Tracking and change of orientation of the child or the stimulus in preschoolers' spatial localization.

Katherine A. Benson

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Tracking and Change of Orientation of the Child
or the Stimulus in Preschoolers' Spatial Localization

A Thesis Presented
by
Katherine A. Benson

Submitted to the Graduate School of the
University of Massachusetts in partial fulfillment
of the requirements for the degree of

MASTER OF SCIENCE

March, 1976
PSYCHOLOGY
Tracking and Change of Orientation of the Child or the Stimulus in Preschoolers' Spatial Localization

A Thesis Presented

by

Katherine A. Benson

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March, 1976
Acknowledgments

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Abstract

A spatial localization task was presented to 1½- and 3½-year-olds. A cereal reward was hidden randomly in one of two identical left-right positions on a turntable, and then a 180° movement of either the child or the turntable reversed the left-right location of the hidden cereal with respect to the child. The entire turntable was covered during half of the trials of each type of movement to measure reliance on visual tracking. The results indicated that some ability to mentally coordinate perspectives is present in the child as young as 1½ years of age, given optimal task conditions. In addition, performance improved with age. Better performance during the child's own movement supported the hypothesis that the child's action is a mechanism for the development of the ability to coordinate perspectives. Visual tracking aided the child but was not solely responsible for good performance. The possibility of an early egocentric spatial reference system was supported.
Introduction

The present research has focused on one aspect of Piaget and Inhelder's theory of the development of the concept of space. It is the ability to coordinate perspective changes produced by movement of an observer or an array of objects. If a child views an array of toys on a table and then walks around the table, the spatial relationships of the toys to each other and to the child are changed. The same changes occur if the array is rotated. From infancy on, the child can coordinate the successive views perceptually. They are recognized to be different views of the same array of toys. But the ability to conceptually coordinate the changes develops later; its presence may be inferred when the child can anticipate a view of the array never seen before. Thus the child would know in advance where a particular toy would be in relation to the others, if he were to move around the table. It is the conceptual level of the coordination of perspective changes which is of interest in the present study. It involves the mental representation and manipulation of the projective relations in the array.

Theory and Research of Piaget and Inhelder

According to Piaget and Inhelder, the type of spatial relations which the child can understand changes with age. Initially the child only uses topological relations such as proximity, separation, and order, because of an inabil-
ity to coordinate two sensory spaces. The inability is due to a limited repertoire of spatial activities, a tendency to center on one aspect of the spatial relations, and the failure to distinguish between these relations and the child's activity. As the child increases the scope of his activities, he begins to decenter and to distinguish the results of his own actions. Gradually the child learns to coordinate different spaces, such as those produced by his own movements, and is able to use projective and Euclidean relations in solving problems. Examples of projective and Euclidean relations are a straight line between two points and Cartesian coordinates, respectively. After mastering all of these spatial relations, the child enriches them through systematic exploration and observation.

Piaget and Inhelder (1967) studied the problem in their three-mountain experiment. Four- to twelve-year-olds were asked to predict what a model of three mountains would look like to a doll who had moved around it. Considerable topological information was available in the form of objects which were on the mountains, as well as the different sizes, shapes, and colors of the mountains themselves. Three different response tasks were required: reconstruction of the doll's view from cut-outs, identification of the doll's view from four or five possible pictures, and placement of the doll to match one of the pictures. Feed-
back was given after each of the 12-15 trials when the child moved to the new perspective. The task proved to be very difficult for the child under 9 or 10 years of age, who tended to reproduce only his own point of view. Usually he was not struck with the incongruity between the correct view and his errors, and he did not improve over trials.

**Studies Supporting Piaget and Inhelder's Findings**

Pufall and Shaw (1973) and Pufall (1973) studied the coordination of perspectives in rotation tasks. These involve the actual or imagined rotation of the stimulus with respect to the observer, instead of movements of the observer. The latter will be termed perspective changes. The stimuli and tasks were similar for both studies. Two identical boards were divided into quadrants with different markings and colors. One board was the experimenter's and the other was the child's. The experimenter's board was rotated with respect to the other as the child watched, and a marker was placed on it. Then the child had to place a marker on the nonrotated board so that it would match the location and orientation of the marker on the rotated board, when the latter was moved back into position. Both of these studies measured the child's ability to imagine the rotation of a visible stimulus. Pufall and Shaw found that the 4-year-olds were unable to either locate or orient the marker, the 6-year-olds were able to locate but not to
orient, and the 10-year-olds were proficient at both tasks. This developmental pattern is comparable to that in Piaget and Inhelder's study. Pufall systematically eliminated the colored markings differentiating the quadrants and found that the 10-year-olds could no longer perform the task. Errors, moreover, were egocentric because they reproduced the child's point of view significantly more often than would be predicted by chance.

