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ABSTRACT

The development of young children's internal representations of large space was assessed by asking 15 boys and 15 girls to construct a three-dimensional model of their kindergarten classroom. Three groups of 10 children (ranging in age from 4 years, 8 months to 6 years, 3 months) were tested, two in the spring and one in the fall. One of the groups of children tested in the spring was given several accurately placed landmarks prior to their model construction. Constructions were scored on the bases of Euclidean, projective, and topological accuracy. On all three measures, the accuracy of the boys was greater than that of the girls. Increased experience in the classroom significantly increased the children's Euclidean accuracy, but had relatively little effect on the projective and topological accuracy of their presentations. The provision of landmarks enhanced the children's projective and topological accuracy but had no effect on Euclidean accuracy. These effects were found to be independent of chronological age. (Author/DT)

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Abstract

In an attempt to assess the development of young children's internal representations of large space, 15 boys and 15 girls were asked to construct a three-dimensional model of their kindergarten classroom. Three groups of 10 children (ranging in age from 4 years, 8 months to 6 years, 3 months) were tested, two in the Spring and one in the Fall. One of the groups of children tested in the Spring was given several accurately placed landmarks prior to their model construction. Constructions were scored on the bases of Euclidean, projective, and topological accuracy. On all three measures, the accuracy of the boys was greater than that of the girls. Increased experience in the classroom significantly increased the children's Euclidean accuracy, but had relatively little effect on the projective and topological accuracy of their presentations. The provision of landmarks enhanced the children's projective and topological accuracy but had no effect on Euclidean accuracy. These effects were found to be independent of chronological age.

THE DEVELOPMENT OF YOUNG CHILDREN'S SPATIAL REPRESENTATIONS OF THEIR CLASSROOM

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Concomitant with recent interest in the social and psychological consequences of the environment and ecology on the lives of individuals (Wohlwill, 1970), there has been considerable interest on the part of architects, geographers, and urban planners (cf. Appleyard, 1970; Downs & Stea, 1973; Lynch, 1960) in how adults and children perceive, represent, and remember arrangements of objects in the large-scale environment. For the most part, however, psychologists have paid little attention to this topic.

With few exceptions (e.g., Acredolo, Pick, & Olsen, 1975; Pick, Acredolo, & Gronseth, Note 1), experimental research on the development of children's knowledge of macrospace has been limited to the study of knowledge in novel, artificial, and/or simple environments (e.g., Maier, 1936; Pufall, 1975). Little attention has been paid to the investigation of children's knowledge of actual and familiar large scale spaces, yet it is within these domains that children develop, acquire, and utilize their spatial knowledge. The child's classroom is prototypic of such domains, especially the preschool or kindergarten classroom which typically is more complex and varied than a classroom whose central feature is multiple rows of desks. Even though age-related differences in children's knowledge of large spaces within which they move has been examined in recent studies (e.g., Acredolo et al., 1975), no attempt has been made to examine the development of children's knowledge over relatively long time spans. Surely, one would expect that kindergarteners somehow "know" more about their classroom in June than they do in September.

The present study is an attempt to determine what young children know and remember about the arrangements of objects in their own classroom and how this knowledge changes over a school year.

The experimental task involved the construction by the child of a model of his or her classroom. Children were tested in either the Spring, after some eight months of experience in the classroom, or in the Fall, after one to two months in the classroom. Although Acredolo et al. (1975) found that familiarity with the environment had no effect on the performance of 5-year-olds, the environments used were neither highly differentiated or complex. It was generally expected that increased experience in the classroom would produce a more accurate spatial representation which would be reflected in a more accurately constructed model in the task.

Three groups of children were tested, two in the Spring and one in the Fall. One of the groups of children tested in the Spring was given four accurately placed landmarks prior to model construction to determine if they would serve as organizers to facilitate performance. Previous research has shown that familiarity and differentiation influence the adult's knowledge of large-scale spaces. Lynch (1960) concluded that an adult's image of an environment is the product of the clarity and number of landmarks in that environment (differentiated cues) and the amount and quality of past experience (familiarity) the individual has had there. Acredolo et al. (1975) and Siegel and White (1975) have argued that differentiated landmarks and familiarity are important variables influencing the development of large-scale representations of both children and adults.

The three "conditions" (or groups) can be conceptualized as representing different degrees of "load" (e.g., task demands, stimulus noise, lack of experience), and it was expected that the children's constructions would reflect this. Specifically, the accuracy of the models produced by the children should be least when the children have little familiarity with the classroom and are given no cues to guide their performance (high load), should be better when the children are quite familiar with their classroom even though not given cues (intermediate load), and should be greatest when the children are both familiar with their classroom and are provided cues to guide their performance (minimal load).

