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ABSTRACT

The quality of representations of nine spatial arrays varying in transparency and occlusion was observed in order to test the generalization that younger children are concerned about the ambiguity of their representations and to observe the influence of a change in the medium used to create the representations. Children 5, 7, and 9 years old completed three tasks: (1) drawing a ball positioned in front of, inside, and behind transparent, striped, and opaque glasses; (2) arranging puzzle forms to represent each array; and (3) constructing each array in response to conventional drawings. Adult judges identified ambiguous drawings and puzzles and incorrect constructions. Findings indicated that younger children produced more ambiguous drawings and puzzles and more incorrect constructions than older children. Within each age group, there were equal numbers of ambiguous drawings with fewer incorrect constructions. Results indicate that the young child does not unambiguously represent conceptual information in drawings of a series of complex spatial arrays, and that the production of unambiguous representations is not necessarily facilitated by the provision of forms. (Author/RH)

Developmental and Task Influences on the Ambiguity of Children's Spatial Representations

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Running head: CHILDREN'S SPATIAL REPRESENTATIONS

This article is based upon a M.A. thesis by the first author and supervised by the second author. Reprint requests may be sent to either author at the Department of Psychology, University of Western Ontario, London, Ontario, Canada, N6A 5C2

Abstract

The quality of representations of nine spatial arrays varying in transparency and occlusion were observed in order to test the generalization that younger children are concerned about the ambiguity of their representations and to observe the influence of a change in the medium used to create the representations. 5-, 7-, and 9-year-old children completed three tasks: drawing a ball positioned in front of, inside, and behind transparent, striped, and opaque glasses; arranging puzzle forms to represent each array; and constructing each array in response to conventional drawings. Adult judges identified ambiguous drawings and puzzles and incorrect constructions. Younger children produced more ambiguous drawings and puzzles and more incorrect constructions. Within each age group, there were equal numbers of ambiguous drawings and puzzles but fewer incorrect constructions. These results indicate that the young child does not unambiguously represent conceptual information in drawings of a series of complex spatial arrays and that the production of unambiguous representations is not necessarily facilitated by the provision of forms.

Developmental and Task Influences on the Ambiguity of Children's Spatial Representations

Developmental changes in and task influences on the quality of young children's representations of simple spatial arrays have been reported in the drawing research literature and have frequently been interpreted as reflecting the young child's concern for the ambiguity of these representations. The purposes of the present study were to consider developmental differences in the ambiguity of representations of a series of complex two-object spatial arrays and to observe the influence of a change in the medium used to create the representations.

In spontaneous and structured drawing tasks, young children are likely to include nonvisible but defining features of an object in their drawings. After the age of about 8 years, children are more likely to include visually accurate perceptual information and exclude nonvisible conceptual information (Clark , 1897; Freeman & Janikoun, 1972; Kellogg, 1970). For example, Clark (1897) observed a developmental change in children's drawings of a pin stuck through an apple. Six year-old children drew the pin as a continuous line through the apple; older children excluded the occluded section of the pin.

The principal developmental change in drawings of spatial arrays is an age-related increase in the use of the visually realistic device of partial occlusion to represent one object behind or in front of another (Freeman, Eiser, & Sayer, 1977; Light & Humphreys, 1981). During early childhood, children use alternative drawing devices to represent depth instead of this realistic device (Cox, 1978; Freeman, et al., 1977: Lewis, 1963; Lindstrom, 1957; Light & Humphreys, 1981; Willats, 1977). For example, when asked to draw a small toy behind a glass, young children frequently draw the two objects separately in a vertical arrangement (Light & MacIntosh, 1980); this is an unrealistic but relatively unambiguous solution to the problem of representing a two object array.

