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CHILDREN'S REPRESENTATION OF SPATIAL INFORMATION

by

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B.S. May 1980, Old Dominion University

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ABSTRACT

CHILDREN'S REPRESENTATION OF SPATIAL INFORMATION

Rebecca L. Beard
Old Dominion University, 1982
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The present study utilized a multi-dimensional approach to examine children's communication of spatial information. Sixty male and female elementary school children, ages 6-7, 9-10, and 11-12, learned a route through a pedestrian maze with four color-coded intersections and animal photographs to serve as landmarks. After learning the route to a specified criterion level, the children were required to complete three remaining tasks: a verbal recall task, a nonverbal reconstruction task, and a route reversal task. For each task the children were asked to provide a reason for their directional choice at each intersection. Analyses indicated developmental differences in performance only for the maze learning task and the verbal recall task. Sex differences were found to be significant only in an interaction with age for the reconstruction task and with age and starting position for the maze learning task. An analysis of variance examining the design of the maze (i.e., errors per intersection) indicated that one intersection produced differences in performance depending upon starting position. Chi-square analyses of the verbal reasons for each directional choice indicated a primarily egocentric frame of reference in the youngest children and a more allocentric one in the middle and older children. Discussion focused on the cognitive demands associated with the spatial tasks employed and their influence on children's communication of spatial information.

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INTRODUCTION

When individuals interact with the environment on a daily basis they incorporate knowledge of that environment into a spatial representation. This representation permits an individual to move from one place in the environment to another along either learned or novel pathways and to communicate spatial knowledge. Reliance on a spatial representation allows the individual to make inferences about his/her environment through the efficient use of what is already known. When an individual learns a new environment, he/she must go through a sequence of cognitive and spatial organization that is characterized by attention to separate environmental features (landmarks), then focus on connecting these separate features into a sequence (routes), and finally integration of these components into a complex representation. This representation, in Tolman's view (1948), refers to the construction of an "overview" of the implicit spatial relations contained in a space, rather than the remembering of a set of spatial relations. Shemyakin (1962) indicated that complex spatial representations are characterized by the simultaneous comprehension of a number of details. Numerous studies of spatial knowledge have indicated that the cognitive maturity of the individual has a major influence on the formation of representations (Hardwick, McIntyre, & Pick, 1976; Piaget, Inhelder, & Szeminska, 1960; Stea & Blaut, 1973).

In the study of spatial representation, large-scale space has been defined as a space so large that its overall configuration cannot be perceived from a single vantage point (Kuipers, 1976). Acquisition of a large-scale spatial representation can be viewed as a sequence of events that begins with the development of landmark knowledge, progresses to route knowledge, and finally culminates in configurational knowledge. When learning a new environment, both children (Siegel & White, 1975) and adults (Zannaras, 1976) have been found to progress through this specified sequence, although children proceed through the sequence at a slower rate than that of adults. A child must progress through each step of the sequence before he/she can negotiate within the environment with the same efficiency as an adult.

Frames of Reference and Spatial Representations

Landmark knowledge.

Landmarks are spatial anchors which serve as the main focus of a young child's attention while he/she is interacting with the environment. Landmark knowledge develops first in the development of spatial representations of large scale space and involves reliance on an objective as opposed to subjective frame of reference for organizing space. Pick and Lockman (1981) define frames of reference as "a locus or set of loci with respect to which spatial position is defined." An egocentric frame of reference determines spatial locations through their relationship with one's own body, as opposed to an allocentric frame in which positions are defined external to the individual. Moore (1976) refers to this concept indicating that landmark knowledge involves an ongoing process of differentiation between self-orientation and outside orientation. The frame of reference is essential in aiding the recall and reconstruction of location, orientation, and inter-object relationships among the landmarks (Pick, 1970). It provides a means of maintaining some connection between isolated objects or experiences and therefore makes them easier to remember. Previous research has found that the ability to recognize single, discriminate objects (i.e., landmarks) remains fairly stable over the life span (Brown, 1973), indicating that what distinguishes between various ages is the formation of this frame of reference, not the recognition of landmarks themselves. Siegel and White (1975) incorporated this idea into their concept of developmental change in "recognition in context memory."

Therefore, the focus of attention should be on the frames of reference used by the child and not landmark knowledge itself. Piaget and Inhelder (1967) state that the young child begins with an egocentric frame of reference, where spatial information is encoded in reference to his/her own body, and gradually develops a more objective mode of representation. This objective system enables the child to focus on landmarks as central features, then progress to the use of abstract Euclidean concepts to coordinate spatial relations. Along similar lines, Hart and Moore (1973) describe the development of cognitive mapping as stages of increasingly integrated frames of reference from a) undifferentiated egocentric to b) differentiated egocentric, partially coordinated into fixed subgroups (reflecting a delineation into routes) to c) abstractly coordinated and integrated systems (through the influence of Euclidean thought).

This developmental trend from egocentric to allocentric responding has been found in a series of studies by Acredolo (1976, 1977, 1978). Her results indicate that the age at which this difference in response occurs depends largely on situation variables such as the nature of the task, the salience of the landmarks, and the complexity of the change of position in responding. If the task is kept simple and the landmarks are very distinctive, the shift in frame of reference utilized appears between the ages of three and seven (Acredolo, 1976). In situations where the landmarks are less distinctive or the response required of the child is complex and difficult, the shift occurs later (between the ages of seven to ten). Goldsmith (1979) in a study examining performance in relation to either egocentric, allocentric, or the simultaneous use of both frames of reference found that performance according to one reference system was dependent on orientation according to the other reference system. Thus, at three years of age, children performed at chance level on tasks requiring the use of the single allocentric or the contingent use of both egocentric and allocentric. At five years of age children are able to perform at chance level when both reference systems are required. It is not until the age of seven that children are able to perform above chance on the single or combined reference systems. These differences were attributed to the difficulty involved in the contingent use of reference systems (Goldsmith, 1979). When a child attempts to perform in a large-scale environment, the frame of reference used influences his/her ability to successfully complete the task. The allocentric reference promotes better performance by providing an objective relationship between isolated objects rather than focusing on the child's relationship to the objects.

Route knowledge. After the child learns how to represent isolated objects through frames of reference, the next step in this developmental sequence is the formation of routes. Route formation provides a connection between landmarks producing an essential aspect of wayfinding ability, i.e., the knowledge of what direction to pursue in order to link the landmarks. This step is necessary for the development of a representation of the environment -- it adds a frame of reference for negotiating through the environment (Siegel, Kirasic, & Kail, 1978). Route knowledge is expressed through either an egocentric (body-centered left-right) frame of reference or an objective (landmark oriented) frame of reference. Route learning indicates the presence of a higher-order knowledge allowing landmark-bearing associations to become successive temporal and spatial sequences.

Previous research utilizing large-scale mazes has found a trend toward age related increases in performance level, according to the stage of spatial development of the child. Batalla (1934) in a study of the performance of nursery school and elementary school children in a maze-like structure found that children reacted to pathways as separate units, lacking an understanding of the whole relationship of the various paths. Similarly, Maier (1936) was interested in determining whether children were able to integrate or combine isolated experiences in a maze into a coherent whole. His results indicate that it is not until the child has reached the age of six or seven that he/she is able to combine experiences to reach a goal. Prior to this age the children were merely forming serial associations. Other research examining route formation has found developmental differences for cue utilization in the placement of objects along a route (Acredolo, Pick & Olsen, 1975), in the selection and ability to judge the value of potential landmarks for distance judgements (Allen, Kirasic, Siegel, & Herman, 1979), and in inferences (such as if we are here, what is in the other room) made about landmarks along a route (Hazen, Lockman, & Pick, 1978).

Configurational knowledge. The culmination in the acquisition of a large-scale representation involves the formation of a configurational representation of the relations between routes and landmarks. Configurational representations provide a means of storing environmental knowledge, integrating existing route knowledge, and deriving new routes without the actual experience that is necessary for route learning. With configurational knowledge, the child can ascertain the best route between two points even though he/she has never transversed it. This configuration is more efficient in storing and retrieving spatial knowledge due to its organization and representation of the environment as a whole. Piaget, Inhelder, and Szeminska (1960) found this general trend in development during the ages of four to twelve years when the children were asked to draw and build models of their school and the local surroundings (including a well known route). The younger children relied basically on landmark knowledge and did not attempt to link the landmarks. Older children reconstructed routes and used an object-oriented frame of reference but did not create a configuration of the area. The formation of an overall configuration of the area appeared in the most advanced children thus supporting the concept of a sequential development in spatial representation.

