest that it is useful to distinguish between children's perception of how far apart two points are and their conception of what transformations alter distance. The first is the finding that children were in fact not very good at picking the stick that would just fit between the endpoints. At no age level were children significantly better than chance at picking the correct stick. The layout of the experiment, with small differences in lengths of sticks and placement of sticks perpendicular to the line connecting the endpoints, made it difficult to judge which stick would in fact fit between the two points. Nonetheless, children tended to assume that screening did not mean that a stick of a different size would be required to span the gap. The second finding is that the various screen variables used (width, orientation, and height) did not affect children's judgments in either task. How much of the gap was occluded (width of screen), whether or not a stick could be placed between the objects (orientation of screen), or whether the child could observe the space between the tops of the blocks (height of screen) had no significant effect on children's performance. Instead, introducing any sort of occluding screen caused most children to assert that the endpoints were nearer together, and most over 4 years of age persisted, nonetheless, in choosing the same stick as spanning a given gap before and after occlusion.

At least by the time children are 4 years old, a globally topological representation of space cannot account for their belief that occlusion makes objects nearer. As with other time-lags between mastering parallel tasks, such as the horizontal décalages observed for conservation tasks (e.g., Piaget, 1970b), the large difference in children's performance across two parallel tasks raises rather than answers questions about the sources of difficulty underlying the Piagetian task. Two possible explanations, one focusing on children's comprehension of the terms *near* and *far,* and the other looking at perceptual effects of occlusion, were addressed in two additional studies. The studies were run in conjunction with each other, using the same subjects, but are reported separately because they address separate explanations for the occlusion = nearer phenomenon.

Study 2: What Do Children Know About *Near* and *Far?*

If 4-year-olds understand that occlusion does not affect the length of stick needed to fit between two points, why do they assert that screening makes things nearer? One interpretation of the results of Study 1 is that children simply do not understand what *near* and *far* imply concerning the relation between length and distance. There is a substantial literature on the difficulty children have in mastering dimensional adjectives such as near and far, big and little, and so forth (Clark 1972, Donaldson & Balfour, 1968). As data have accumulated on the acquisition of dimensional adjectives, it has become clear that the relation between how children and adults use and interpret these terms is a complex one, with large differences between production and comprehension and large stimulus preference effects complicating any simple characterization of children's understanding of these terms (see Carey, 1982, and Clark, 1983, for reviews). As Carey summarized the situation, it appears "that often the child maps the wrong concept onto a word in his lexicon, and that this wrong concept is neither broader nor narrower than, nor even necessarily closely related to, the adult's lexical entry for the same word" p. 374.

There is specific evidence that children have difficulty understanding *near* and *far.* Tanz (1980) looked at children's ability to find an object under a plate that was identified as *close to* or *far from* a cup. Preschool children were much more likely to succeed on the close-to than the far-from task, and it was not until her 5-year-old group that most children succeeded on both items. Durkin (1981) described 3- to 6-year-old children's difficulty with a very different task (Durkin, 1978), in which they were asked to place something near another object. Young children were likely to place the two objects in contact with each other, and there was a significant increase across age groups in the distance between the objects. These two studiés suggest that during the age range when children fail the Piagetian length and distance task, they are also likely to interpret *close* somewhat differently than do adults. Furthermore, even children who have mastered terms such as *near* and *far* may face additional difficulty learning to use these terms in their comparative form (Kallio, 1988; Shaffer & Ehri, 1980).