Young children's solutions to these types of representational problems have been interpreted as a tendency to represent unambiguous, conceptual information about spatial relationships between objects when drawing. Arnheim (1974) related children's drawing to perceptual development. Drawing is a transformation of visual concepts into a two-dimensional medium. During early childhood, drawings include undifferentiated forms and simple spatial organization and indicate the child's understanding of the basic structural similarities between an object and its representation. Thus, for Arnheim, drawing is inventive. In contrast, for Piaget, drawing is an aspect of symbolic functioning whose purpose is to imitate reality. He placed drawing within the context of stages of cognitive development (Piaget & Inhelder, 1969). During the period of early childhood, drawings are characterized as an assimilation to existing schemes which include, therefore, conceptual rather than perceptual attributes of a signified object or array. The young child's use of alternative drawing devices to represent depth has also been interpreted as an indication of a sensitivity to problems of spatial representation

(Cox, 1978); and a tendency to represent conceptual, array-specific (rather than view-specific) information about a spatial array (Light & Humphreys, 1981; Light & MacIntosh, 1980; Taylor & Bacharach, 1982).

Drawing researchers have also considered the influence of task dimensions on the quality of representations (Barrett, 1983). In a study of the influence of medium on the representation of simple spatial arrays, Cox (1981) compared drawings to representations produced when the child arranged experimenter-provided forms. In both tasks, younger children used an unrealistic but unambiguous device to represent depth, whereas older children occluded one form with another with the experimenter provided forms. Model features can influence the quality of children's drawings. For example, young children may produce qualitatively different drawings of visible and nonvisible components of a two-object array; in a study of the transparency/opacity dimension, Light and MacIntosh (1980) observed that young children differentiated "inside" from "behind" when a small object was paired with a transparent container. Findings such as these have provided support for the generalization that young children are concerned with the ambiguity of their representations.

The Present Study

Five, seven and nine year-old children completed three tasks, each involving the representation of nine arrays produced by a ball positioned in front of, inside, and behind a transparent glass, a striped glass, and an opaque glass. The children were shown the arrays and asked to draw what they saw and to arrange puzzle forms to represent what they saw. In the third task, a construction task, the children arranged the ball and glasses to correspond to conventional, visually realistic line drawings of the nine arrays. The purpose of the puzzle task was to determine if the provision of forms in a complex problem facilitates the production of unambiguous representations. The purpose of the construction task was to provide a comparison between the ambiguity of drawings and the accuracy of the three dimensional constructions produced in response to conventional line drawings.

On the basis of previous research on children's drawing, it was hypothesized that younger children are more likely to represent unambiguous conceptual information about spatial relationships between two objects. In the present study, drawing and puzzle representations were evaluated on the basis of their effectiveness as representations. This approach did not require that the children use conventional, visually realistic devices in order to complete the drawing task. Thus, a task in which drawings were evaluated on the basis of their effectiveness as representations provided a test of the generalization that young children are concerned about the ambiguity of their representations.

Method

Subjects

The subjects were 35 kindergarten children (15 girls and 20 boys), 37 second grade children (17 girls and 20 boys) and 41 fourth grade children (21 girls and 20 boys). The mean age of the kindergarten children was 5 years, 11 months (range: 5 years, 5 months to 6 years, 4 months); the mean age of the second grade children was 8 years (range:7 years, 5 months to 8 years, 4 months); and the mean age of the fourth grade children was 9 years, 10 months (range: 9 years, 4 months to 10 years, 4 months). Each child was at the appropriate grade level for his or her chronological age.

Materials

The model materials were a pink rubber ball (circumference = 19.4 cm) and three clear plexiglas cylindrical glasses (8.75 x 12.5 cm). One glass was rendered opaque by a white paper covering; a second glass had a 1.5 cm wide black stripe around its circumference positioned 3 cm from the base; the third glass remained transparent. Drawing materials were red and black fine tip markers and newsprint drawing paper (30 cm x 30 cm). The puzzle materials, illustrated in Figure 1, were two-dimensional forms designed to represent the

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Insert Figure 1 about here

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three glasses and the three ball positions; two bisected ball forms were included so that the ball's positions inside the striped glass could be represented in an unambiguous manner. The construction task materials were nine 30 cm x 30 cm line drawings of the nine spatial arrays, and were rendered with red and black markers while the array was slightly below eye level.