Sex Differences in Spatial Performance

Throughout the literature, developmental trends in spatial representation have become well supported, with the findings indicating that differences in spatial ability exist between children of various cognitive levels. Another difference that has been found in previous research pertains to an inequality of performance on spatial tasks exhibited by males and females. In general, males tend to exhibit better performance on spatial tasks than females.

Research examining sex differences on tasks requiring the quick identification of body parts (hands, feet, ears, and eyes) as either appearing on the left or right side of the body found that college aged women made significantly more errors than men (Harris & Gitterman, 1977). Similar findings were obtained in a study in which subjects were asked to describe their own body movements under speeded conditions. Money, Alexander, and Walker, (1965) asked their subjects to imagine following a standard route on an outline map of city streets telling whether each turn is to his/her left or right, without turning the map. The results indicate that among seven to eighteen year olds, boys outscored girls at each age level; those turns requiring left-right reversal were the most difficult, especially for girls.

In tasks varying from small scale to large scale space, sex differences in spatial ability continue to be supported. Keogh (1971) designed a "pattern walking" task where eight to nine year olds were asked to draw simple designs or combinations of designs and then create the same patterns by walking. The three conditions involved walking on the unmarked floor of a large room, on a 9 x 9 foot mat, and in a 9 x 9 foot sandbox (leaving footprints). Males and females were equally accurate in their drawing and walking in unbounded space (unmarked floor), but males' performance improved as more visual cues became available (i.e., the bounded space of the mat and sandbox), becoming significantly more accurate. Similarly, Herman and Siegel (1978) had kindergarten, second, and fifth grade children walk through a large scale model town and then recreate the town from memory. Overall, accuracy was found to improve with age, and boys were significantly more accurate than girls at the second and fifth grade levels.

Questions concerning why these differences between the two sexes occur have focused on brain lateralization (Dawson, Farrow, & Dawson, 1980; Witelson, 1976), the influence of genetics and hormonal imbalances (McGee, 1979) or socialization processes (Harper & Sanders, 1975). It has been proposed that in brain lateralization, males develop the right hemisphere earlier (spatial component) and females develop the left hemisphere earlier (verbal component), contributing to their spatial performance variability. Genetics (McGee, 1979) has been examined in light of sex differences, with the finding that these differences may be attributable to an X-linked recessive gene or to the hormonal imbalances associated with puberty. The influence of socialization has also been examined with respect to behavior in play and types of toys used. Harris (1981) suggests that it is the females' superiority in verbal skills that is the critical factor in performance on spatial tasks. This greater reliance on verbal mediation is less efficient for processing spatial information, thus producing a decrement in scores.

Spatial Knowledge and the Concept of "Reversal"

In the formation of a spatial representation of large scale space, it is evident that frames of reference play an integral part in landmark knowledge and route learning. One aspect of route learning that has received attention is the ability to transverse a route in the reverse direction from which it was learned.

Research examining the ability to perform the reverse of spatial knowledge previously learned has found a difference according to the frames of reference employed by the child. Not until the child has obtained the level of concrete operations (around nine to ten years of age) is he/she able to reverse the perception of right and left when examining an object or person in front of and facing him/her (Piaget & Inhelder, 1967). Before this stage is reached, the child is unable to break away from such egocentric notions. Laurendeau and Pinard (1970) state that there are three stages in the development of the concepts of right and left. Stage one involves the perception of left-right as tied to the child's own body and are not always viewed as opposites. In stage two, the child becomes aware of the function of his/her own point of view and that there are other potential viewpoints, but is not always capable of recognizing and utilizing these. In the last stage, the child realizes that there are absolute and relative views of left and right without fully comprehending the concepts of "to the left of" and "to the right of." At approximately four to five years of age the first stage is reached, stage two appears at seven to eight years of age and stage three at ten to twelve years of age. In this respect, children who consider spatial relations from an egocentric point of view exhibit a lower level of performance in distinguishing left from right in a reversal task.

Previous research has found that the reversal of spatial knowledge has an effect on the frame of reference. In examining the difference between place as opposed to response learning, Acredolo (1977) found that place learning increased the performance of the younger children in the three to five year old age range. In the task the children learned to walk straight ahead from one end of a room and turn to the left or right to find a trinket hidden on either side of the room. Once performance had reached the criterion level of one perfect trial, the children were required to find the trinket starting from the opposite side of the room, under two conditions where either the cups were distinctively marked or the starting position was marked. The three year old children performed above chance level in the second condition. It appears that the younger children's performance was greatly aided by the place cues that were available. In order to study the abilities of preschoolers to reverse spatial knowledge, Brown and Lawton (1975) required these children to reconstruct a route taken by a baby elephant (plastic toy) in a model jungle. Their findings indicate that these children were able to complete the route in the reverse direction. Along similar lines, Brown and Murphy (1975) found that children in the preoperational stage of development are capable of recreating a forward sequence of events, but it is not until the concrete operational level is reached that the child is able to reverse the sequence.

These trends in the development of the ability to reverse spatial representations indicate that a certain level of cognitive ability must be attained before reversal is possible. The younger children operating under an egocentric frame of reference were again less able to reverse the spatial knowledge when a complex task was presented. In the task examined by Acredolo (1977) there was no sequencing involved so the younger children were able to reverse the response when place cues for the starting point were given. In the more cognitively demanding tasks by Brown and Lawton (1975) and Brown and Murphy (1975) involving sequencing, the younger children were unable to reverse the sequence. A later study supporting the ability of young children to reverse spatial knowledge tested three to six year old children on their ability to learn a specific route and then reverse it (Hazen, Lockman, & Pick, 1978). Their results indicated that even the youngest children were able to reverse the route, the only difference between ages being that fewer errors were made by the older children. These findings contradict those found by Brown and Lawton (1975) although the difference may be accounted for by the type of space that is being used, as in large vs. small scale space. Young children are capable of completing a sequence in a forward direction but research so far shows a limited ability to reverse the sequence, perhaps as a function of the frame of reference utilized.

Assessing Children's Spatial Representations

Several different methods have been used to assess the development of children's spatial representations. One measure of spatial performance utilizes motor behavior to examine how well the child can negotiate through a given space. Several studies (Acredolo, 1977; Batalla, 1934; Hazen,Lockman, & Pick, 1978; Maier, 1936) mentioned earlier all required the children to move actively in the environment in order to study their spatial knowledge. However, the use of navigation itself does not necessarily imply the presence of cognitive representation, it may merely reflect an ability to use perceptual cues (Liben, 1982). A second measure involves the use of reversal (motoric) as a measure of spatial representation. This requires an external frame of reference but reveals spatial representation only on a primitive level using nothing more than the ability to recognize cues in the surrounding environment and the knowledge that rules must be used to reorganize perception of the environment. A third means of assessing spatial representation involves the reconstruction of large-scale space within the confines of a small scale space. Siegel and Schadler (1977) had children reconstruct a table top model of their elementary school classroom, concluding that even though some of the children were unable to reconstruct the room they still maintained spatial representation. Unfortunately, there is no concrete evidence about the ability of children to translate from one scale environment to another scale the salient features of the environment. Previous research has also used map drawing as a measure of spatial representation (Moore, 1976). Although Siegel (1981) states that children know more than they can draw, the measure of knowledge is confounded with their drawing ability. A final, seldom-used measure of spatial representation is the use of verbal description. In connection with verbal ability, Siegel (1981) indicated that there may be separate verbal and visual-spatial knowledge systems. Consequently, a child's verbal ability may lag behind his/her visual-spatial ability.

Typically, a single task, with its own strengths and weaknesses, has been involved in each experiment. Liben (1982) suggests that there is no best method. All of these methods involve products of spatial knowledge (maps, verbal descriptions, etc.) which are the result of stored spatial information, being translated by different cognitive operations. Liben (1982) suggested that in order to learn more about the development of these operations, studies could employ the strategy of providing several different tasks to measure spatial representation.