Huttenlocher and Presson (1973) designed a study to compare the ability of 8- and 10-year-olds to coordinate perspectives produced by two types of movement. The types were the perspective change of the observer and the rotation of the stimulus array. In addition they contrasted imagined and actual forms of each type of movement, placing a cover on the array during imagined movement. The stimulus was a row of three differently colored blocks. After the movement was performed, the child was required to choose the picture which he thought would match the stimulus from the observer's new point of view. But two problems with the study have qualified the results. The task was so difficult that the children were poor at matching the visible stimulus with no movement whatsoever. Secondly, only a spatial transformation involving the movement of the child as observer can be termed an actual perspective change. But in this study the observer was a toy, not the child, and thus the transformation was imagined
on the child's part. Huttenlocher and Presson corrected the observer problem in a second experiment and found that actual movements were easier than imagined movements. Imagined rotation of the stimulus was easier than imagined perspective change. Actual perspective change of the child was never compared with actual rotation of the stimulus, however. Performance improved in the presence of an outside cue indicating amount of movement.

Pufall, Megaw, and Aschkenasy (1974) compared actual rotation and perspective change with 4-, 6-, and 10-year-olds. The experimenter and the child had matching circular boards with an isosceles triangle in each. Two animals were placed on two of the angles of the experimenter's triangle before the experimental conditions were begun. In the perspective condition the experimenter's board was hidden with the child's board and the child walked around them. Then he was asked to place the two animals on his board so that it would be like the other board underneath, which he could not see. In the rotation condition the child's board was placed alongside the experimenter's board and then rotated. The child was told to place the two animals so that, when his board was turned back, the two boards would be the same. The experimenter's board was visible during the latter condition. Two problems are evident with this study. Memory was required in only one of the tasks. Also, the intention was to compare
two actual movements, but the rotation task required the child to imagine the movement. The 4-year-olds' performance was below chance levels on both tasks, although they made fewer rotation errors. The 6-year-olds were at chance levels, and the 10-year-olds were proficient at both tasks but showed fewer perspective errors. The poor choice of controls made the results uninterpretable, however.

**Criticisms of Piaget and Inhelder's Research**

Piaget and Inhelder's research has been supported in general by the studies discussed above. But other studies have questioned the findings for a number of reasons. Smothergill, Hughes, Timmons, and Hutko (1975) used actual movement of the child and imagined movement of the stimulus with interesting results. They indicated that the young child is not always egocentric in spatial tasks, as Piaget and Inhelder suggested. Two block-line Y-shaped figures were placed on easels. The child had to match on his response Y the location of a marker which had been placed on one of the two upper arms of the experimenter's Y. The child's Y was either at 0° orientation like the experimenter's, or it had been rotated to 60°, 90°, 120°, 180°, or 270°, counter-clockwise with respect to the experimenter's Y. Two conditions were presented to 5-, 7-, and 11-year-olds. In one the easels with the Y stimuli were placed side-by-side, in the other they were placed
back-to-back. Both conditions required the child to mentally rotate his Y to match the experimenter's; the back-to-back condition also required a perspective change around the two easels.

The results showed significant effects due to age and condition. The 5-year-olds performed poorly in general, the 7-year-olds did well on both tasks, but not as well as the 11-year-olds. The side-by-side trials were easier than the back-to-back ones for all ages. There was an unexpected interaction between conditions for the 5-year-olds. Although generally responding at chance levels in the side-by-side condition, this group performed significantly above chance levels on the $0^\circ$ trials, and significantly below chance levels on the $180^\circ$ trials. In back-to-back conditions the pattern was reversed. Smothergill suggested that the 5-year-olds localized the marker with respect to its relative position to some landmark in the room. In any case it indicated use of a strategy or spatial reference system that was external and not egocentric.

Another criticism of Piaget and Inhelder's research is that the child had to imagine the transformation produced by the movement. Huttenlocher and Presson's study suggests that imagining the movement does make the task more difficult. Shantz and Watson (1970, 1971) lent support to the criticism with the following studies. In the first study (1970) they had 3-5-year-olds view a scene of
toys through a peephole and then move around to view it from the other side. The scene was secretly rotated $180^\circ$ so that the child's expectancies of change (if any) would be violated. Both age groups exhibited surprise. In a second study (1971) three toys were hidden in a $3 \times 3$ matrix of boxes with lids. The child had to locate each toy after moving around the stimulus to the other side. Performance was above chance levels even with the more exacting response task. Then a task with imagined movement was given. The child viewed an array of three toys and was asked to predict what a doll would see from various positions as it moved around. The response was to select the correct view from five photographs of different views of the array. Predicting what a doll would see proved to be much more difficult. The results suggest that part of the difficulty of Piaget and Inhelder's task was the fact that the transformation had to be imagined instead of experienced.