The difficulty children have in learning the terms used to describe proximity raises the possibility that poor performance on the Piagetian task may reflect a lack of understanding of the terms used. Perhaps children think that any change in the spatial array before them is relevant to distance. In order to assess whether children's belief that occluding objects brings them together reflects a global misunderstanding of *near* and *far,* we looked at children's understanding of the effects on distance of a broader set of transformations. Specifically, Study 2 compared the Piagetian occlusion task with two additional transformations that tested whether children can appropriately distinguish between movements that make objects closer and those that do not. Movement was chosen as the contrasting transformation because movement between two points (or the lack thereof) is the sole determinant of whether the distances between them have changed. The ability to distinguish the kinds of movements that alter the distance between two points is clearly central to understanding the use of *near* and *far.* If children who believe that occlusion alters distance are nonetheless able to distinguish distance-altering from distance-preserving movements, it will be clear that poor performance on the Piagetian task does not result from factors such as a general misunderstanding of *near* and *far* or a general tendency to change judgments in the face of repeated questioning (e.g., McGarrigle & Donaldson, 1974). Accordingly, we compared children's ability to distinguish the movements that make things *nearer* from those that do not, with their understanding of the effects of screening part of the distance between two points.

Method

Subjects. Subjects were 32 children, 16 (8 boys and 8 girls) at each of ages 4 years (M = 4.6; range = 4.2–4.9) and 5 years (M = 5.5; range = 5.25–6.0), drawn from two preschool programs in Austin, Texas, serving a largely middle-class population. Subjects in Study 2 also took part in Study 3, with order of task presentation counterbalanced within each Age × Sex group.

Stimuli and apparatus. The stimuli used in this study were identical to those used in the Piagetian task in Study 1, as shown in Figure 1, with three changes: (a) Only two screens and two spans were used in Study 2, one tall screen (measuring 7 in. × 8 in. [17.78 cm × 20.32 cm]) and one short screen (measuring 2 in. × 8 in. [5.08 cm × 20.32 cm]). The spans used were 18 in. (45.72 cm) and 24 in. (60.96 cm). (b) Both screens were deployed in the along orientation, as shown in Figure 1. (c) A soft toy turtle was used as the agent of change for the modified Piagetian task in an effort to make the task more interesting and to reduce possible experimenter demand effects that might cause children to assume that experimenter-induced transformations affect amount (e.g., McGarrigle & Donaldson, 1974).

Procedure. The experimenter spent several hours in the children's classrooms prior to testing in order to become familiar with them. Children were tested individually in a single 15-min session in a room within their school, during which they took part in both Studies 2 and 3.

The experimenter introduced the game by producing his turtle friend, Charley, and then commented that Charley was not a very nice friend because he always tried to mess up the experimenter's games. The child was told that the experimenter would ask the child if some blocks were near together or far apart, then the turtle would alter the game, and the child would have to decide whether the blocks were nearer together, farther apart, or still the same distance apart.

The blocks were presented at two spans (18 in. and 24 in.). Four transformations were presented at each span, for a total of eight trials. Children made an initial judgment of whether the blocks were near together or far apart (with order of alternatives randomly varied). Charley, the turtle, implemented four transformations, whereas the experimenter described what the turtle was doing. In the *rotate block* transformation, each block was rotated 180° around the long axis connecting the two blocks, so that each was upside down in the same place, with the notch at the bottom. In the *move block* transformation, one block was pushed approximately 6 in. [15.24 cm] toward the other block. In the *short screen* transformation, the short screen was interposed midway between the blocks in the along orientation shown in Figure 1, and in the *tall screen* transformation, the tall screen was placed in the same manner. After each transformation, the child judged whether the blocks were closer together, farther apart, or still the same distance apart. Then the blocks were restored to their original position, and the child was again asked whether the blocks were near together or far apart before the next transformation was presented. Two experiment sets were created, varying whether children saw the 18-in. or 24-in. span first, and experiment set was counterbalanced within each Age × Sex × Task Order group. Transformations were presented in the following order: rotate block, tall screen, move block, short screen, for the first span shown, then short screen, move block, tall screen, and rotate block for the second span.