The Present Study: Hypotheses

The present study focuses attention on the influence of age and sex on children's performance on several types of tasks (motor, verbal, and visual-spatial) in a large-scale space. As discussed earlier, the frame of reference used by children to orient themselves in space has a great influence on their performance in spatial tasks. This study was designed to examine a) how well children can "reverse" spatial knowledge to enable them to walk from the end to the beginning of a route, b) how well they can reconstruct the route nonverbally, c) how well children are able to communicate verbally directions after motorically learning a route, and d) which of the available cues they utilized in each task. Previous research has not studied all of these components in a single experimental design.

Maze learning. The first task utilized in this experiment was a walkthrough maze, requiring the children to learn a route consisting of four choice points. A verbal component was included in this task in order to obtain information regarding the type of cue utilized by the children in learning the maze. From the research cited earlier, it was expected that the older children would learn the maze faster and more efficiently than the younger children, with males performing superior to females.

"Reversal" of spatial knowledge. This task required the children to walk through the maze once in the reverse direction from which it was learned and to indicate at each intersection how they knew to follow that direction in the intersection. Older children were expected to be more accurate than the younger children with males performing better than females.

Visual-spatial task. To examine large scale spatial representation in several forms the third task involved re-creating the route through line diagrams of the choice points, utilizing sequencing (color) and place cues (animal pictures) provided along the route. This task enables the child to communicate the path through the maze in a nonverbal manner. A verbal component was added to examine the type of cue used in making directional choices. Males were expected to perform better than females on this task due to the more visual-spatial characteristics of the task, along with an increase in performance level with age.

Verbal communication. The use of verbal communication has received little attention in relation to large-scale spatial representation. A previous study examined the ability of preschool children to communicate directions to another child after they had learned a pathway through tunnels. Goldstein and Kose (1978) asked children who had learned the route through a tunnel to describe to another child who was in the tunnel how to get through it. Their results indicated that the children were able to communicate effectively the correct route through the tunnel while viewing it from above, but that their familiarity (as in number of trials in the learning phase) affected their performance.

In the present experiment, children were asked to communicate verbally how to get through the maze when provided with no external cues. Since females appear to be more verbal at an earlier age than males, it was expected that females would perform better on this task than the males. The same age trends discussed earlier were proposed to occur for this task, with performance level increasing as age increases.

Proposed Developmental Sequence of Tasks

The ability to perform the proposed tasks should appear in a developmental framework, with motor performance as the easiest task, followed by the ability to reverse the route, then reconstruction, and finally the ability to communicate verbally spatial information appearing around the age of eleven to twelve years of age. Since motor learning of the maze involves the ability to recognize salient cues in the environment and to use them in negotiating the maze, this ability should appear even in the youngest children. The ability to reverse the maze requires the child to recognize the cues in the environment and to know that they must be reversed to successfully perform in this task. This knowledge that a manipulation must be performed on the relations previously learned in order to negotiate the maze in reverse is cognitively demanding and thus will appear late in child development. The reconstruction of the maze requires the child to transform knowledge gained in a large-scale space into performance on a small scale space.

Although some cues are available to aid the child in reconstructing the maze, recall is also involved so a high level of performance on this task will appear in the older children. The verbal task requires the transformation of visual-spatial information into linguistic descriptions through the total use of recall and thus should not appear until late in development.

METHOD

Subjects

Sixty children were recruited from the families of college faculty, staff, and students on a voluntary basis. Twenty first graders (ranging in age from five years eleven months to seven years nine months, $\overline{x} = 6.61$), twenty fourth graders (ranging in age from eight years eleven months to ten years six months, $\overline{x} = 9.88$), and twenty sixth graders (ranging in age from eleven years two months to twelve years eight months, $\overline{x} = 11.31$) participated in the experiment. An equal number of males and females were included in each group. Parental permission was obtained for each child.

Apparatus

A pedestrian maze was constructed of cardboard in a 7.3 m x 9.4 m experimental laboratory. The walls of the maze were 1.8 m high and the pathways 45.7 cm wide. The maze contained four choice points, each an intersection providing the subject with the options of turning left, right, or continuing forward (see Figure 1). The design of the maze prevented the subjects from seeing which two of the three options led to cul-de-sacs. Each intersection was color coded (either orange, red, blue, or green) with a square of colored paper located on the floor at the center

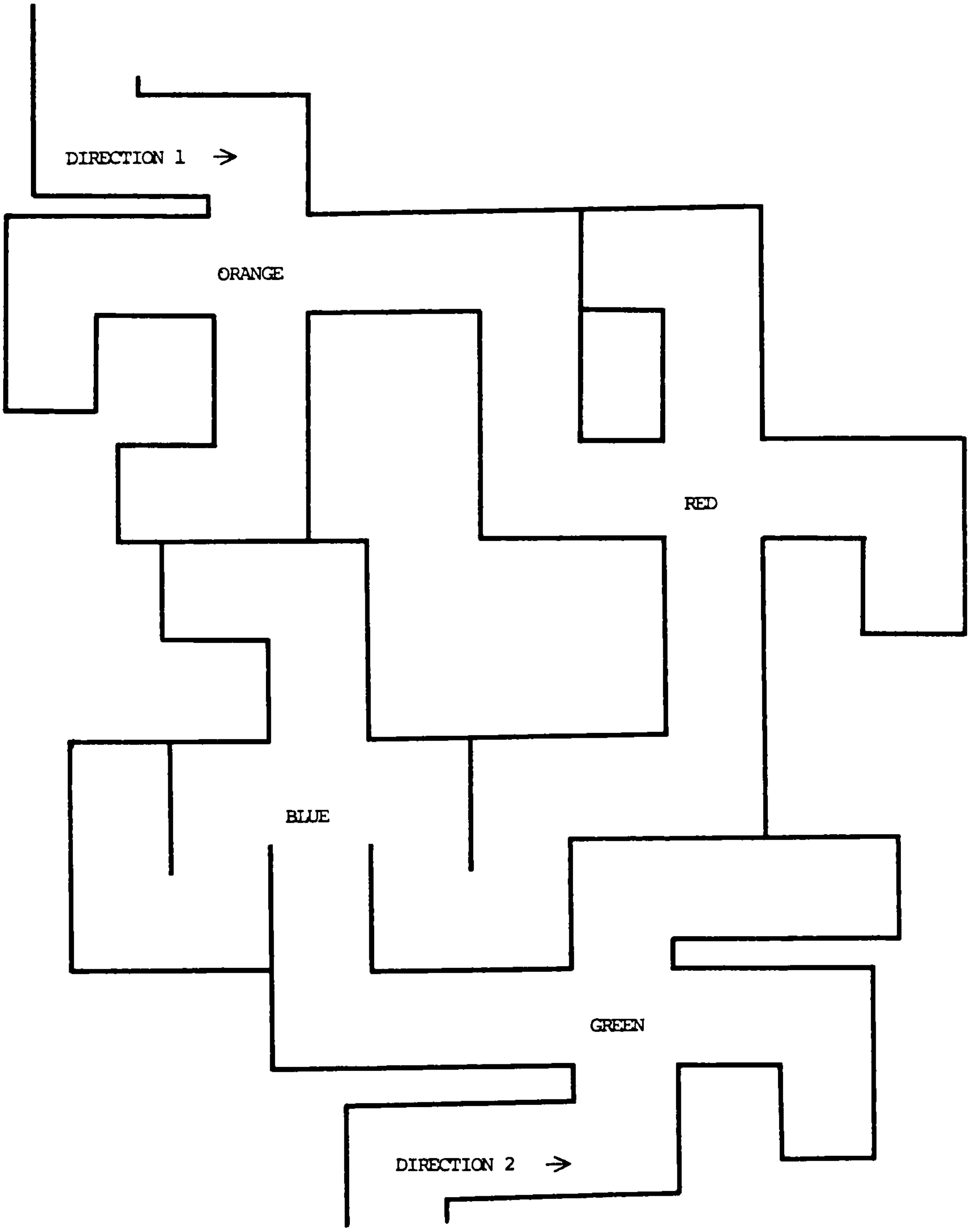

Figure 1. Diagram of the Maze

of the choice point. Pictures of animals were located on the floor at each branch of the intersections. Each picture was a color photograph of an animal mounted on a 20.3 cm^2 piece of yellow construction paper. These pictures, which faced the center of the intersection, provided a total of sixteen potential cues along the pathways comprising the maze. A beige cargo parachute was draped over the top of the maze to prevent external cues.