Method

Subjects

Fifteen boys and 15 girls from the same kindergarten classroom in a Pittsburgh public elementary school participated in the experiment. Ten boys and 10 girls, whose mean chronological age (CA) was 5 years, 8 months (with a range of 5 years, 4 months to 6 years, 3 months), were tested in the Spring of 1973. Five boys and five girls, whose CA was 5 years, 2 months (with a range of 4 years, 8 months to 5 years, 6 months), were tested in the Fall of 1973. Children tested in the Fall thus had been in their classroom for one to two months, while children tested in the Spring had about eight months of experience.

Materials

The materials were scale models (1 inch = 2 feet) of the kindergarten classroom and its contents. A 12- x 20-inch Masonite frame with 5-inch high walls was used to represent the classroom; 4- x 2 3/4-inch rectangular holes were cut in each end of the unpainted frame, their position corresponding to the location of the two doors in the actual classroom. Forty scale models (1 inch = 2 feet) of the furniture and other major items in the classroom (e.g., piano, table, TV, chalkboard, teacher's desk, cabinets) were cut from balsa wood, and the primary identifying features were inked or colored on them. Children easily recognized the items. A schematic diagram of the classroom and the arrangement of items within it is presented in Figure 1.

Procedure

Children were tested individually in a small room down the hall from their classroom. The child was brought into the testing room and seated in front of the model on a table opposite the experimenter. The child was shown the model and was told that it represented his/her classroom. The doors leading to the hall and the street were pointed out, and children were required to identify each of these doors before proceeding. In the cued condition, the experimenter then named and accurately placed four items in the model: the teacher's desk (on the hall door wall), the piano (near the adjacent wall), and two of the movable walls of the "playhouse" (on the street door wall). This part of the procedure was omitted for children in the uncued condition.

The child was then asked to tell the experimenter some of the things that belonged in his/her classroom. If the child named a structural feature (e.g., lights, ceiling) or supply items (such as toys or crayons for which there were no models), (s)he was asked to name some of the furniture and "bigger" things in the classroom. When the child named an item of furniture, (s)he was given the model of that item and was told to put it in the model where it belongs--"just like it goes in your classroom." This procedure continued as long as the child named items spontaneously. When the subject stopped volunteering items, or said that "that's all there is," or the like, the experimenter randomly selected one of the remaining items hidden behind a screen, named it, showed it to the child, and asked if it belonged in the child's classroom. If the child said it belonged, (s)he was asked to place it where it belonged; if the child said that the item did not belong, it was put aside. The procedure continued until all 40 items had been identified and either placed in the model or rejected. The child was not bound to his/her initial