The questioning used to elicit children's judgments in Study 2 were identical to the procedure used for the Piagetian task in Study 1, with one exception. Children who stated that the blocks were initially far apart, then that they were farther apart after the transformation (or that they were initially close, then closer together) were further probed by asking if they were the same far apart/close together, more far apart/close together, or less far apart/close together, (with order of alternatives varied across trials). Children who judged that the objects were the same far apart/close together, after probing, were treated as having judged the objects to be the same distance apart. Children who said that the blocks were initially far apart, then that they were closer together, or vice versa, were not probed further.

Results and Discussion

Figure 3 shows the percentage of correct responses (judgments of same distance after each transformation except for move block, which required a *closer together* response) for each age group. Correct responses were analyzed with an age (2: 4, 5 years) × sex (2: boys, girls) × task order (2: bridge first, Piagetian first) × transformation type (4: rotate block, move block, short screen, tall screen) MANOVA, with transformation as a within-subjects factor. Results indicated significant main effects of age, $F(1, 24) = 6.118$, $p < .05$, and transformation, $F(3, 72) = 20.308$, $p < .001$, with a significant Age × Transformation interaction, $F(3, 22) = 2.995$, $p < .05$. Post hoc tests on the Age × Transformation interaction indicated that the two movement transformations (rotate block and move block) were significantly easier than the two screen transformations (short screen, tall screen), with no significant differences between the two screen transformations or between the two movement transformations.

Results of Study 2 show that many preschool children realize that rotation does not affect distance and that movement together does, but nonetheless believe that screening some of the distance between the two points does alter distance. This pat-

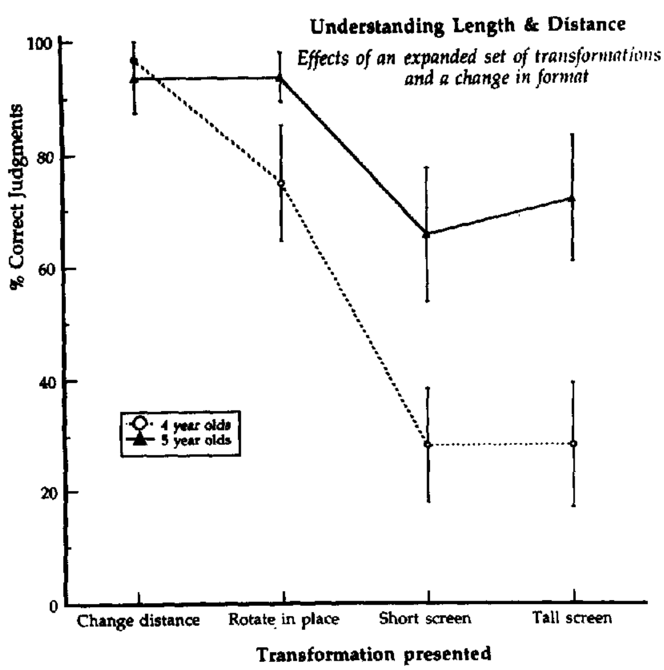

Figure 3. Percentage of correct judgments about the effect on distance of four transformations.

tern of results indicates that children's failure on the Piagetian task cannot be explained by a general misunderstanding of what *nearer* means. The basic pattern of performance on the Piagetian task found in Study 1 was replicated in Study 2 (although there was a nonsignificant difference in performance for the 5-year-olds across studies: 68% correct judgments and 10/16 children passing in Study 2 vs. 60% correct judgments and 8/16 children passing in Study 1).

Where children failed to realize that occlusion does not affect distance, they were more than twice as like to assert that screened objects were closer together after occlusion as to state they were farther apart. Four-year-olds judged screened objects to be closer on 52% of screen trials and farther apart on 20% of screen trials; 5-year-olds judged screened objects to be closer on 22% of screen trials and farther on 9% of these trials. A Wilcoxon signed-rank test comparing individual children's closer versus farther judgments of screened trials showed that this difference was significant, $T(15) = 24.5, p < .05$.