Four line diagrams of the intersection with their appropriate colors, small replicas 12.7 cm x 17.8 cm of the animal pictures and a 5.1 cm tall small plastic man were provided for use in the reconstruction task. Copies of the maze diagram were used in recording the child's path through the maze in the maze learning task. A tape recorder was employed to record the child's description of the path through the maze in the verbal communication task. Standardized data sheets were used for recording data in the reconstruction task.

Procedure

Maze learning. Each child was instructed that he/she was supposed to learn the way through the tunnels from one side to the other. The child was told to pretend that he/she was the scout for a group of people and his/her job involved finding the correct path through the tunnels to the other side. The experimenter was described as an assistant to the child who followed through the maze, stopping the child and asking questions. It was also stressed that it was important to concentrate on learning the way to the other side so that the group could be told how to get through.

Each child was taken individually through the maze and allowed as many trials as necessary to learn the correct path until reaching the criterion level of three consecutive perfect trials. After the initial exploratory walk through the maze, the child was stopped at each intersection and asked which way he/she would go and how he/she knew to go that way. The number of trials to reach criterion, the directional errors on each trial and the child's response to the question at each intersection were recorded.

Verbal communication. In this task, the child was given the following instructions: "Now that you know the correct path to the other side I want you to describe to me how to follow that path. Tell me how you found your way along the path from the starting point to the other end. It is important to give me as much information as you can."

The child then performed the verbal task, giving directions to the experimenter describing how to complete the route through the maze from the beginning to the end. The child's response was tape recorded in order to examine the efficiency of the directions given, whether sequential order was maintained, the number of correct statements, and the types of cues utilized.

Maze reconstruction. For this task, small replicas of the animal picture along with four color-coded, line diagrams of the intersections were placed on a table in front of the child. He/she was instructed to choose from the line diagrams the first intersection that he/she came to in the tunnel. After a diagram was chosen, a small doll was placed on the diagram in the path leading from the child's direction facing toward the intersection. The child was instructed to take the little man and walk him through the intersection so that he followed the correct path. After the doll was moved, the child was asked to explain how he/she knew to walk the little man that way. The diagrams were shuffled, placed before the child again and the same procedure followed for the next three intersections. A record of the sequence of intersections chosen, the number of directional errors made at each intersection and the cues utilized in explaining why the direction was taken were analyzed.

Reversal. Before completing the final task, the child was allowed to negotiate the maze again in the forward direction. The child was then required to complete the maze in the reverse direction from which it was learned. The experimenter followed the child through the maze and asked at each intersection--which way he/she would go and how he/she knew to go that way. Only one trial was given in the reversal task. The number of directional errors and the cues utilized in negotiating the maze were recorded.

The order of presentation of the verbal communication and maze reconstruction tasks were counterbalanced through the study, with the maze learning task always occurring before these tasks and the reversal task last. Half the subjects in each age group learned the maze in direction 1; the other half learned the maze in direction 2.

RESULTS

Analyses of variance (ANOVAs) of the 3 (age) x 2 (sex) x 2 (direction of travel) design were performed on dependent measures in each of the following tasks a) the maze learning task: analyzing the number of trials to learn the maze and the number of errors per intersection, b) the reversal task: analyzing the number of errors, c) the reconstruction task: analyzing the number of errors made in recalling the sequence of directions and the number of directional errors, and d) the verbal task: analyzing the number of errors. The type of cue utilized (whether "other," animal, or directional), in each of these tasks were analyzed through the use of the Chi-square statistic. All post hoc comparisons were computed with a Tukey honestly significant difference (hsd) at the .05 level.

Maze Learning Task

As indicated in Table 1, for the number of trials to reach the criterion level of three errorless trials, the main effect of age was significant. The post hoc analysis showed that the youngest group ($\overline{x} = 7.75$) required more trials to learn the maze than either the middle ($\overline{x} = 4.30$) or oldest ($\overline{x} = 4.6$) children. An analysis of direction of travel was also significant for the number of trials to learn the maze, with those children who learned direction 1

Table 1

Summary of Analysis of Variance for the Number of Trials to Reach Criterion Level in the Maze Learning Task

Source of Variation	df	MS	*F*
Age (A)	2	73.050	14.634*
Sex (X)	1	7.350	1.472
Direction (D)	1	50.417	10.100*
AX	2	0.650	0.130
AD	2	10.617	2.127
XD	1	3.750	0.751
AXD	2	25.550	5.119*
S(AXD)	48	4.992	

$^*p<.05$

($\bar{x}$ = 4.63) requiring fewer trials to learn the maze than those who followed direction 2 ($\bar{x}$ = 6.47). The three way interaction of age, sex, and direction of travel was also found to be significant. A post hoc analysis revealed that the youngest females traveling in direction 2 ($\bar{x}$ = 11.60) required significantly more trials to learn the maze than did any other age group (ranging from $\bar{x}$ = 3.20 to $\bar{x}$ = 5.20), excluding the youngest males (see Figure 2).

A 3 (age) x 2 (sex) x 2 (direction of travel) x 4 (intersections) mixed ANOVA with intersections as a within factor was performed on the number of errors committed in learning the maze (see Table 2). The main effect of age was significant and a post hoc analysis showed that the youngest age group ($\bar{x}$ = 2.05) made significantly more errors than either the middle ($\bar{x}$ = 0.60) or oldest ($\bar{x}$ = 0.75) age group. A significant difference was found for direction, revealing that those children learning the maze from direction 2 ($\bar{x}$ = 1.52) made more errors than those learning from direction 1 ($\bar{x}$ = 0.75). These effects mirrored those in the previous ANOVA involving trials to criterion. However, the main effect of intersection was also significant. More errors were committed at the blue intersection ($\bar{x}$ = 2.22) than any other intersection, and more errors were made at the green intersection ($\bar{x}$ = 1.12) than at the orange intersection ($\bar{x}$ = 0.22). The age x intersection interaction was significant, the results show that the youngest age