Another more subtle explanation for the difference between imagined and actual conditions is that the child not only had to imagine the transformation, he had to infer what someone else (the doll) was seeing. Three studies (Coie, Costanzo, and Farnill, 1973; Fishbein, Lewis, and Keiffer, 1972; and Masangkay, McCluskey, McIntyre, Sim-Knight, Vaughn, and Flavell, 1974) demonstrated that 2- and 3-year-olds can infer the visual percepts of others cor-
rectly, given optimal stimulus conditions. In these studies the child was allowed to walk around the stimulus when he so desired. Consequently, it is not possible to determine the extent to which the inference depended on having experienced the transformation. It suggests that imagining the transformation, rather than inferring the doll's view, is the principal difficulty in imagined movement.

The studies (Coie, et al., 1973; Fishbein, et al., 1972; Masangkay, et al., 1974; and Shantz and Watson, 1970, 1971) which have found ability to coordinate perspectives in preschoolers differ from Piaget and Inhelder's study in other important respects besides imagined movement. They employ different types of stimuli and response tasks. The stimuli tend to be a few discrete objects or features, rather than large, nonspecific or abstract arrays. Shantz and Watson were successful with simpler response tasks such as indicating surprise, which required no specifying, and locating objects. Borke (1975) studied these stimulus and task properties in a replication and extension of the three-mountain task. Performance was better with discrete toy figures as opposed to the array of mountains, suggesting the importance of easily discriminable cues. Similarly, when the response was changed to revolving a similar display until the child would see what the doll was inferred to be seeing,
performance improved markedly. Reconstructing the stimulus and identifying a photograph of the stimulus were difficult.

Meyer (1940) devised a number of spatial tasks in an attempt to find antecedents to the advanced level of conception of projective relations which Piaget and Inhelder identified. She found that in some cases, the child between the ages of 18 months and 5½ years had mastered some of the components of the ability, namely, comprehension of the spatial relations between objects and comprehension of the individual's own shift of position. However, the child could only perform tasks separately and with simple stimuli.

Laurendeau and Pinard (1970) replicated Piaget and Inhelder's findings in a series of five experiments with children from 2 to 12 years of age. They cautioned against attributing too much to the correct responses on simple tasks of the preschooler who is just beginning to form a concept of space. At this stage the child has well-developed perceptual abilities, and he can use them to solve spatial problems in a practical way without mental representation at all. Similarly, the child is able to mentally represent primitive topological relations. If they are available, he can sometimes use them to solve what would otherwise be a projective problem.

Several conclusions can be drawn from the discussion. Contrary to Piaget and Inhelder, some awareness of multiple
perspectives seems to be present in preschoolers. In some cases the awareness includes the ability to coordinate these perspectives. One critical factor seems to be the role of the child in the change from one perspective to another, which supports Piaget and Inhelder's theory of the importance of the child's own action in the development of spatial knowledge. Another important factor is the availability of topological information, which Piaget and Inhelder assert can be used to solve perspective problems at this age in the place of more advanced projective information. A third important factor is the use of perceptual abilities to solve perspective problems, rather than solving them at the level of representation. All of these factors depend in addition, on stimulus complexity and the complexity of the response task.

The present study will evaluate the importance of the child's own action in spatial development through a comparison of the perspective change of the child and stimulus rotation. Controls will be included to measure the degree of reliance on such primitive mechanisms as the use of topological relations, visual tracking, and perceptual memory. The age range will be lowered to 18 months to explore the beginnings of the representation of space. The possibility of an early egocentric representation of space will be explored.
Method

Subjects

The subjects were 32 children from the Amherst, Massachusetts area. Half were between 18 and 24 months of age, and half were between 42 and 48 months of age. The average ages in the two groups were 22 and 45 months, respectively. There were equal numbers of males and females in each group. Two subjects in the younger group did not complete the experiment and were replaced. The first had refused to cooperate in the initial training procedure; the second was withdrawn by his mother, who objected when the child was not reinforced for incorrect responses.

The parents of the younger group were located through birth records, informed of the project, and invited to bring their child to the Child Psychology Laboratory at the University of Massachusetts. These parents accompanied their child during testing and received $3 per visit for travel expenses. A few older children were also selected and tested in this way, but most were tested at their respective nursery schools and thus did not receive travel money for participating. The Psychology Department's "Committee on the Use of Human Subjects" approved the experiment.