Procedure

Pretest and familiarization The WISC-R maze subscale

(Weschler, 1974) was administered according to standardized instructions as a general evaluation of fine motor control. A familiarization task was included to facilitate the production of unambiguous representations. For the familiarization task, the experimenter presented the three glasses slightly below the child's eye level; described the features of each one; and demonstrated and described each of the nine spatial arrays produced by the combination of the glass type (transparent, opaque, striped) and the ball positions (in front, inside, and behind). The experimenter then presented the ball to the left of the first glass, described the materials, and asked the subject to "Draw what you see." This procedure was repeated for each of the two remaining glasses.

<u>Experimental tasks</u> For the drawing task, the experimenter presented the first spatial array, described the glass and the position of the ball, and asked the child to "Draw what you see." This procedure was repeated for each of the eight remaining spatial arrays. For the puzzle task, the experimenter introduced the puzzle forms, saying "Here are some cutouts for you to look at," as she arranged the forms in front of the child. She presented the first spatial array and asked the child to "Arrange the cutouts so they look like what you see. Just pick the ones you need." The experimenter recorded the child's representation by sketching the ball's position relative to a predrawn sketch of the glass form the child chose. The puzzle forms were then returned to their original arrangement. This procedure was repeated for each of the eight remaining spatial arrays. For the construction task, the

experimenter told the child that it was his or her turn to arrange the ball and the glasses and placed the ball and the 3 glasses in front of the child. The experimenter then presented the first conventional line drawing, told the child that it was a drawing of the ball and one of the glasses, and asked the child to "Show me what this is a picture of." The experimenter recorded the subject's arrangement of the model materials as correct or incorrect. This procedure was repeated for each of the eight remaining spatial arrays.

The order of the drawing and puzzle tasks was counterbalanced between subjects. All subjects completed the construction task last so that they would not see conventional drawings prior to the representational tasks. The presentation order of the glasses was randomly determined for each subject; all three ball positions for a specific glass were presented in sequence and in a randomly determined order for each subject. This order was the same for the familiarization task and for all three experimental tasks.

Scoring The scoring system assessed the effectiveness of the drawings and puzzles as representations; an effective representation was conceptualized as one that unambiguously represented specific model materials. The familiarization drawings were randomly presented to two independent adult judges who were familiar with the materials; the judges decided which glass was represented in each drawing. A familiarization drawing was classified as ambiguous if the judge's decision differed from the actual glass condition. Two independent adult judges who were familiar with the arrays followed a similar procedure for the experimental drawings and reproductions of the child's puzzle representations. A representation was classified as ambiguous if the judge's decision differed from the actual spatial array condition.

Exact agreements between the judges were 92%, 88%, and 81% for the familiarization drawings, the experimental drawings, and the puzzles, respectively. The reliability of the ambiguous classification was established by summing the number of exact agreements with the number that neither judge correctly identified. The reliabilities of the ambiguous classification were 94%, 92%, and 88% for the familiarization drawings, the experimental drawings, and the puzzles, respectively.

Results

Age and Task Effects

Table 1 presents the mean scores on the three experimental tasks as a function of age. The average number of ambiguous drawings, ambiguous puzzles and incorrect constructions decreased with increasing age. Within each age group, the mean number of ambiguous drawings and puzzles were equivalent to each other and greater than the number of incorrect constructions.