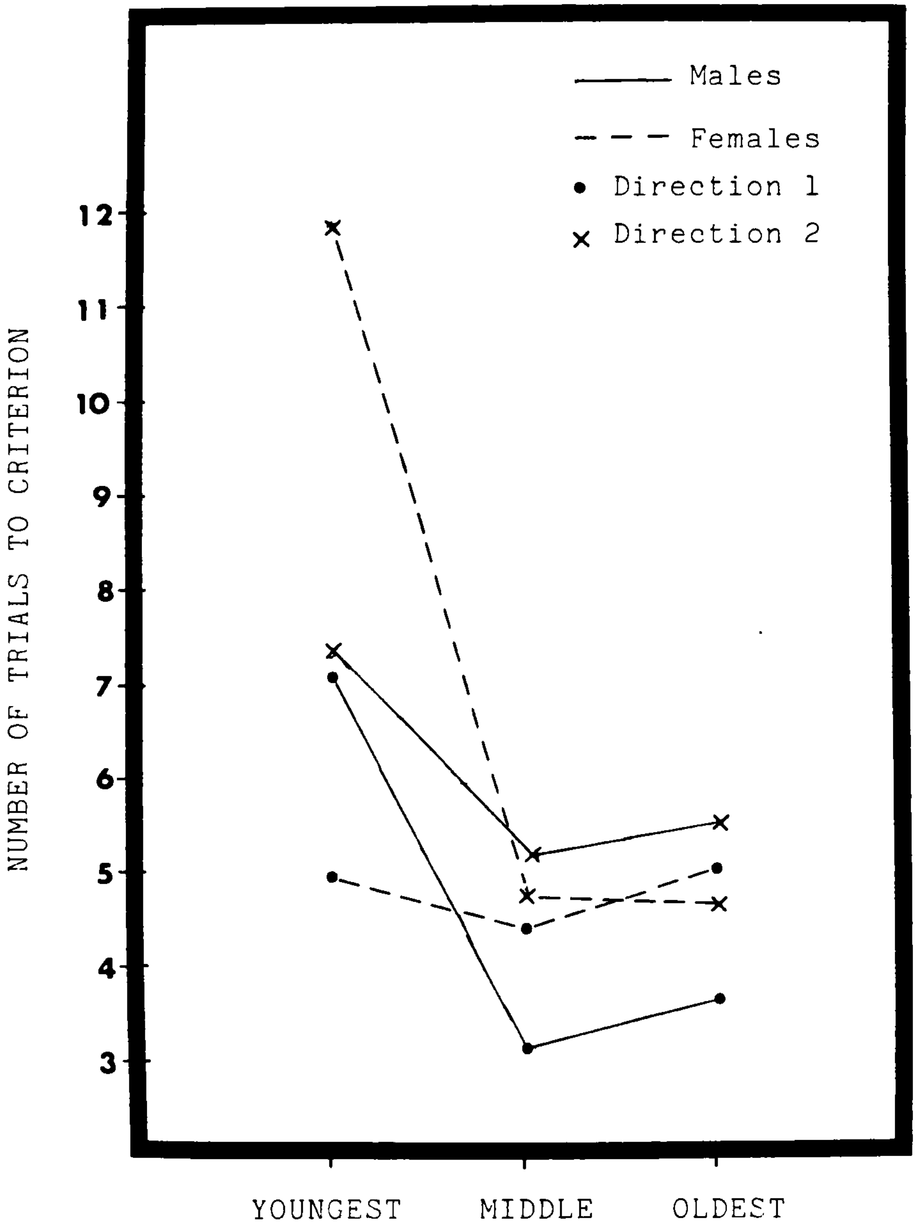

Figure 2. Mean Number of Trials to Criterion in the Maze Learning Task as a Function of Age, Sex and Starting Position

Table 2

Summary of Analysis of Variance for the Number of Errors per Choice Point in the Maze Learning Task

Source of Variation	df	MS	_F_
Age (A)	2	50.867	7.94*
Sex (X)	1	5.400	0.84
Direction (D)	1	35.267	5.50*
Intersection (I)	3	41.100	18.90*
AX	2	1.400	0.22
AD	2	8.017	1.25
XD	1	2.400	0.37
AI	6	9.733	4.48*
XI	3	0.344	0.12
DI	3	33.078	15.21*
AXD	2	23.450	3.66*
AXI	6	1.378	0.63
ADI	6	7.094	3.26*
XDI	3	1.256	0.58
AXDI	6	3.639	1.67
K(AXD)	48	6.410	
KI(AXD)	144	2.174	

*$p < .05$

group made significantly more errors at the blue intersection ($\bar{x} = 4.30$) than did any other age group (ranging from $\bar{x} = 0.05$ to $\bar{x} = 1.95$). Also, the youngest age group made more errors at the green intersection ($\bar{x} = 1.95$) than either the middle age group ($\bar{x} = 0.05$) or oldest age group ($\bar{x} = 0.10$) at the orange intersection.

The direction x intersection interaction revealed a significant difference, with those children learning the maze from direction 2 making more errors at the blue intersection ($\bar{x} = 3.70$) than any other age group (ranging from $\bar{x} = 0.10$ to $\bar{x} = 1.33$) and more errors at the green intersection ($\bar{x} = 1.33$) than at the orange intersection ($\bar{x} = 0.10$). As shown in Table 2, the three way interaction of age x sex x direction interaction was found to be significant. The post hoc analysis revealed that the youngest males learning the maze in direction 2 ($\bar{x} = 3.70$) made more errors than the middle ($\bar{x} = 0.05$) or oldest ($\bar{x} = 0.20$) males who learned from direction 1 ($\bar{x} = 0.50$) (see Figure 3). The age x direction x intersection interaction was also significant, with the youngest children who learned the maze in direction 2 making more errors at the blue intersection ($\bar{x} = 7.10$) than any other group at any intersection (ranging from $\bar{x} = 0.00$ to $\bar{x} = 2.20$) as seen in Figure 4 and Figure 5.

In analyzing the type of cue utilized in negotiating the maze, a significant difference was found between various ages. The chi-square analysis, x^2 (4) = 9.65, $\underline{p}<.05$, in Table 3 indicated that there was a shift in the utilization

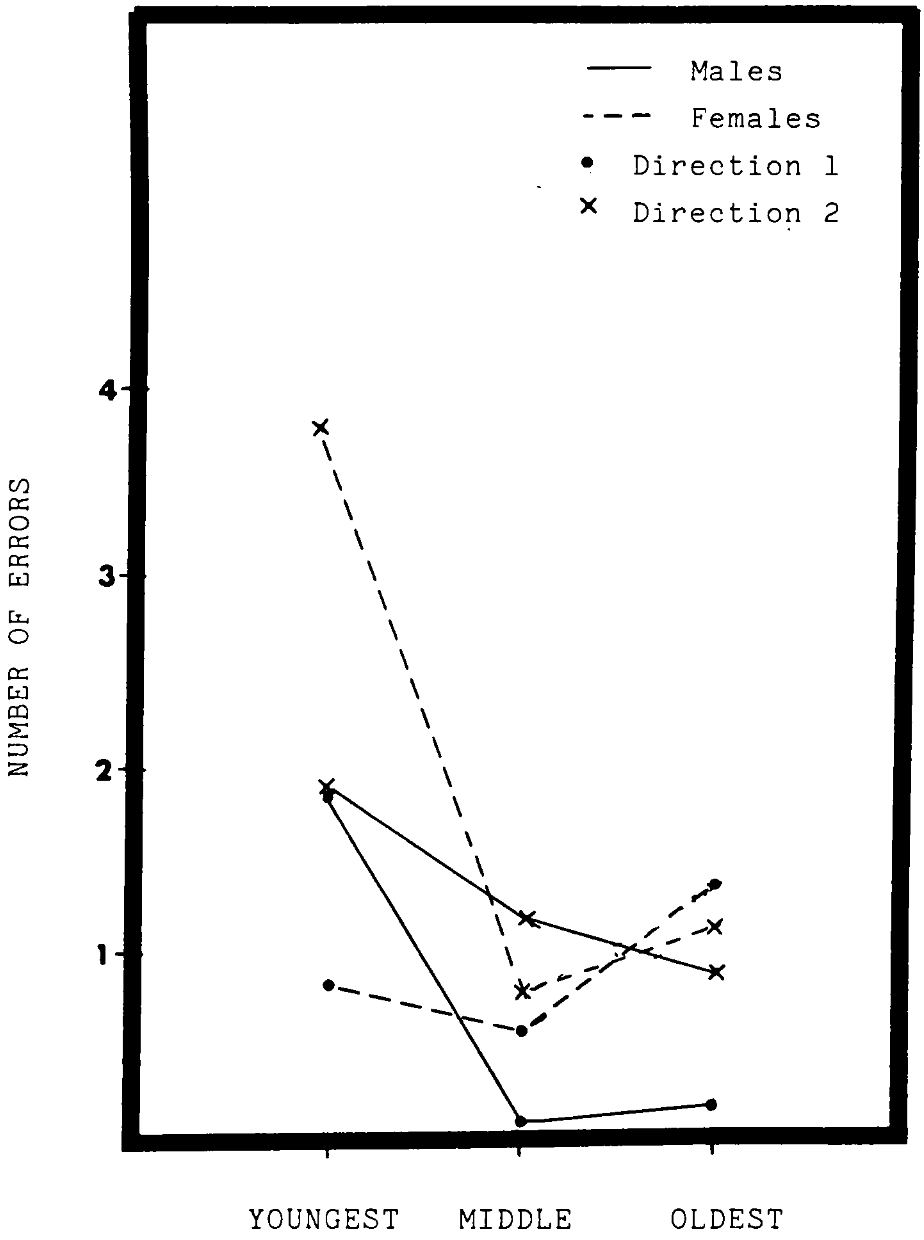

Figure 3. Mean Number of Errors in the Male Learning Task as a Function of Age, Sex and Direction of Travel