Children at both ages were able to distinguish appropriately between movements that alter distance and those that do not. Thus, children know that some kinds of movements make things nearer, and others do not, suggesting that poor performance on the Piagetian task cannot be attributed to a general misunderstanding of what makes things nearer and farther.

The replication of Piaget's occluded = nearer phenomenon suggests that children do indeed believe that screened gaps are smaller than unscreened gaps. Why children believe that screening a gap makes the objects it contains closer together remains unclear. Perhaps children are simply reporting their perception of the apparent distance between the two points, a perception that they were able to ignore in the bridge task used in Study 1. Study 3 used a modification of the bridge task employed in Study 1 to assess whether children perceive screened distances as being shorter than unscreened spans.

Study 3: The Perceptual Basis for Occlusion Effects

Perhaps the simplest explanation for children's assertion that screening a gap brings the endpoints closer together is that they are reporting their separate perceptions of the distance between the two endpoints before and after screening. In other words, screened gaps may appear smaller than unscreened gaps.

This perceptual explanation is consistent with the results of Study 2. Children who are making posttransformation judgments of nearness might well judge that rotation does not affect distance (the objects would appear no closer after rotation), whereas moving them together does make them closer.

A simple modification to the bridge-building task used in Study 1 provides a nonverbal technique for testing whether screened gaps appear smaller than unscreened gaps. If children perceive screened gaps as smaller than unscreened gaps, children should tend to pick shorter sticks as fitting across screened rather than unscreened gaps when the spans are presented separately (that is, without using the before-and-after format used in Study 1). Most 4-year-old and older children in Study 1 asserted that the same stick would just fit between the endpoints after screening. If this is based on conceptual knowledge about the relation between movement and stick length, then even children who understand that screening does not affect stick length should be unable to take advantage of this knowledge and might therefore pick shorter sticks for screened than for unscreened gaps.

Method

Subjects. Subjects for this study were the same children who took part in Study 2. Both tasks were run in the same session, with order of task presentation counterbalanced within each Age × Sex group.

Stimuli and apparatus. The stimuli used in this study were identical to those used in the bridge-building task in Study 1, as shown in Figure 1, with two changes: (a) In order to increase the number of trials, an additional 5-in. [12.7-cm] span was used for the practice trials for all of the children, with sticks of lengths 3 in. [7.62 cm], 5 in. [12.7 cm], 7 in. [17.78 cm], and 9 in. [22.86 cm]. (b) A single tall screen was used, measuring 7 in. × 8 in. (17.78 cm × 20.32 cm), and deployed in the along orientation, as shown in Figure 1.

Procedure. Procedures for developing rapport were described under the procedure for Study 2. The modified bridge-building task used in Study 3 resembled that used in Study 1 with the exception that children made a single-stick choice (either screened or unscreened) rather than making before- and after-screening choices. The pretraining was identical to that used in Study 1, except that it involved the same (3-in.) span for all children. Each child saw eight trials, 4 spans (12 in., 18 in., 24 in., 36 in.) × 2 screen conditions (screened, unscreened). Two trial order sets were created (Set 1:12 in./no screen, 24 in./screen, 18 in./no screen, 36 in./screen, 12 in./screen, 24 in./no screen, 18 in./screen, 36 in./no screen; Set 2 presented the same distances in the same orders, but altered the screen status of each trial from that in Set 1). Trial set was counterbalanced within each Age × Sex × Task Order group, so that whether a particular distance was seen first screened or unscreened was balanced.

One concern in piloting was that children might remember their initial judgment (screened or not) when reshown the same span and sticks on the second occasion. Pilot data suggested that the number of sticks involved (there were a total of 16 sticks, seen four at a time, all differing in color, placed in a random arrangement each time and presented only briefly) obviated this problem. In the actual experiment, only 3 subjects out of 32 commented on having seen the sticks before the second time a span was presented, and only 2 subjects consistently picked the same sticks in both screened and unscreened trials. Otherwise, the procedure was the same as in Study 1. Children were allowed to check their choices during a single pretraining trial conducted as in the bridge pretraining for Study 1. After this, they were not allowed to check their choices, but were given general positive encouragement about their performance.