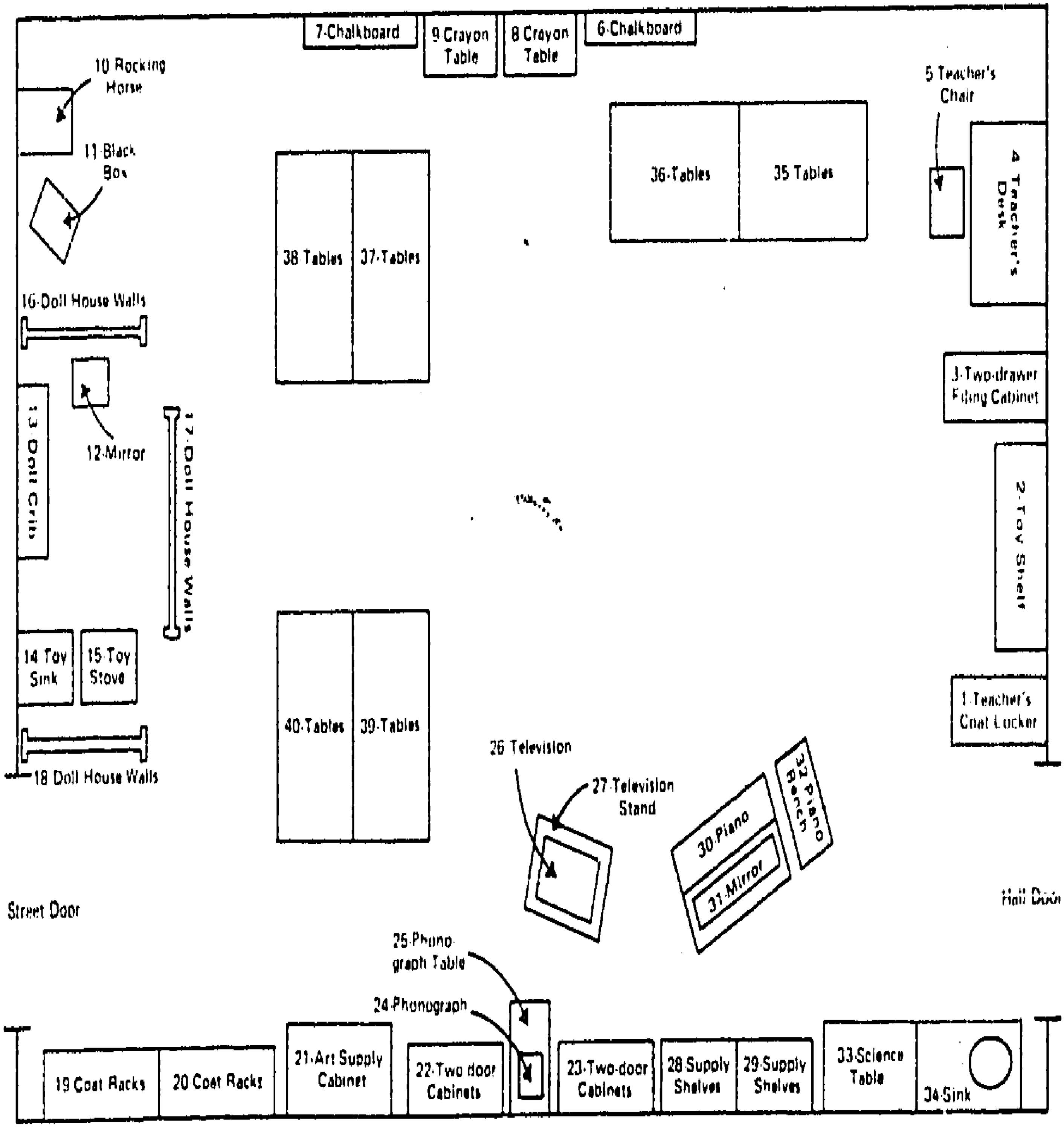

Figure 1. Schematic diagram of the classroom layout.

Clusters

Items 1 - 5
Items 6 - 9
Items 10 - 18
Items 22 - 27
Items 28 - 32

placement of any item and was free to relocate any items at any time. No feedback as to accuracy of identification or placement was given at any time. However, the child was given frequent encouragement in terms of the number of items (s)he had named and how much (s)he knew about the classroom. After the task was completed, the child was thanked for his/her participation and returned to the classroom. A female and a male experimenter each tested approximately an equal number of boys and girls in each condition.

Each test session was audiotaped. In addition, an observer recorded each item the child named and its location in the child's model on a small grid-map not visible to the child. The child's final production was photographed from above. All measurements and scoring were performed on the basis of 8- x 10-inch black and white photographs of the children's models. The audiotapes and observer's records were used to confirm the identification of the items in the photographs.

Design

A 2 (Sex) x 3 (Conditions) factorial design with five children in a cell was used. In the first condition, five boys and five girls were tested who had one to two months experience in the classroom and were given no cues; in the second condition, another group of five boys and five girls were tested who had eight months experience and no cues; and in the last condition, five boys and five girls were tested who had eight months experience and cues.

Scoring

Children's performances were scored on three dimensions of accuracy, each of which was based on a different aspect of spatial relationships. The three measures seemed to reflect the different kinds of spatial knowledge suggested by Piaget (Piaget & Inhelder, 1967; Piaget, Inhelder, & Szeminska, 1960): Euclidean, topological, and projective.

Absolute/(Euclidean) accuracy. This measure was designed to reflect the accuracy with which the child placed a given item in the model with respect to that item's position in the classroom. One point was given for each item that was placed within 2 inches of where it actually belonged in the model (i.e., within 4 feet of where it belonged in the actual 24- x 40-foot classroom). Since children in the uncued conditions could place a possible 40 items, while those in the cued condition could place only 36 (the experimenter had already placed four), these scores were converted to a proportion of items placed accurately.