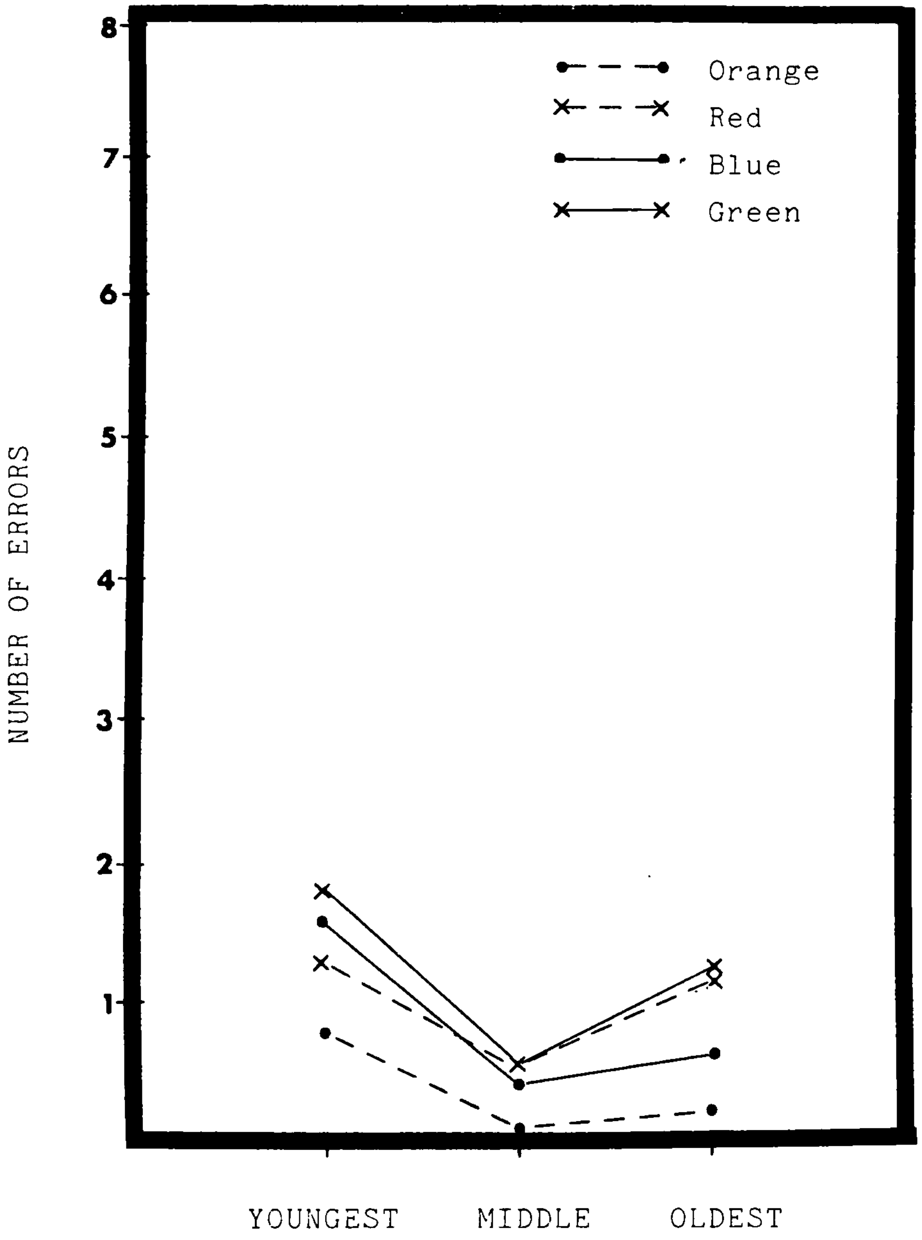

Figure 4. Mean Number of Errors for Direction 1 in the Maze Learning Task as a Function of Intersection and Age

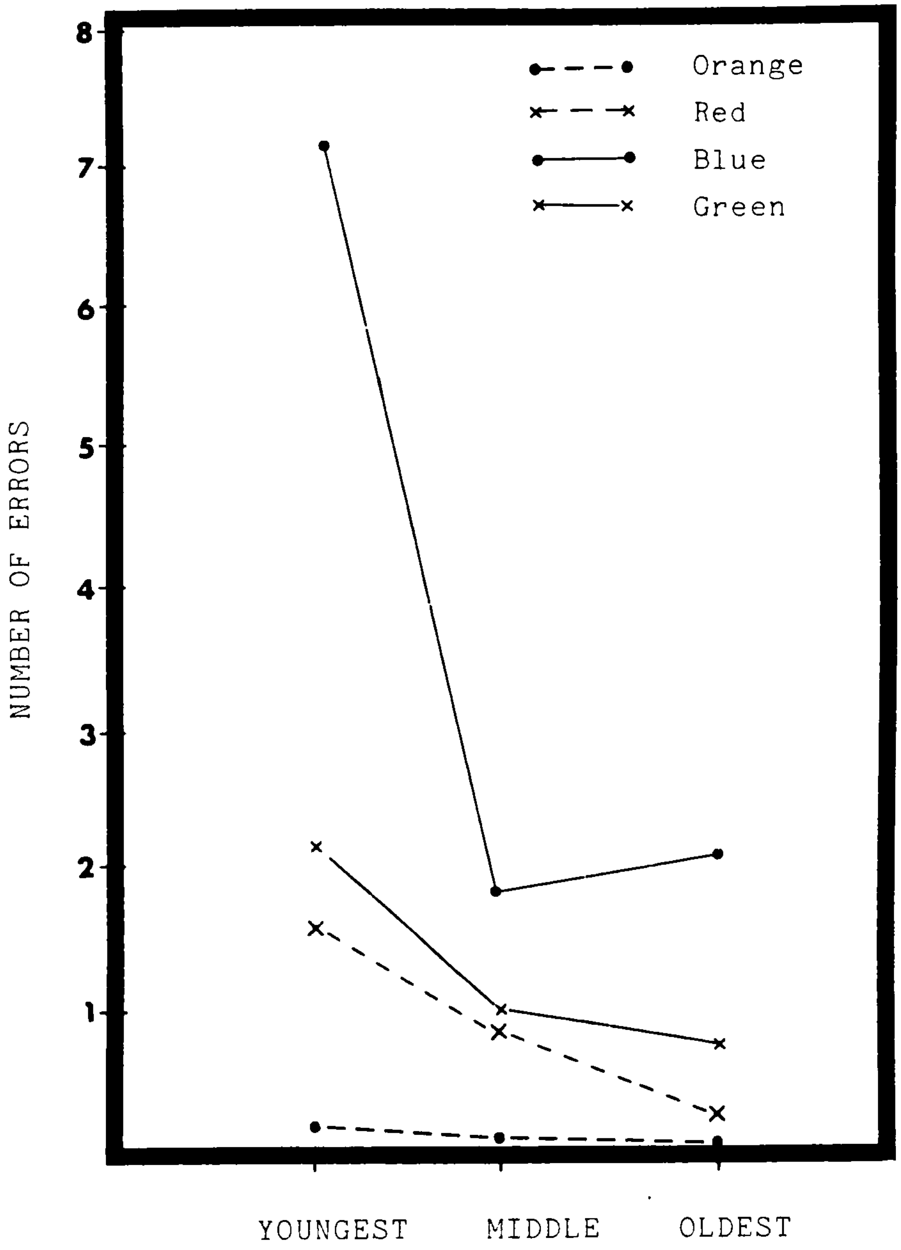

Figure 5. Mean Number of Errors for Direction 2 in the Maze Learning Task as a Function of Intersection and Age

Table 3

Contingency Table for the Maze Learning Task
Examining Type of Cue Utilized

Age	Cue Utilized Other	 Animal	 Directional	Row Total
Youngest	12	8	0	20
Middle	8	12	0	20
Oldest	4	14	2	20
Column Totals	24	34	2	60

$\underline{p} < .05$

of cues as age increases. The children in the youngest age group explained their actions with mainly "other" responses ("I know" or "I remember") and animal cues, without referring to directional cues (left, right). Children in the middle age group used more animal cues than other cues, but they did not use directional cues. Children in the oldest group were the only ones to use directional cues, although they primarily relied on animal cues.