Stimulus Materials and Procedures

The child was invited to the experimental room to play a "hiding" game. The apparatus, on a table in the
center of the room, consisted of a turntable 26.67 cm in diameter, to which two coasters were attached. The coasters were placed on the diameter about 6.98 cm apart, and equidistant from the center of the turntable. Each child received initial training trials to a criterion of five consecutive correct responses. On each trial, the child watched as a piece of cereal was placed on one of the coasters and both coasters were covered by identical brightly painted lids. The child's task was to find the cereal, which he was allowed to eat when he was correct. When he was incorrect, the experimenter hid the cereal again. All but three children had no training errors. To prevent learned bias during training the order of right or left position was randomized with the restriction that not more than three of the five correct trials would be on any one side.

When the training criterion was reached, the experimenter hid the cereal again and said, "Now we are going to do something else before we find the cereal. Watch what happens." At this point, one of two possible movements took place, with the turntable and lids either the same as before or hidden by a cake cover prior to the movement. The movement was either the 180° rotation of the turntable or the child walking around to the opposite side of the table. The latter will be referred to as perspective change. Both movements created a left-right re-
versal of the turntable with respect to the child. During the rotation condition the experimenter slowly rotated the turntable 180°. During the perspective change, the turntable was pulled towards the experimenter, opposite the child, and the child was told to go around to the other side of the table to find the cereal. The experimenter indicated in which direction the child should walk by saying, "Go that way", pointing to the correct path, and blocking the incorrect one. Half of the trials of each type of movement occurred with a visible turntable, and half with a covered one. Children who had many errors were given a raisin to eat between every few trials to prevent frustration.

A special demonstration was used when hidden rotation preceded visible rotation, to insure that the child knew a movement of the turntable was occurring with the cover's movement. The turntable was rotated once without the cover and with no hidden reinforcement. Then the child was told, "Now I'm going to turn it like that again. But I'm going to have the cover on top". When the child had already had the visible rotation, the experimenter said, "Now I'm going to turn it the same way as before. But I'm going to have the cover on top".

The cake cover was painted black on one half and white on the other to increase the salience of the rotation and to provide an environmental cue for rotation trials. Some
environmental cues such as doors, windows, parents, etc., were available to the child as he changed perspective, although they were minimized as much as possible. The cover was always placed so that only one color was facing the child at a time. For example, it would be placed so that the white half was facing the child, and after the reversal the black half would face the child.

Each child received 32 experimental trials. The trials were divided into four sessions of eight trials each. Each child received only two sessions on any one day, and was offered a short break between them. Within each session the movement and visibility conditions were held constant. Within the two sessions on any one day, the type of movement was held constant, since pilot research suggested that exposure to one kind of movement produced negative transfer to the other in some cases. The order of the visibility conditions was held constant for each child over the two days. Two children were randomly assigned to each of the four orders within every age/sex cell. For purposes of analysis, the eight trials in each session were divided into two blocks of four trials. Within each block of four trials, the left-right position of the hidden object and the direction of movement for the child or the turntable were counter-balanced in a random order. Two dependent variables were recorded on each trial: whether or not the response was correct,
and a rating from 0 to 5 of the amount of looking at the turntable during movement. The $180^\circ$ movement was divided into five parts (arcs of $36^\circ$), and the child was given one point for every part during which he was judged to be looking at the turntable.

Results

Analyses of Correct Responses

Analysis of Variance. A 2 (Age) x 2 (Sex) x 4 (Order) x 2 (Movement) x 2 (Visibility) x 2 (Blocks of Trials) analysis of variance was conducted on the sums of the correct responses for the four consecutive trials within each block. The percentages of correct responses for each condition are presented in Table 1.

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Insert Table 1 About Here
---

When the turntable was uncovered, it made no difference if the child performed the movement himself or not. The percentages of correct responses for perspective change and rotation were 70.3% and 69.5%, respectively. With a covered turntable, 46.9% of the responses were correct when the child walked around, compared to only 36.0% when the turntable was rotated. The interaction of type of movement and visibility was significant, $F(1,16) = 9.39$, $p < .05$, but the overall difference between movements was not. Performance was better when the
Table 1

| Perspective | 18-24-Month Old Children | 42-48-Month Old Children | Movement | Movement Under Visible and Hidden Stimulus Conditions | Percentage of Correct Localization for Different Types of
<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Visible</td>
<td>Averaged over the Stimulus</td>
<td>Averaged over the Stimulus</td>
<td>Visible</td>
<td>Averaged over the Stimulus</td>
<td>Averaged over the Stimulus</td>
</tr>
<tr>
<td>Visible</td>
<td>Averaged over the Stimulus</td>
<td>Averaged over the Stimulus</td>
<td>Visible</td>
<td>Averaged over the Stimulus</td>
<td>Averaged over the Stimulus</td>
</tr>
</tbody>
</table>
turntable was visible: 69.9% of the responses were correct with an uncovered turntable, but only 41.4% were correct with the cover on, $F(1,16) = 57.30, p < .05$. Performance improved significantly with age; the percentages were 65.6% and 45.7% for the older and younger child, respectively, $F(1,16) = 30.96, p < .05$.