Insert Table 1 about here

The scores were analyzed by way of an analysis of variance with age, sex, and task order (drawing task first vs puzzle task first) as between-group factors and task (drawing, puzzle and construction) as the within-group factor. There were significant main effects for age, $F(2,202) = 49.43$, $p < .001$; sex, $F(1,101) = 5.08$, $p < .03$, and task, $F(2,202) = 49.01$, $p < .001$; there was no significant effect of task order; and there was a significant interaction between age and task, $F(4,101) = 2.97$, $p < .02$. Girls produced more ambiguous representations and incorrect constructions ($M = 3.08$, $SD = 1.47$) than boys did ($M = 2.73$, $SD = 1.53$). As there were no significant interactions between sex and age or sex and task, scores were collapsed across sex for all subsequent analyses.

Planned multiple comparisons of the mean age group scores were conducted using Dunn's multiple comparisons procedure (Kirk, 1982); each of the nine comparisons was tested at the .005 level. These indicated that there were significant differences between each age group on the drawing and the puzzle tasks and between the youngest and oldest children on the construction task.

The number of line and corner crossings made by each subject during successful WISC-R maze completions was tabulated. A correlational analysis of these line crossing scores and experimental drawing scores with each age group indicated that there was no significant correlation between the two scores ($r = .23$, $p < .10$; $r = .11$, $p < .25$; and $r = .02$, $p < .45$ for the 5-, 7-, and 9-year olds, respectively). Ambiguous drawings, then, were not correlated with this index of poor hand control.

A correlational analysis of the experimental task scores drawing and puzzle scores for the 5-year olds (n = 35), r = .45, p < .04, the 7-year olds (n = 37), r = .48, p < .001, and the nine year olds (n = 41), r = .41, p < .004. There were no significant correlations between representational and construction scores.

Model Effects

The proportions of ambiguous familiarization drawings of the transparent (.584), opaque (.080) and striped (.034) glasses were compared by way of the McNemar test for the significance of changes. There were significantly more ambiguous drawings of the transparent glass than of either the opaque glass, $X^2(2, N = 113) = 44.17$, $p < .004$, or the striped glass, $X^2(2, N = 113) = 59.14$, $p < .004$. Age effects on the proportons of ambiguous familiarization drawings were analyzed by way of a Chi-square test. There was a significant age effect, $X^2(2, N = 113) = 27.78$, $p < .004$, on the proportions of amgiguous familiarization drawings of the transparent glass produced by the 5- (.914), 7- (.568), and 9-year olds (.317).

The effect of model features on the experimental representational tasks was analyzed to observe more detailed differences between the drawing and puzzle tasks. Figure 2 presents the proportions of ambiguous representations of each spatial array for all age groups. The McNemar test for the significance of changes was used to compare these proportions; the error rate was controlled by setting an alpha level of .005 for each comparison.

Insert Figure 2 about here

This comparison of the drawing and puzzle data indicated that although the tasks were equivalent in terms of the mean number of ambiguous representations, the patterns of proportions were different. There were significantly fewer ambiguous puzzles than ambiguous drawings of the in front opaque, $\chi^2(2N = 113) = 9.03, p <$ .003, in front transparent, $\chi^2(2, N = 40.50, p < .0001$, and in front striped arrays, $\chi^2(2, N = 23.36, p < .0001$; there were significantly more ambiguous puzzles than ambiguous drawings of the inside striped array. $\chi^2(2, N = 113 = 27.84\ p < .0001$. The puzzle forms facilitated the production of unambiguous representations of the in front arrays but resulted in an equal or greater number of ambiguous representations of all others.