Verbal Task

A significant Pearson Product Moment Correlation Coefficient was obtained for two raters' judgments of the number of errors per subject ($r = .82$) in the verbal task. Those subjects' data upon which the raters did not agree were rated by a third person who resolved the discrepancies. An ANOVA (see Table 4) for the number of errors indicated a significant effect for age, with the youngest age group ($\overline{x} = 2.35$) committing more errors than the oldest age group ($\overline{x} = 1.25$).

The chi-square analyses of the type of cue utilized when an error was made were analyzed as a function of age, sex and direction of travel. As seen in Table 5, a significant difference was obtained for the age x sex interaction, x^2 (4) = 10.87, $\underline{p}<.05$. The data indicate that males made more animal and "other" errors than did females while the females made more directional errors.

Reconstruction Task

As shown in Table 6, an ANOVA for the number of sequential

Table 4

Summary of Analysis of Variance for the Number of Errors in the Verbal Task

Source of Variation	df	MS	*F*
Age (A)	2	6.650	3.455*
Sex (X)	1	2.400	1.247
Direction (D)	1	0.000	0.000
AX	2	0.350	0.182
AD	2	1.950	1.013
XD	1	0.600	0.312
AXD	2	0.650	0.338
S(AXD)	48	1.925	

*$p<.05$

Table 5

Contingency Table for the Verbal Data Given the Answer was Incorrect

		Cue Utilization			
Age	Sex	Other	Animal	Directional	Row Total
Youngest	Male	5	5	2	12
	Female	2	2	7	11
Middle	Male	4	4	1	9
	Female	3	2	3	8
Oldest	Male	1	2	4	7
	Female	2	4	0	6
Column totals		17	19	17	53

$p < .05$

Table 6

Summary of Analysis of Variance for the Number of Sequential Errors in the Reconstruction Task

Source of Variation	df	MS	F
Age (A)	2	0.867	0.897
Sex (X)	1	0.600	0.621
Direction (D)	1	0.267	0.276
AX	2	3.200	3.310*
AD	2	0.267	0.276
XD	1	4.267	4.414*
AXD	2	0.867	0.897
S(AXD)	48	0.967	

*$p < .05$

errors (sequential refers to the ordering of the color-coded intersections) showed a significant age x sex interaction, F (2,48) = 3.31, $p < .05$. A post hoc analysis of these results did not reveal a significant difference between the groups, although as seen in Figure 6, an examination of the means shows more errors for the males in the middle age group, while for the females more errors occurred in the youngest age group. The interaction of sex and order was also significant, F (1,48) = 4.41, $p < .05$, for the number of sequential errors. Again, post hoc analysis did not reveal a significant difference between any two groups, although the means indicate that the males made more errors in learning from direction 1 than direction 2, whereas females made more errors when learning from direction 2. No significant differences were found across the main effects of age, sex, or direction of travel.

The ANOVA computed for the number of directional errors was found to be insignificant for all main effects and interactions (see Table 7).

Analysis of the cues used in the reconstruction task indicated a significant difference between ages when the direction given was correct, x^2 (4) = 10.45, $p < .05$. Table 8 indicates that there is a difference in cue utilization, with the youngest children relying mainly on "other" cues and animal cues with no directional cues given, while the middle age group used more animal cues but still no

Table 7

Summary of Analysis of Variance for the Number of Directional Errors in the Reconstruction Task

Source of Variation	df	MS	*F*
Age (A)	2	1.217	0.880
Sex (X)	1	0.417	0.301
Direction (D)	1	0.817	0.590
AX	2	0.817	0.590
AD	2	0.217	0.157
XD	1	2.017	1.458
AXD	2	1.017	0.735
S(AXD)	48	1.383	

*$p<.05$

Table 8

Contingency Table for the Reconstruction Task Given that the Answer was Correct

	Cue Utilized			
Age	Other	Animal	Directional	Row Total
Youngest	17	6	0	23
Middle	10	14	0	24
Oldest	9	12	2	23
Column totals	36	32	2	70

$p<.05$

directional cues. The oldest age group showed use of directional cues, with less use of "other" and animal cues.

Reversal Task

A three way analysis of variance (age, sex, direction of travel) of the number of errors made in negotiating the maze in reverse revealed no significant difference for any main effect or interaction (see Table 9). No indication of underlying trends were apparent in an examination of the means.

Chi-square analyses of the type of cue utilized in the reversal task, however, was found to be significant when the answer was incorrect for the age x sex interaction, x^2 (4) = 16.34, $p<.05$. Table 10 indicates an increase in the number of directional errors with age along with a decrease in "other" errors.

When the answer given was correct, there was a significant difference in type of cue utilized by the various ages, x^2 (4) = 10.16, $p<.05$. Table 11 shows the same usage with the youngest children relying on mainly "other" and some animal cues, while the oldest age group indicated a greater use of the directional cues. An analysis of the cue utilized by the direction of travel when the answer was correct indicated a significant difference between the direction of learning the maze x^2 (2) = 6.11, $p<.05$. More "other" and less animal cues were used when the children learned direction 2 as opposed to those children who learned direction 1 (see Table 12).

Table 9

Summary of Analysis of Variance for the Number of Errors in the Reversal Task

Source of Variation	df	MS	*F*
Age (A)	2	1.050	0.597
Sex (X)	1	0.267	0.152
Direction (D)	1	6.667	3.791
AX	2	0.217	0.123
AD	2	0.417	0.237
XD	1	1.667	0.948
AXD	2	1.517	0.863
S(AXD)	48	1.758	

$^{*}p < .05$

Table 10

Contingency Table for the Reversal Task Given that the Answer was Incorrect

Age	Sex	Cue Utilized Other	 Animal	 Directional	Row Total
Youngest	Male	12	5	2	19
	Female	12	6	3	18
Middle	Male	11	4	3	19
	Female	6	8	8	22
Oldest	Male	9	5	6	20
	Female	6	7	5	18
Column totals		56	36	24	58

p<.05

Table 11

Contingency Table for the Reversal Task Given that the Answer was Correct

Age	Other	Animal	Directional	Row Total
		Cue Utilized		
Youngest	16	5	0	21
Middle	7	9	0	16
Oldest	6	7	2	15
Column totals	29	21	2	52

$\underline{p}<.05$

Table 12

Contingency Table for the Reversal Task Given that the Answer was Correct

	Cue Utilized			
Direction	Other	Animal	Directional	Row Total
Door	12	15	2	29
Kitchen	17	6	0	23
Column totals	29	21	2	52

$p<.05$

DISCUSSION

Hypotheses

In this study four tasks, postulated to tap spatial knowledge represented in different ways, were used to assess children's knowledge of a maze: motor learning, reversal of the route, reconstruction, and verbal recall. The ease with which the tasks were expected to be performed were dependent upon the cognitive demands (i.e., the level of representation) intrinsic to the tasks. Maze learning was thought to require only recognition of the appropriate cue at each intersection and was hypothesized to be the easiest task. The later tasks required more constructive memory processes involving the child's ability to transform or recall previously learned spatial information. Within this latter group (reversal, reconstruction, and verbal recall), task demands increased in cognitive complexity and were expected to exhibit developmental differences in performance.

In all tasks, older children were expected to have a higher level of performance than the younger children. Superior male performance was predicted for all tasks except the verbal task in which females were expected to excel.

The Present Findings

One area of primary concern was for any differences which may be found in the frames of reference utilized in each of the spatial tasks, varying cognitive demands. Previous research has shown that frames of reference play an important role in the development of spatial representation in children (Piaget & Inhelder, 1967). The use of an egocentric vs. allocentric frame of reference influences the child's ability to represent space, through focusing attention on a body-centered as opposed to an environment-centered approach to the formation of relationships (i.e., between landmarks). In route knowledge, the frames of reference used are either egocentric (left-right) or objective (the use of landmarks), although the ability to distinguish left-right appears later in development than the ability to use landmarks. In this study, the frames of reference used by the children were assessed for developmental differences. It was expected that younger children would rely on the animal cues or some type of cue they were unable to identify whereas the older children were expected to use directional (left-right cues). Each task required a different memory process, therefore, providing an opportunity to examine what type of frame of reference would be used for these different processes (i.e., verbal recall, nonverbal recall, and recognition).