In general, practice improved performance, with the percentage of correct responses increasing from 51.8% to 59.6%, $F(1,16) = 8.51, p < .05$. This trend did not hold for all conditions separately. The percentage correct increased from 44.9% to 60.6% during rotation trials, but remained at 58.6% during the child's perspective changes. This contrast in effects of practice was significant, $F(1,16) = 7.41, p < .05$. Practice effects during covered and uncovered trials were also different. There was little effect during uncovered trials when the percentage correct rose from 69.5% to 70.3%. But when the stimulus was covered the percentage correct increased from 34.0% to 48.8%. The difference in effects of practice with and without a cover interaction was significant, $F(1,16) = 4.76, p < .05$.

The effect of practice during uncovered and covered movement was significantly different for the two age groups, as may be seen in Figure 1. The older child's percentage correct fell from 82.0% to 75.0% over
Figure 1

Improvement With Practice at Each Age Level in Different Visibility Conditions

![Graph showing improvement with practice at each age level in different visibility conditions. The graph compares visible and hidden performance across different blocks and age levels. The x-axis represents different blocks and age levels, while the y-axis shows the percentage of correct localizations. The graph indicates a trend of improvement with practice, with higher percentages for older subjects compared to younger ones, and higher percentages for visible conditions compared to hidden conditions.]
blocks with an uncovered turntable, but increased from 40.6% to 64.8% with a covered one. The younger child improved with both covered and uncovered turntables, although more so with uncovered ones. The percentage of correct responses rose from 57.0% to 65.5% with an uncovered turntable and from 27.4% to 32.8% with a covered one. The Age x Visibility x Blocks interaction was significant, $F(1,16) = 7.12$, $p < .05$. Several higher order interactions were significant, but were uninterpretable, (see Appendix A). Except for these interactions, there were no significant effects due to the variables of sex or order.

**Tests of Random Responses.** In addition to the analysis of variance, four two-tailed t-tests were performed separately for each age level on the responses within the covered and uncovered perspective changes and the covered and uncovered rotations. Levels of performance that differed significantly from chance expectations indicated consistent use of a strategy, whether a correct or incorrect one. The older child performed above chance levels when the turntable was uncovered. During perspective movement he averaged 78.1% correct responses, and during stimulus rotation he averaged 78.9% (perspective: $t(15) = 6.70$, $p < .05$; rotation: $t(15) = 5.10$, $p < .05$). Performance in the covered movement conditions did not differ from chance expectations. During covered perspective
change and rotation the older child averaged 57.0% and 48.4% correct responses, respectively.

The younger child made more errors. The only condition where his performance was above chance levels was uncovered perspective movement, where he was correct 62.5% of the time, t(15) = 3.04, p < .05. He was correct 60.2% of the time during uncovered rotation, but this was not significantly different from chance expectations. The younger child made a significant number of errors during hidden trials. There were only 35.9% correct responses during perspective change, t(15) = -3.74, p < .05. The percentage was even smaller for covered rotation, only 23.4%, t(15) = -7.41, p < .05.

Analysis of Trial 1 Responses. The responses of both age groups were analyzed with the sign test to determine if the number of correct Trial 1 responses in covered and uncovered perspective changes and covered and uncovered rotation was greater or less than would be expected by older chance. Only one of the 16/children erred on the first perspective change trial, x² (1, .05) = 10.56. First trial performance during covered perspective change and uncovered rotation were not different from chance expectations, however; there were 9 and 5 errors, respectively. There were 14 errors on the first trial of covered rotation; this was significantly below chance expectations, x² (1, .05) = 7.56. The younger child performed at chance
levels on the first trial of covered and uncovered perspective changes as well as uncovered rotation. The number of errors on the first trial were 6, 10, and 10, respectively, for these conditions. Performance on the first trial of covered rotation was significantly below chance levels for the younger group; all 16 children were incorrect, \( x^2 (1, .05) = .14.06 \).

**Analyses of Attention Ratings**

**Analysis of Variance.** A 2 (Age) x 2 (Sex) x 4 (Order) x 2 (Movement) x 2 (Visibility) x 2 (Blocks) analysis of variance was conducted on the attention ratings (see Table 2). The overall attention rating on a scale from 0-5 was 3.82, indicating that children on the average looked at the turntable during 76.5% of each movement. The older child averaged significantly higher attention ratings than the younger one. The percentages of rated looking time for the two age levels were 82.0% and 70.9%, respectively, \( F(1,16) = 4.67, p < .05 \). The ratings were also significantly higher for rotation than for perspective change; the percentages were 87.8% and 65.2%, respectively, \( F(1,16) = 19.88, p < .05 \). Covering the turntable did not affect rated attention. The child looked at covered and uncovered trials 75.9% and 77.0% of the time, respectively. There was no change in rated attention over
Table 2

Each block consists of 4 trials.

