AN ABSTRACT OF THE THESIS OF

Stephanie A. Kozick for the degree of Doctor of Philosophy in Human Development and Family Studies presented on April 28, 1986

Title: Preoperational Spatial Representation Among Preschool Children in Small-Scale Space

Redacted for Privacy

Abstract approved: ______________________
Dr. Alan I. Sugawara

This study examined the effects of stage of preoperational thought, sex and mode of exploration on preschoolers ability to represent a small-scale model configuration of objects. Forty-eight subjects between the ages of 2 years, 5 months and 5 years, 4 months were classed in spatial conceptualization as either Stage I (i.e. recognition of common objects but not of geometric shapes) or Stage II (i.e. recognition of relations of an elementary type) by the Stereognostic Recognition of Objects and Shapes Test (Laurendeau & Pinard,1970). Children were then assigned to four treatment groups each consisting of twelve subjects; Stage I boys, Stage I girls, Stage II boys and Stage II girls. Following an encountering phase at two levels, one which involved

viewing a display of objects from a standing position (i.e. stationary) and another which involved movement by means of walking around the display (i.e. locomotive), subjects recalled and reconfigured a table-top layout of objects during a response phase. Children's representations of space were measured and scores for displacement, relation and order were computer calculated.

A 2 (Stage: I vs. II) X 2 (Sex: males vs. females) X 2 (Mode of Exploration: stationary vs. locomotive) factorial multivariate analysis of variance was applied to the spatial representation scores of subjects. Results revealed a significant main effect for stage on the displacement scores of subjects. Stage II subjects outperformed Stage I subjects on the displacement representation task. In addition, a significant stage X mode of exploration interaction effect was obtained for subjects' displacement, relation and order scores. Post-hoc comparisons using the Scheffe test revealed Stage II subjects outperforming Stage I subjects on the displacement and order tasks in the stationary mode of exploration. The Scheffe test also revealed that Stage II subjects performed better on the displacement task in the stationary rather than locomotive mode of exploration, a result which was in contrast to theoretical expectations and previous findings on the impact of movement in space.

Preoperational Spatial Representation Among Preschool Children in Small-Scale Space

by

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A THESIS

Submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Doctor of Philosophy

Completed April 28, 1986

Commencement June 1986

APPROVED:

Redacted for Privacy

Professor of Human Development and Family Studies
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Date thesis is presented April 28, 1986

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INTRODUCTION

How young children organize and use the information surrounding them is of utmost importance to their daily survival. How young children organize and use the information surrounding them is of equal importance to the development of their intelligence. From birth to school-age, children are confronted with aspects of their environment which increase in complexity to one degree or another. As young children grow and move, their environment broadens and they are faced with a more perplexing situation which requires the necessary skill of interpreting their environments. Fortunately, children are equipped with the sensory modalities designed to interpret their expanding world. This ability to interpret the environment requires experience and perception, and as such, can be referred to as a child's knowledge or cognition of space.

In their daily routines young children experience a variety of fields of space. These fields of space include the greatness of the outdoors, the reduced space of an early childhood classroom, and even the narrower space of "interest centers", tabletops and rug activities. Expansive and compact spaces offer children varied opportunities to make interpretations. Understanding how children create their own individual interpretations of spatial information is as complex and curious as the phenomenon of space itself.

Theoretical Framework

Jean Piaget and Barbel Inhelder (1967) in their classic work, The Child's Conception of Space, first published in French in 1948, recognized that

> ...if the development of various aspects of child thought can tell us anything about the mechanism of intelligence and the nature of human thought in general, then the problem of space must surely rank as of the highest importance (Piaget & Inhelder, 1967,preface).

More recently, the relationship of spatial ability in young children to academic success has been recognized in several studies, including problem solving (Nelson & Kieren, 1977), mathematical ability (Punwar, 1970), reading and spelling (Kaufman & Biren, 1977; Johnson & Crano, 1978; Punwar, 1970) and geography (Hewes, 1982).

In the past, several fields of study have developed to facilitate the comprehension of this area of knowledge. Theoretical debates about the nature of space from the philosophical and psychological arenas include a rich history. Evans (1980), referring to the space phenomenon as "environmental cognition", divides this vast area of inquiry into two broad categories; frame of reference and representation.

> Frame of reference ...focuses on the types of information people use to spatially orient themselves in space. Representation ...examines the degree of accuracy and complexity in an individual´s memory for spatial relationships in the environment (Evans, 1980, p.266).

In terms of the category, "frame of reference", young children have only one, their own. This concept, known as spatial "egocentricity" was described and initially researched by Jean Piaget (Piaget & Inhelder, 1967; Piaget, Inhelder & Szeminska, 1960). Subsequent experimental research in egocentric perspective taking, or the child´s inability to differentiate between his or her own point of view and those of others, has provided support for this concept (Laurendeau & Pinard, 1970; Shantz & Watson, 1971; Hart & Moore, 1973; Pufall & Shaw, 1973; Acredolo, 1976).