Discussion

Age, sex, and the nature of the task influenced the children's performance on the drawing, puzzle and construction tasks. There were significant differences between all age groups on the drawing and puzzle tasks; and there was a significant difference between the construction scores of the youngest and oldest children. Within each age group, the mean number of ambiguous drawings and ambiguous puzzles were equivalent; there were fewer incorrect constructions than ambiguous drawings or puzzles; and there was a significant positive correlation between the drawing and puzzle scores. The model features influenced the proportions of ambiguous drawings of each spatial array. Although the mean drawing and puzzle scores were equivalent, there were different proportions of ambiguous

The age effect on the drawing task is not consistent with the expectation created by previous research results in which the young child tends to unambiguously represent simple spatial arrays (Light & Humphreys, 1981; Light & MacIntosh, 1980). Rather, this effect demonstrates that, in a task consisting of several contrasts betweeen spatial arrays, the young child may not unambiguously represent spatial relationships. The ambiguity of children's drawings of complex spatial arrays decreases with increasing age. The drawing task in the present study was relatively complex; there are, then, a different pattern of developmental differences (as well as possible individual differences) in sensitivity to the potential ambiguity of visual contrasts presented in a complex structured drawing task (Cox, 1981; Davis, 1984; Light & Simmons, 1983). A more speculative explanation of the strength of age differences is that repeated instructions for visual realism may influence younger children to abandon the unrealistic, but unambiguous drawing devices in their repertoire such as vertical separation.

In the present study, girls produced more ambiguous drawings, more ambiguous puzzles, and more incorrect constructions than boys. The main effect of sex on performance is unexpected, but in the same direction of findings of sex differences in performance on other spatial tasks (Burstein, Bank & Jarvik, 1980). The investigation of sex effects on the quality of drawings and solutions to related spatial problems is a new direction for future research; it has been suggested, however, that conceptual and methodological issues must be carefully considered (Caplan, MacPherson & Tobin, 1985).

The task effect indicates that the provision of forms does not necessarily facilitate the production of unambiguous representations or eliminate age differences. Although the puzzle task eliminates many planning problems, it presents a complex representational task which is similar to the drawing task in terms of overall difficulty. The significant correlations between these tasks supports this observations.

In spite of this equivalence, there is a different pattern of ambiguous representations of each spatial array. The provision of forms, then, does not simply eliminate one step in the process of producing an unambiguous representation. Rather, the provision of forms creates a different representational problem which, in some cases, is more difficult than drawing. The task effect demonstrated by the comparison of the drawing and construction scores and model effect differences between the two tasks are consistent with findings that the perception of partial occlusion in drawing precedes the production of this representation of depth (Hagen, 1976) and also demonstrate a trend in which production and perception gradually converge as development proceeds (Gardner & Wolf, 1979).

The results of the present study provide mixed support for the varied theoretical interpretations of children's drawing. The findings are consistent with Arnheim's (1974) interpretation of artistic growth, in which ambiguous solutions to drawing problems are discarded as development proceeds. The Piagetian interpretation receives support from the strong relationship between the drawing and puzzle tasks. The persistence of age differences and the correlation between these tasks support the expectation that the child's performance on both tasks reflects developing spatial and representational abilities.

These findings demonstrate that the five-year-old child may not be more likely to unambiguously represent conceptual information about a complex spatial array in drawing. Rather, a consideration of the interaction between the task dimensions and the capacities and priorities of the child may provide a clearer understanding of the process of developmental change in children's drawings.

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Table 1

Mean Scores and Standard Deviations (in Parentheses) on the Drawing, Puzzle, and Construction Tasks as a Function of Age

Task	Age: 5 years	7 years	9 years
Drawing	5.11[a]	3.32[b]	2.29[c]
	(1.64)	(1.75)	(1.49)
Puzzle	5.09[a]	3.22[b]	2.05[c]
	(1.27)	(1.83)	(1.69)
Construction	2.74[a]	1.73[a,b]	1.12[b]
	(1.84)	(1.73)	(1.23)

Note: Age groups with the same superscript do not significantly differ from each other; groups with different superscripts differ at $p < .005$.