Note: N = 10 for all cells.

<table>
<thead>
<tr>
<th>Trial Type</th>
<th>Visibility</th>
<th>Movement</th>
<th>Movement Under Visible and Hidden Stimulus Conditions</th>
<th>Percentage of Rater Attention for Different Types of 42–48-Month Old Children</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block 1</td>
<td>Visible</td>
<td>74.0%</td>
<td>75.0%</td>
<td>42–48-month old children</td>
</tr>
<tr>
<td>Block 2</td>
<td>Visible</td>
<td>72.0%</td>
<td>74.0%</td>
<td></td>
</tr>
<tr>
<td>Block 3</td>
<td>Visible</td>
<td>70.0%</td>
<td>72.0%</td>
<td></td>
</tr>
<tr>
<td>Block 4</td>
<td>Visible</td>
<td>68.0%</td>
<td>70.0%</td>
<td></td>
</tr>
<tr>
<td>Block 5</td>
<td>Visible</td>
<td>66.0%</td>
<td>70.0%</td>
<td></td>
</tr>
</tbody>
</table>

Average over blocks.
blocks. One higher order interaction was significant but was considered unimportant, (See Appendix A).

**Analysis of Trial 1 Attention Ratings.** The percentages of rated attention for the first trial of each condition are presented separately for the two age groups in Table 3. It can be seen that the better performance for the older children on the first trial of visible perspective change was not due to better attention, as measured by the ratings.

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Insert Table 3 About Here

---

**Correlations of Attention Ratings and Responses**

Spearman correlation coefficients were obtained for the children's attention ratings and number correct in the four perspective and rotation conditions separately. Higher attention ratings were associated with correct responses during uncovered perspective change, $r = +.43$. The association was even stronger for trials with uncovered rotation, $r = +.71$. Both correlations were significant, $p < .05$, $N = 32$. There was no relation between attention rating and response during covered movement (perspective: $r = .09$, $N = 32$; rotation: $r = +.13$, $N = 32$).

**Discussion**

**The Ability to Coordinate Perspectives**

The most important finding was that both $1\frac{3}{4}$- and $3\frac{1}{2}$-year-olds can coordinate perspectives in some conditions.
Table 3
Mean Rating of Percentage of Time Attending to Display for Each Age on the First Trial of Each Condition

<table>
<thead>
<tr>
<th>Type of Movement and Visibility of the Stimulus</th>
<th>Age of the Child</th>
<th>18-24-Month-Olds</th>
<th>42-48-Month-Olds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perspective</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visible</td>
<td></td>
<td>60.0%</td>
<td>71.2%</td>
</tr>
<tr>
<td>Hidden</td>
<td></td>
<td>53.8%</td>
<td>80.0%</td>
</tr>
<tr>
<td>Rotation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visible</td>
<td></td>
<td>82.4%</td>
<td>95.0%</td>
</tr>
<tr>
<td>Hidden</td>
<td></td>
<td>93.8%</td>
<td>98.8%</td>
</tr>
</tbody>
</table>

Note: N = 16 for all cells.
The younger child's performance was above chance during visible perspective change. The older child performed at above chance levels during both visible movements. This clearly contradicts Piaget and Inhelder's assertion that preschoolers cannot coordinate perspectives except on an immediate perceptual level. It also contradicts the findings of those who have verified their results, (Huttenlocher and Presson, 1973; Laurendeau and Pinard, 1970; Pufall, 1973; Pufall, et al., 1974; Pufall and Shaw, 1973). The finding supports other researchers, however, (Borke, 1975; Coie, et al., 1973; Fishbein, et al., 1972; Masangkay, et al., 1974; Meyer, 1940; Shantz and Watson, 1970, 1971).

**The Use of Primitive Mechanisms.** Piaget and Inhelder have stated that 3-year-olds can mentally coordinate perspectives of a single object with distinct features. They add that this is not true for arrays with more than one object because of the changing relationships not only of the observer to the objects but between the objects themselves. Thus, this explanation does not apply to the present study. Piaget and Inhelder and Laurendeau and Pinard maintain that preschoolers can mentally coordinate perspectives of arrays with more than one object only by three mechanisms. One is the coordination of topological relations, which are the first spatial relations to be mentally represented. The others are the perceptual
mechanisms of tracking and perceptual memory. The use of topological relations will be considered first.