Results and Discussion

Children's stick choices were coded by the number of sticks in the series intervening between the chosen and correct stick, which was either the second stick (for the 24-in. span) or the third stick (for the 12-, 18-, and 36-in. spans) when the choices were ordered by length. Thus, children's judgments varied from −1 to 2 (for the 24-in. spans) or −2 to +1 (for the 12-, 18-, and 36-in. span), with negative values designating sticks shorter than the correct value. Data were coded by relative order because the choices for the 36-in. span differed by a greater absolute value than did those for the other spans. These stick-error data were analyzed with an age (2: 4, 5 years) × sex (2: boys, girls) × task order (2: bridge first, Piagetian first) × span (4: 12-in., 18-in., 24-in., and 36-in. span) × screen (2: unscreened, screened) MANOVA, with span and screen as within-subject factors. In contrast with the other studies, there were no longer

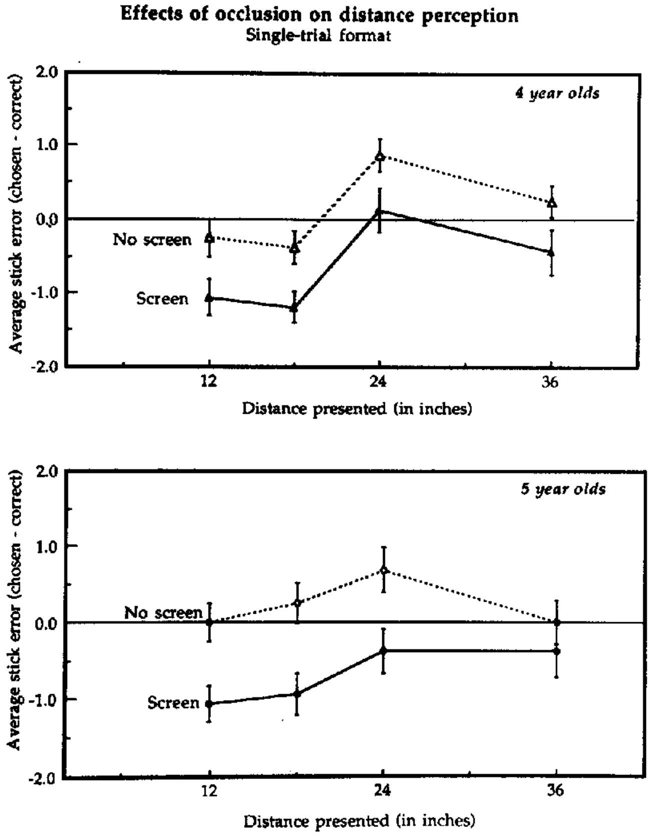

Figure 4. Mean error in length of stick judged to fit a gap between two blocks as a function of the length between the posts and whether or not the gap was partially occluded. (Top panel shows results for 4-year-olds; 5-year-olds are shown in the bottom panel. Dependent variable shows by how many sticks the choice was too long [if positive] or too short [if negative]. The correct choice is shown by the horizontal line through the origin of the vertical axis.)

significant effects or interactions involving age. There was a significant main effect of screen, $F(1, 24) = 77.052$, $p < .001$, with screened spans leading children to pick a shorter stick than did unscreened spans. The only other significant effect was a main effect of span, $F(3, 22) = 14.489$, $p < .001$. There were larger positive errors for the 24-in. span than for the others, and post hoc tests showed that the 24-in. span produced significantly longer judgments than the 12-in. and 18-in. spans, with the 36-in. span falling in between. This result is most likely due to the scale used. For the 24-in. span, the correct choice was the second stick in length, whereas for the other spans it was the third. Figure 4 shows mean error by span, with the top panel showing results for 4-year-olds, and the bottom panel showing results for 5-year-olds. Although there was no age effect, the data are plotted separately by age to emphasize the finding that occluded spans looked smaller to children at both age levels.