Local relational accuracy. This measure of topological accuracy was designed to reflect the accuracy with which the child placed a given item in the model with respect to items adjacent to it in the classroom. Of the 40 items used, 32 belonged to five "clusters," each containing four to nine items. These clusters were determined intuitively on the basis of the perceptual grouping within the classroom, and on the basis of the teacher's judgment. The clusters had three common characteristics: (a) items within a cluster were in close physical proximity and were relatively isolated from other clusters; (b) each cluster had a central or key item that was used by children to identify the location of other items in the cluster; (c) the key item in a cluster was the functional center for children's activities (i.e., chalkboard, teacher's desk, TV, piano, and playhouse). One point was given for each relationship correctly reproduced. For example, the teacher's desk cluster consisted of the following items (from left to right along the "hall wall"): teacher's desk, teacher's chair, filing cabinet, toy shelf, and teacher's coatlocker. The following five relationships, if properly reproduced, earned one point each: (a) desk at left end of cluster, (b) filing cabinet to right of desk or to left of toy shelf, (c) toy shelf to right of desk or filing cabinet, or to the left of the coatlocker, (d) coatlocker at right end of cluster, (e) items in cluster in a line along a wall, and (f) no other objects intruding in the cluster. The number of relationships scored for each of the clusters varied from four to six: total possible score was 25. Each child's score was converted to the proportion correct.

Macro-relational accuracy. This measure was designed to reflect projective accuracy, and was based on the relationship between pairs of clusters. For each pair of clusters, two relationships were measured (and given one point each if correct): (a) each cluster was roughly to the left, to the right, or opposite of every other cluster: (b) each cluster was roughly on the same, opposite, or perpendicular wall relative to each of the other clusters. For example, the "piano cluster" (see Figure 1, items 28-32) should be to the left of and on the same wall as the TV cluster (items 22-29). The maximum possible number of points for this measure was 16. Each child's score was converted to the proportion correct.

Results

All children spontaneously recalled and/or correctly recognized at least 39 of the 40 items (35 of 36 in the cued condition). Thus, subsequent differences found in the three measures cannot be attributed to differences in item recognition. Since preliminary analyses indicated that the scores of children tested by the two experimenters did not differ, the scores were combined in all subsequent analyses. A 2 (Sex) x 3 (Conditions) analysis of variance was performed on each of the three dependent measures. (Analyses were performed on both raw and arcsin-transformed proportions. Since the results of the analyses were essentially identical, only the analyses on raw proportions are reported here.) Interestingly, all three analyses yielded significant main effects for Sex and Condition and nonsignificant Sex x Condition interactions, $p > .10$.

The mean Euclidean accuracy (i.e., absolute distance) for boys (.46) was significantly greater than that for girls (.27), $F(1, 24) = 7.51$, $p < .05$. That is, boys placed 40% of the items accurately (i.e., within 2 inches of their correct position in the model or 4 feet in the 24- x 40-

foot classroom), whereas girls placed 27%. Mean Euclidean accuracy was significantly affected by Condition. $F(2, 24) = 9.88$, $p < .001$: Confidence intervals (.05. *MSE* = .036, Critical Value = .16) indicated that given no cues, children with eight months of experience had higher absolute placement scores (.40) than did children with only one to two months of experience (.16). For children with eight months of classroom experience. those given cues were somewhat more accurate (.53) than those not given cues (.40).

Since age and experience in the classroom are highly confounded, it could be argued that the performance difference between children tested in the Fall (two months experience) and children tested in the Spring (eight months experience) was due to maturation, independent of experience. To assess this possibility, the scores of the youngest and the oldest children in the Fall and Spring uncued groups were compared. If the effects obtained were due to maturation. as opposed to experience, then younger and older children in the Fall group should differ, older and younger children in the Spring group should differ, but younger children in the Spring group should not do better than the older children in the Fall group. Although the sub-sample sizes were small, an explanation of performance differences due to maturation was ruled out. The mean absolute accuracy for the five youngest (mean CA of 61 months) Fall children (.19) was not significantly different than that for the five oldest (mean CA of 65 months) Fall children (.13), $t < 1$; similarly, the mean absolute placement scores for the five youngest children (mean CA of 66 months) in the Spring group (.38) was not significantly different than that of the five oldest (mean CA of 70 months) children in the Spring group (.42), $t < 1$. However. the performance for the youngest children in the Spring group (mean CA of 66 months) was significantly greater than that for the oldest children in the Fall group (mean CA of 65 months). $t(8) = 1.87$, $p < .05$.

The mean local-relational accuracy for boys (.69) was, again, significantly greater than that for girls (.47), $F(1, 24) = 8.82$, $p < .01$. Mean local-relational accuracy (the proportion of relationships among spatially proximal items correctly reproduced), was also affected by Condition, $F(2, 24) = 4.53$, $p < .05$. Confidence intervals (.05, MSE = .044, Critical Value = .17) indicated that the pattern of results was different than for the absolute placement measure. Children in the Spring uncued condition (.56) did not have significantly higher relative locational accuracy than children in the Fall uncued condition (.45). However, the performance of children given cues (.73) was significantly greater than that of either group of children given no cues.