The present apparatus afforded no topological cues to the child. There were topological cues in the room, however. Smothergill, et al., accounted for a unique pattern of responses in their youngest group by suggesting that they had used room cues. But there are several reasons for rejecting this explanation in the present study. Relating the cereal's position to some object in the room would have produced correct responses in the covered and uncovered perspective changes, and incorrect responses in covered and uncovered rotation. This pattern was not present in the responses of either age group. Furthermore, there is no evidence that children habitually respond in this way, and it seems more to be an artifact of Smothergill's task, possibly due to the vertical placement of the stimulus. Topological relations with respect to the child's body symmetry could have been used here, and would explain the below chance responding in covered trials. They indicate the presence of an egocentric reference system.

The use of tracking can partially explain the results since performance was impaired by the cover. However, the good performance during perspective change suggests that it was not alone as an aid. First of all, there was significantly more tracking in rotation trials than in per-
spective trials, as measured by attention ratings. Correct responses were associated with higher attention ratings during both visible movements. Yet performance during rotation wasn't correspondingly better, if anything it was slightly worse. Secondly, covered perspective change was significantly better than covered rotation, even though tracking was prevented in both and the attention ratings were not different for the two conditions. However, performance in both covered conditions was lower than in the uncovered conditions. Thus, while tracking does seem to be an aid for the task, and may be an important contributor to the development of spatial abilities, it is not wholly responsible for the subjects' above chance performance.

Perceptual memory is another primitive mechanism which could have been used by the preschoolers in place of conceptual processes. Perceptual memory is the remembrance of the sequence of static images arising from the movement of a visible stimulus or an observer. However, the movement in the experiment was never demonstrated with the cereal uncovered, which would have created a visible perceptual sequence for recollection in trials with the hidden cereal. Thus, perceptual memory cannot account for the results here.

Learned Response Bias. Another explanation is that a response bias was learned apart from any real ability to
coordinate perspectives, because the child was given feedback and reinforcement. This explanation can be called into question because learning did not occur in all conditions. There was little or no learning in the perspective change and visible conditions, where performance was above chance levels from the beginning. Also, the older child performed above chance levels on the first trial of visible perspective change.

A Combination of Primitive Mechanisms and Learned Bias. It is possible that a combination of tracking and learning could account for performance being above chance levels. The only condition where the first trial resulted in performance above chance levels was the older child's visible perspective change. Visual tracking could account for the correct responses here, and a learned response bias could have raised subsequent responses to a level above chance for the older child's visible rotation and the younger child's visible perspective change. If this were the case, then the older child's performance on the first trial of visible rotation should also have been above chance, however, and it was not. This was not due to a significant difference in attention ratings for these trials; if anything, attention ratings were better for the rotation condition. And if a learned bias were to account for the younger child's performance during visible perspective change, then a learned bias would also
be expected during the younger child's visible rotation trials. Again, this was not found, and there were no differences in rated attention which could account for it. It would seem that the child's own action enabled him to mentally represent the perspective change taking place, and the coordination of perspectives did occur.

The Role of Type of Movement. Part of Piaget and Inhelder's theory supports the notion that conceptual coordination of perspectives occurred in the present study. They stress the importance of the child's own actions in spatial development, even to the extent of equating a perception of an object to the action on that object. In perspective trials the child's action caused the reversal. Perhaps the child was able to mentally represent the perspective reversal because it was based on his own actions. The older child was nearly able to overcome the interference caused by a covered turntable during perspective change, and perhaps with more subjects or slightly older subjects this would have been the case. The high level of performance during perspective change in spite of significantly lower attention ratings certainly indicates less dependence on visual tracking at any rate, and more dependence on conceptual processes.

Perhaps the child has had more experience with movements of the self rather than of objects, and the fact that it is the child's own action is not relevant. The
reverse would seem to be the case, however, because infants watch and manipulate objects before they develop locomotion. Also Meyer (1940) found that one of the latest spatial abilities to develop was the spontaneous movement of the self to solve a task. Rotations of objects occurred earlier. A test of this hypothesis would be a task where the child would spontaneously rotate a stimulus $180^\circ$, as he was motivated to move around the table in the present study. If he performed that action himself, perhaps he would also be able to mentally represent it.

**The Improvement Over Trials**

As for the finding of the ability to coordinate perspectives, the presence of learning in the experiment was contrary to Piaget and Inhelder's results. The child in the mountain experiment did not improve during 12-15 trials, yet learning began to occur early in the present study. This could have been due, at least in part, to the simpler task. Pufall (1975) has proposed that discrepancies due to egocentric errors motivate the child to change his activities and strategies, and so promote cognitive growth. This explanation is consistent with the present study, and could explain the improvement in conditions where egocentricity dominated. But performance in these conditions still did not surpass chance expectations.