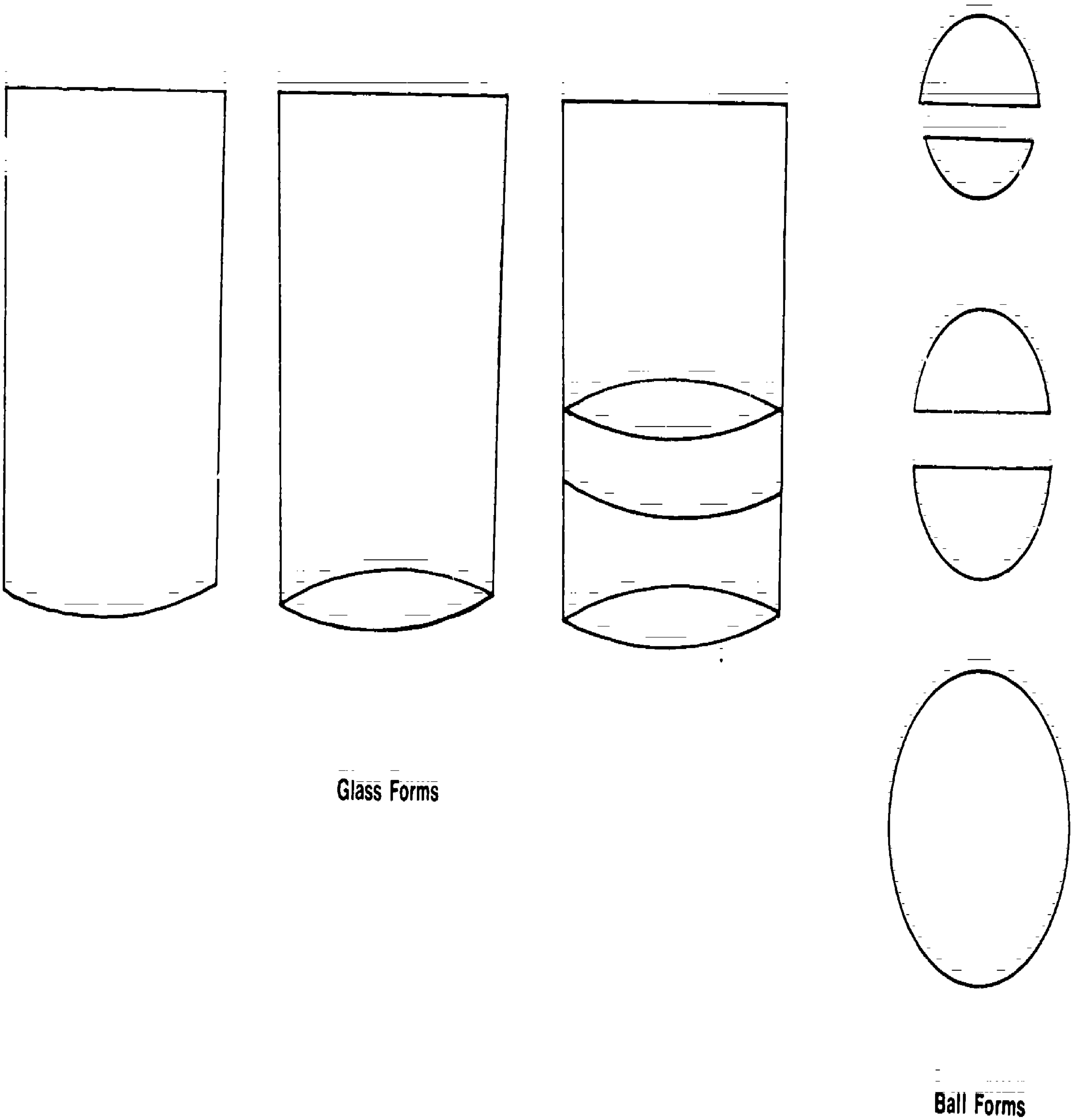

Figure 1. Two dimensional puzzle materials used in puzzle task.