The limited scale used makes it difficult to estimate the magnitude of the screening effect, but it is clear that children showed a strong tendency to pick shorter sticks when the screen was interposed, relative to those picked for unoccluded trials. Comparing screened versus unscreened judgments within child for the same span (totaled across spans), we found that 61% of the time they chose a shorter stick for the screened span than unscreened span, 5% of the time they chose a longer stick, and 34% of the time they chose the same stick. This is a very different pattern from that seen in Study 1, in which 4- and 5-year-olds (averaged together) chose a shorter stick 7.5% of the time, a longer stick 4.8% of the time, and the same stick 87.7% of the time. Wilcoxon signed-rank tests of the probability of picking the smaller versus larger stick in Study 3 showed that children at each age level were significantly more likely to pick a smaller than a larger stick when they picked a different stick. Eleven of twelve 4-year-olds (excluding 4 with ties) were more likely to pick smaller sticks for screened gaps than for the same unscreened gaps, $T(12) = 1.0$, $p < .01$. All sixteen 5-year-olds picked smaller sticks for screened gaps, $T(16) = 0$, $p < .0001$.

Results of the single-trial bridge task indicated that young children do perceive screened distances as being shorter than unscreened ones. Although occluded gaps appear smaller than do unscreened gaps, results from Study 1 showed that most 4-year-olds and almost all 5-year-olds nonetheless believe that screening does not mean a shorter stick will be required to span the gap. Taken together, results of the bridge tasks indicate that 4-year-old and older children show a precocious if limited understanding that objects do not become closer together in the absence of movement toward or away from each other. This knowledge is sufficient to overcome the fact that screened gaps appear smaller than do unscreened gaps. At the same time, this early understanding co-exists with what would seem to be an incompatible concept: that screening a distance between objects means that they are now closer together.

General Discussion

Summary of Results

Studies 1–3 document the existence of an early tacit knowledge of the relation between length and distance. Several years before children can say that occlusion does not make objects nearer, they understand a basic implication of this relation: that occlusion does not affect the length of stick needed to span a gap. The 2-year time-lag between when children realize that occlusion does not require a shorter spanning stick and the point when they realize that it also does not make the endpoints closer together, could be explained in several ways. Studies 2 and 3 investigated possible explanations for this difference in performance between two largely identical tasks.

Study 2 looked at the possibility that children's poor performance on the Piagetian task might reflect a general lack of understanding of the application of *near* and *far*. The screening transformation was contrasted with tasks requiring children to realize that rotation in place does not affect distance, whereas movement does. Results show that even children who realize how motion of the endpoints affects distance are likely to assert that screening makes endpoints closer.

Study 3 investigated the possibility that children do indeed perceive screened gaps to be smaller than unscreened gaps. The 4- and 5-year-old children had performed well on the bridge-building task in Study 1, asserting that the same stick was required to span a gap before and after screening. When children saw the same gaps without observing the screening transformation, children at both ages showed a strong tendency to pick smaller sticks to span the screened gaps. Thus, screened gaps do appear shorter.

Status of the Topological Primacy Hypothesis

The studies reported here provide no support for the idea that preschool children represent space in a basically topological manner. Most 4-year-old and older children in Study 1 insisted that occlusion does not affect the length of stick required to span a gap. Although the topological primacy thesis has been widely cited (e.g., Cohen, Weatherford, Lomenick, & Koeller, 1979; Herskovits, 1986) to account for the difficulty young children have in a variety of spatial tasks, there is no convincing empirical support for the idea that children differ from adults in the geometry underlying their spatial reasoning (this argument has also been made by Mandler, 1983, 1988).