A developmental difference in performance was speculated to occur for the tasks used in this study. Analyses indicated that the maze learning task was mastered by all children, and performance on the verbal task indicated that it was the most difficult task. The reconstruction and reversal tasks fell between the two. Due to the cognitive demands of this task, the few errors that were made on the reversal task suggest that no recall of the spatial representation was necessary, only recognition was being utilized. For the reconstruction task, the visual-spatial components provided the child with visual cues to aid recall, thus making it easier than the verbal task where no cues were available.

As with most developmental work, age is typically used as a primary discriminator. However, the findings of this study reveal that age was a factor only in learning the maze, in verbally recalling it, and in reconstructing the sequence of the intersections. Age did not have an effect on reconstructing the direction chosen at each intersection or in negotiating the maze in the reverse direction from which it was learned. In both tasks, environmental cues were available for the children's use and although performance was not perfect, no developmental differences in performance appeared. Sex differences in spatial performance were also expected to occur in the findings. However, no main effect of sex was found for any task, indicating that sex of the child was not a discriminating factor. The variable of sex was found to have an interactive effect only in determining the number of errors in reconstructing the sequence of the intersections. For the results of this visual-spatial task, sex interacted with age and with direction of learning the maze, although there is no indication of between which groups the difference could be found. The age by sex interaction expected in the verbal task was not found, only an age effect was shown, revealing that the sex of the child did not alter the difficulty of the task.

The analyses of the type of cue utilized for the various tasks provided an indication of the frame of reference being used by the child. The use of the "other" cue, where the children actually stated "I know" or "I remember," was viewed as an egocentric response in that the children were focusing on themselves and unable to distinguish an external reason for their actions. At best, it must be viewed as an idiosyncratic, non-communicative response. The use of the animal cue was regarded as an objective frame of reference, whereas the directional cues (left-right) were viewed as indicating a more cognitively complex representational form, since this ability develops after the ability to recognize landmarks.

The findings of this study showed that the younger children relied more on "other" cues with some reliance on animal cues while the middle aged and older children relied mainly on the animal cues. Thus, the younger children were using egocentric frames of reference, while the middle and older age groups relied on an objective frame of reference. Directional cues (left-right) were used only by the oldest children, except when an incorrect answer was given in the verbal and reversal tasks. For these tasks, the number of directional cue errors increased as age increased. In assessing the answers that were correct for each task, there were no directional cues used in the youngest age group, indicating a knowledge of these cues but an inability to use them reliably. However, there does appear to be a transfer of usage of the cues across tasks revealing a use of a frame of reference. Children continued to use the same cue that was reported during the learning of the maze for the other tasks as well.

An unexpected finding was that the direction of travel in which the maze was learned had a significant effect on performance. The results indicate that the blue intersection produced more errors for children transversing it from direction 2 than from direction 1. It was also found that the youngest group made significantly more errors at that intersection than any other age group. The explanation underlying this effect focuses on the way in which that intersection is perceived when starting from direction 2. The intersection when starting from this direction is seen as a mirror image by the child. When the child arrives at this intersection, the left and right choices look exactly the same as each other but different from all the other intersections. This apparently posed a problem for the children in that they were unable to recognize which way was correct. Approaching the intersection from the other direction did not present the same problem because the left and right choices looked similar to all the other intersections, only the straight choice and the approach were different. Thus, arriving at the intersection from direction 1 the child had to make a choice similar to all the others and was not misled by the design of the intersection (see Figure 1).

Previous Research

Task demands and the age effect. Previous research has indicated that the age of the child has a major influence on spatial performance (Hardwick, McIntyre, & Pick, 1976; Piaget & Inhelder, 1967; Siegel, Kirasic, & Kail, 1978). The findings of this study indicate that age has a significant effect in learning the maze and its verbal recall but not in the other tasks involving the knowledge gained from that learning phase. Thus, in connection with the reversal task, a study by Hazen, Lockman, and Pick (1978) found no developmental differences for reversal of a route, but differences were found in inferences made about the placement of landmarks along a route (i.e., recall of information), similar to the requirements of the verbal task in this experiment.

The effect of task demands can be seen clearly in a study by Acredolo (1977) of the effect of place vs. response learning in a reversal task. She found that the complexity of the task greatly influenced the magnitude of the age effect. In relation to this study, once the children found a frame of reference that would enable them to learn the maze, the requirements of the other tasks relied on this information and thus were easier. The finding that age was significant for the number of errors in verbally recalling the maze supports the idea proposed by Harris (1981) that transforming spatial knowledge into verbal ideas is a complex process. This transformation involves being required to change visual-spatial information into a verbal description, when there may be no words to describe what was seen or represented.

Verbal mediation and sex differences. The idea of verbal mediation was used in previous research to explain sex differences that were found in performance on spatial tasks. Since sex was not found to be significant as a main effect for any task, the concept of females higher usage of verbal mediation to cause lower performance on spatial tasks was not evident. All of the tasks in this study required the children to explain verbally their reasons for any spatial choice they made, prior to actually carrying out the move. The combination of spatial and verbal components in the tasks may have lessened the effect produced by lateral dominance as proposed by Witelson (1976). As mentioned earlier in the linguistic studies by Cioffi and Kandel (1979), their results indicate that there are several factors influencing sex differences in performance including variations in task difficulty, the linguistic capability of the stimuli, and the type of response that is required. The results of the present study concerning sex differences may have also been influenced by variations in task difficulty and the response required for each task, with the verbal explanations of why each directional choice was made influencing overall performance on the tasks.

Directions for Further Research

From this study and previous research, the importance of developing a multi-dimensional approach to understanding children's spatial representation has been demonstrated. The unique design of this experiment provides a more global understanding of the underlying concepts used in spatial representation. This research utilized several types of tasks to examine the communication of spatial representation in several forms (motor, visual-spatial, and verbal). The first task produced a constant state of knowledge for each child (i.e., knowing the maze to criterion) which was verified in the one trial given before the reversal task. On this trial, regardless of performance on the verbal and reconstruction tasks, all but two children were able to negotiate the maze perfectly, revealing a difference in ability to communicate knowledge according to the task demands, not a difference in the knowledge base. Previous research required children to learn a task only to one or two errorless trials and did not establish or examine the children's knowledge base and its influence on performance. In this study, the emphasis was not only on the spatial products obtained from these various tasks, but also on the underlying frame of reference that was utilized. The results of this study support the idea of a developmental trend in the use of frames of reference across tasks and it is these underlying strategies that require attention. This is an approach that has not been adopted by other researchers. Yet, as Liben (1982, p. 63) points out, "the developmental study of large-scale spatial cognition should be ready to pass into a third phase, in which the emphasis is no longer on which is the best means of externalizing children's spatial representations but is instead on trying to identify the cognitive strategies used to organize and extract information and determining how these change with development."

In light of the present findings, several implications for spatial research can be made. Since no strong sex differences in performance were found, perhaps the influence of this variable on spatial performance is not as prevalent as previously believed. Spatial research should examine the influence of task demands in relation to previous findings concerning age effects and sex differences. Perhaps when children's knowledge is tested through several mediums a better indication of what children's capabilities are will be obtained rather than an index of their performance on a specific task. Previous research which examined only one task may have found age and sex differences due to the task demands, without reflecting true ability.

Future research should focus on determining the frames of reference used in spatial representation. As mentioned previously, the use of several types of tasks may produce a better indication of these underlying frames of reference and how spatial information can be communicated. Spatial research designs should incorporate tasks of varying complexity as well as varying mediums (i.e., increasing complexity by removing the landmarks after a route has been learned). The unexpected result which involved the design of the maze could also be examined to determine the influence of structural design on spatial performance. It may be found that structural design greatly affects children's ability to remember or locate environmental cues. The findings of no developmental trends for the reversal and the directional reconstruction tasks should be examined further to determine if task demands produced these results. The area of communication of spatial information should be researched in connection with its relation to spatial performance and cognitive strategies.

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