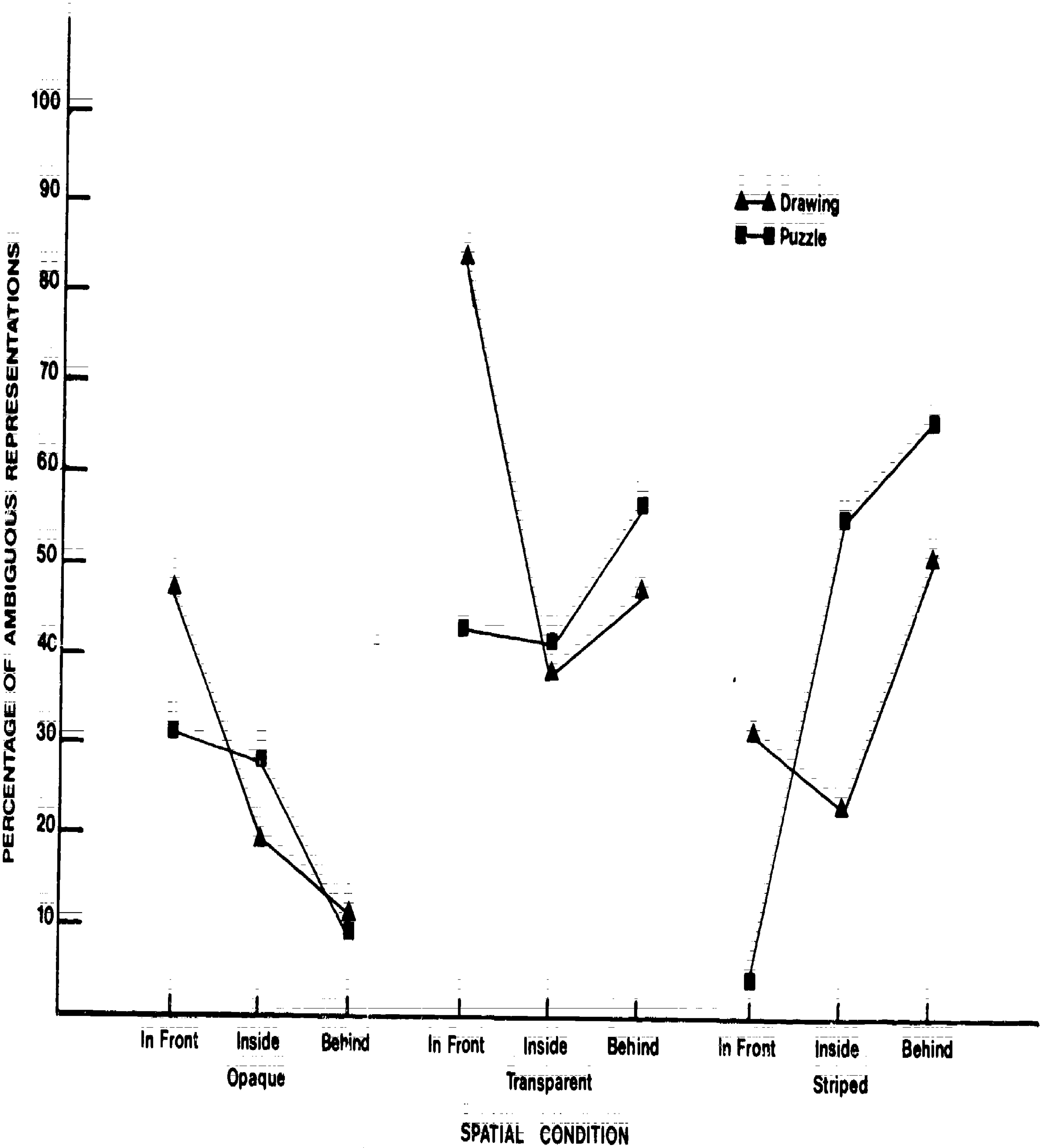

Figure 2. Proportion of ambiguous representations as a function of spatial condition averaged over age.