Boys correctly reproduced nearly twice as many relationships (.90) among clusters of items than did girls (.48), $F(1, 24) = 24.05$, $p < .001$. Not surprisingly, macro-relational accuracy was also affected by condition, $F(2, 24) = 5.61$, $p < .01$. Confidence intervals (.05, MSE = .053, Critical Value = .19) yielded a pattern of differences similar to that obtained with the local relational accuracy measure. In the uncued conditions, children who had eight months of experience (.58) were no more accurate on this measure than children who had only one to two months of experience (.61). Insofar as children in the cued condition were given four "key" cluster items, it is not surprising that their "between cluster" or macro-relational accuracy was very high (.89) and significantly greater than that for children in the uncued conditions. (Six of the ten children, five boys and one girl, in this condition had scores of 1.00, reflecting perfect performance.)

In order to assess the extent to which these three measures were tapping the same or different spatial functions, intercorrelations for the three measures were computed for the entire sample, and for boys and girls separately. For the entire sample, scores on all three measures were highly intercorrelated, r's (28) $\geq .68$, $p < .001$. Although the intercorrelations were all significant, those for the girls were somewhat higher, r's (13) $>$ .78, $p < .001$, than those for the boys, r's (13) $>$ .53, $p < .05$. Insofar as the macro-relational accuracy scores for children who were initially given cues were high and the correlations between this and the other variables might have thus been spurious (due to the restricted range), separate correlations were computed for those 20 children who were in the uncued conditions. Once again, all three correlations were highly significant, r's (18) $>$ .64, $p < .01$.

Discussion

The three measures derived seemed initially to the authors to reflect children's ability to reproduce different kinds of spatial relationships: Euclidean (absolute accuracy), topological (local-relational accuracy), and projective (macro-relational accuracy). In an absolute sense, children had higher topological (.58) and projective (.69) scores than they did Euclidean scores (.36). Although there is no direct comparability among levels of performance on the three measures, in a broad sense these findings are in line with Piaget and Inhelder's (1967) position that Euclidean concepts of space develop ontogenetically later than topological concepts. Even though the absolute levels of performance differed on the three measures, the very high and significant intercorrelations are evidence that they reflect very much the same function.

In general, the results support the notion that both increases in familiarity and the provision of significant landmarks (differentiated cues) enhance young children's spatial representations of their classrooms. At least for kindergarten children, these effects were found to be independent of chronological age per se. The pattern of results indicated that increased experience in the classroom significantly facilitated the Euclidean accuracy of the children's spatial representation but had relatively little effect on the projective and topological accuracy of their representations. This is an interesting finding, and suggests that children's representations of the classroom come to include topological and projective relationships before they include accurate Euclidean relationships. That is, even after one to two months of experience, the child's representation is relatively accurate topologically and projectively; additional experience (e.g., six more months) is required for Euclidean accuracy. This finding and interpretation is not inconsistent with Piaget's theoretical position. Insofar as all children had at least some (i.e., one to two months) experience in the classroom, it would be of interest to look at the differential effects of less experience (i.e., a week or so) on the spatial representations of these young children.

Providing "landmarks" for the children had only a slight facilitative effect on the absolute (Euclidean) accuracy scores, but had a marked effect on the local-relational (topological) and macro-relational (projective) accuracy scores. This is not surprising: giving the children properly placed central or key items in three of the five clusters provided them with both mnemonic and perceptual cues around which to organize the spatial representation.

Sex differences in a variety of tasks have been documented (Maccoby & Jacklin, 1974), and consistent differences favoring males have been found in a number of spatial tasks (Harris, 1976). However, these sex differences in spatial tasks have not been typically found much before 9 or 10 years of age, with maximal differences not usually found increasing at adolescence (Harris, 1976). Thus, the striking performance differences between boys and girls of kindergarten age was somewhat surprising. When we watched the children in action in the classroom, no obvious differences in their patterns of interaction with the environment were noted: both boys and girls seemed to know their way around, and certainly none of the children had trouble moving about in the space of the classroom or locating objects in the room.

Finally, it should be noted that the children performed remarkably well in the task. Given the demands for minification, translating the child's eye view of the classroom to an aerial perspective, and the stringent scoring system for correct absolute placement (i.e., the object had to be placed within a 2-inch circle), the levels of performance obtained indicated that 5-year-olds have a fairly rich cognitive representation of their classroom, and this representation is far more accurate than previous research (e.g., Acredolo et al., 1975; Piaget & Inhelder, 1967) has indicated.

Reference Notes

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