Anecdotal information suggests that some children
were able to improve their performance without understanding what was really happening. During rotation, although they watched and were told that the turntable was moving, some children often missed the first few trials. Then they would begin to choose the correct lid, exclaiming, "It's magic!", or "It walked over there!", or "How did it get there?". They would continue being correct, but each time they would express their delight and amazement at this seemingly impossible occurrence. It was as though the children instructed themselves, "It's magic. You have to look in the 'wrong' place to find the cereal." Similar evidence came from the acts of reaching for the lid on rotation and covered trials. Some children would begin to choose the incorrect lid, but then would, with what seemed considerable effort, force their arm over to the correct lid. It was as if they were acting against their own better judgment. Perhaps the disequilibrium caused by their errors motivated them to change their behavior, but without giving them an understanding of the transformations. This supports Piaget's theory about the role of action in the child's development. The errors provide motivation for increased activity, and the new activities and increased experience allow for the construction of concepts.

The Presence of an Egocentric Spatial Reference System

The egocentrism shown by the younger child in the
covered conditions suggests that the first representation of space is a self-reference system which uses topological relations, as Piaget maintains. The older child who was performing at chance levels in the covered condition was possibly in a transition state between the egocentric system and a projective one for that task. On the first trial of covered rotation he may have used an egocentric reference system. Then his rule-making ability was able to overcome the directives provided by a weakening egocentric system. Perhaps the younger child was in a similar transition during visible rotation. The task specificity of egocentrism has been documented (Pufall, 1973, 1975). Pufall asserts that egocentric and nonegocentric spatial systems coexist in the child, but that the younger operational child cannot coordinate perspectives with symmetrical stimuli. The evidence in the present study contradicts the latter assertion, and suggests that, if the systems do indeed coexist, they do so in preschoolers as well.
References


Appendix A

Uninterpretable Higher Order Interactions Reaching Significance

<table>
<thead>
<tr>
<th>Interacting Variables</th>
<th>Level of Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Analysis of Correct Responses</strong></td>
<td></td>
</tr>
<tr>
<td>Age x Sex x Movement x Visibility</td>
<td>F(1, 16) = 6.72, p &lt; .05</td>
</tr>
<tr>
<td>Sex x Order x Movement x Visibility</td>
<td>F(3, 16) = 4.46, p &lt; .05</td>
</tr>
<tr>
<td>Age x Sex x Order x Movement x Visibility</td>
<td>F(3, 16) = 5.94, p &lt; .05</td>
</tr>
<tr>
<td>Age x Sex x Order x Movement x Blocks</td>
<td>F(3, 16) = 1.62, p &lt; .05</td>
</tr>
<tr>
<td><strong>Analysis of Attention Ratings</strong></td>
<td></td>
</tr>
<tr>
<td>Age x Order x Blocks</td>
<td>F(3, 16) = 3.84, p &lt; .05</td>
</tr>
</tbody>
</table>
APPENDIX B-1

Raw Data: Attention Ratings (A) and Number of Correct Responses (R) for Older Children, Presented Trial by Trial Within Each Block for all Conditions

<table>
<thead>
<tr>
<th>SUBJECT INFORMATION</th>
<th>MOVEMENT X VISIBILITY CONDITION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PERSPECTIVE-VISIBLE (PV)</td>
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<td>BLOCK 2</td>
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<td>05310 111</td>
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Note. Refer to Appendix B-3 for a key to the subject information.
### APPENDIX B-2

**Raw Data: Attention Ratings (A) and Number of Correct Responses (R) for Younger Children, Presented Trial by Trial Within Each Block for all Conditions**

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<tr>
<th>SUBJECT INFORMATION</th>
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</table>

**Note.** Refer to Appendix B-3 for a key to the subject information.
Appendix B-3

Key to Subject Information in Appendix B

<table>
<thead>
<tr>
<th>Number of Space</th>
<th>Item</th>
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</thead>
<tbody>
<tr>
<td>1-2</td>
<td>Assigned subject number</td>
</tr>
<tr>
<td>3-5</td>
<td>Subject age in years (1 or 3) and months</td>
</tr>
<tr>
<td>6</td>
<td>Age group, 1 = older and 2 = younger</td>
</tr>
<tr>
<td>7</td>
<td>Sex, 1 = male and 2 = female</td>
</tr>
<tr>
<td>8</td>
<td>Order of presentation of conditions. The orders are:</td>
</tr>
<tr>
<td></td>
<td>1 = PV, PH, RV, RH</td>
</tr>
<tr>
<td></td>
<td>2 = PH, PV, RH, RV</td>
</tr>
<tr>
<td></td>
<td>3 = RV, RH, PV, PH</td>
</tr>
<tr>
<td></td>
<td>4 = RH, RV, PH, PV</td>
</tr>
</tbody>
</table>