Additional evidence for early understanding of Euclidean distance is found in studies by Schiff (1983) and Bartsch and Wellman (1988). Schiff reported that children who failed to conserve length nonetheless felt both the longer and shorter sticks in a conservation of length task would fit into the same size box. Bartsch and Wellman found that screening did not affect children's understanding that a straight line is the shortest distance between two points.

If children cannot be described as using a different geometry than adults, how is one to account for the difficulties children have on tasks such as the one used by Piaget and Inhelder (1967)? Specifically, do children believe that occlusion alters distance? Results of this research indicates that the answer to this simple question is a complex one. Children's performance on the bridge task shows that at least by the age of 4 years, children possess the basis for inferring that distance is not affected by occlusion. They know that occluding does not mean a longer stick will be required to span a gap, despite the fact that Study 3 found that occluded gaps appear smaller than do nonoccluded gaps of the same size. At the same time, the belief that occlusion does not alter distance is not demonstrated on the Piagetian task used in Studies 1 and 2. Many children who know that occlusion does not affect stick choices nonetheless assert that occlusion does make things nearer. This difficulty is not due to a general misunderstanding about what affects *near* and *far*. As Study 2 showed, many children who failed the Piagetian transformation did so despite knowing which kinds of movement make points nearer and which do not.

Children's difficulty on the Piagetian task may be a function of their confusion about whether *near* and *far* refer to the spatial reality (that occlusion does not affect distance) or to spatial appearances (that occluded gaps appear smaller). Flavell (Flavell, Flavell, & Green, 1987; Flavell, Green, & Flavell, 1986) has demonstrated the difficulty that young preschoolers have in distinguishing real attributes of objects from their appearances. In particular, questions about object properties elicit judgments based on appearances (phenomenism errors, in which children assert that objects really are they way they appear), whereas questions about object identities elicited judgments based on object realities (including intellectual realism errors in which children insist that objects look like what they really are, despite their appearances). Perhaps both kinds of information are available to children, and their errors on the Piagetian task are simply due to confusion over the criteria used in assessing *near* and *far*.

Why might the relation between occlusion and the terms *near* and *far* be so difficult for children? Children's difficulty in realizing that occlusion does not make things nearer may well be due to the relational, context-bound manner in which the terms *near* and *far* are used. The linguistic description of space involves a variety of features that do not neatly map into a single geometry (e.g., Herskovits, 1986; Talmy, 1978). Many uses of distance terms are metaphorical in nature and context-bound in application. One need not look far to find distance terms used in ways that are far from direct spatial description; this sentence contains three of them. Lakoff and Johnson (1980) asserted that "most of our fundamental concepts are organized in terms of one or more spatialization metaphors" p. 17. Although this statement attests to the extraordinary productivity of spatial terms, it should make it less surprising that young children have difficulty understanding the spatial rules that govern use of terms such as *near* and *far*.

The relational nature of the terms *near* and *far* may pose a particular difficulty for young children. *Near* and *far* are relational terms in the sense that altering the context of comparison can make what was near become far, without changing the metric distance between the points involved. Given two locations (e.g., New York and Boston), introducing a third point (e.g., Tokyo) will not affect the distance between the original two points, but it may cause one to change one's judgment of the distance between New York and Boston from being *far* to being *near*. This is *not* the error that children make on the Piagetian task, on which introducing a third point between two initial endpoints causes them to say that the endpoints are now closer. Nonetheless, the relative nature of the use of *near* and *far* may make it difficult for them to understand that occlusion does not affect nearness.

Preschoolers do appear to believe that occlusion makes things nearer, but this is far from a complete measure of their understanding of the relation between occlusion and distance. Given the basic understanding that occlusion does not affect the length of stick needed to span a gap, children who fail the Piagetian length and distance task also possess an incompatible concept: that occlusion does not affect distance. Learning how spatial constancies constrain the use of *near* and *far* takes several years, but it can build on a foundation of early knowledge about the Euclidean relation between length and distance.

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