The second category "representation", which is of main interest to this study, focuses on young children´s spatial abilities. This concept of the mental representation of space is important since it allows for an assessment of how an individual "pictures" an environment that has been previously seen. Complete reviews of works contributing to the conceptualization of this notion have been presented elsewhere (Downs & Stea, 1973; Siegel & White, 1975; Kaplan, 1973; Liben, Patterson & Newcombe, 1981). Various names have been given to this concept of spatial images that individuals mentally store. As early as 1913, Trowbridge referred to them as "imaginary maps". Designers and geographers use the term "spatial image", while Lee used the concept "spatial schema" (Siegel & White, 1975). One of the most familiar terms, used in an early study by Tolman, is "cognitive maps" (Tolman, 1948). In describing his field theory on rats, mazes and learning he wrote:

> ...in the course of learning, something like a field map of the environment gets established in the rat's brain ...incoming impulses are usually worked over and elaborated in the central control room into a tentative, cognitive-like map of the environment (Tolman, 1948).

A more formal definition of cognitive maps was later offered by Downs and Stea (1973):

> "Cognitive mapping is a process composed of a series of psychological transformations by which an individual acquires, codes, stores, recalls, and decodes information about the relative locations and attributes of phenomena in his everyday spatial environment" (p. 9).

What makes the study of spatial intelligence challenging is that measurement of a child's potential in this area cannot be tapped through conventional intelligence tests which focus on linguistic and logico-mathematical intelligence. Harvard University psychologist Howard Gardner (1983) in his "theory of multiple intelligences" points to spatial intelligence as an independent intelligence in the human neural system. Spatial skill to analyze the visual world generally works in isolation with it's own memory bank and life history (Gardner, 1983). This nonlinguistic characteristic of spatial intelligence corresponds to the evidence that spatial processing is a mode of the nonverbal right hemisphere of the brain. Based on the "split-brain" studies of the 1950's carried out by Sperry and others, and on new supporting evidence from researchers working with a normal population, B. Edwards (1979) asserts that it is the right mode that "sees how things exist in space and how the parts go together to make up the whole". "One of the marvelous capabilities of the right brain is imaging; seeing an imaginary picture with the mind's eye" - a nonverbal activity.

In research efforts to more clearly understand the development of a young child's cognition of space, this nonlinguistic characteristic is an investigative requisite. An interesting concurrence is the notion that the preschool child relies on a visual mode of representation in problem-solving, with use of the verbal mode of representation occurring at the time the child reaches school-age (Bruner, 1966). In light of the preceding theoretical ideas, new attempts at creating a nonverbal information-processing task to tap the spatial abilities of young preschool children appears worthy of scientific investigation. Gardner (1983) proposes that alternative tests be employed to gain an accurate picture of a child's intellectual profile so that educators can better match teaching strategies to individual children. In addition to Gardner's rationale for innovative measurement, there is the concern that the young child, currently in a critical period for broadening knowledge about the environment, be presented with situations or settings that best facilitate spatial cognition.

This measurement issue was also addressed by Evans (1980) in his review of research on human spatial cognition. The essential problem focuses on "how to externalize the individual's mental map of the environment" (Evans,1980). Hand-drawn sketches, picture recognition, verbal responses, or pointing tasks require a sophistication of reinterpreted mental response strategies which are likely understood only by the older child. A more direct relationship would exist if a viewed array of objects is "represented" or replicated by young children as they attempt to arrange these objects on the same surface area. This assembled array can then be analyzed for spatial representation accuracy and a derived score calculated through the use of computerized scoring procedures can be assigned to each subject. This study developed such scoring procedures which provided dependent variables for this investigation.

With focus directed on how young children develop spatial cognition in general and spatial representation in particular, the following section summarizes research on the impact of sex, age, cognitive level and movement experiences on children's early spatial abilities.

Sex differences on intelligence tasks have been reported by Maccoby and Jacklin (1974) in their comprehensive work, The Psychology of Sex Differences. Studies of differences in performance on spatial tasks between boys and girls have been completed with differing results. The age of the child appears to be one factor influencing these dissimilar results. When studies have found differences in performance on spatial tasks, the results favor boys (Harris, 1976; Harris, 1981; Siegel & Schadler, 1977; Kail & Siegel, 1977; Herman & Siegel, 1978; Newcombe & Liben,1982; Cohen & Weatherford, 1981; Anooshian & Young, 1981). Yet, other studies have not found boys to be significantly higher in performance than girls (Emerson, 1931; Siegel et.al., 1979; Hazen, 1982; Herman, 1980; Ives, 1980; Etaugh & Levy, 1981; Herman et.al., 1982). Additional studies would be beneficial in examining sex differences specific to the focused area of spatial cognition identified in this study as spatial representation.

According to Piaget's cognitive-developmental theory, the period of early childhood before the age of about 3 years is designated as the sensorimotor period. During this period, lack of symbolic functioning in intelligence limits spatial representation abilities. A transition occurs in young children from about the age of 3 years when they begin to develop mental representations of space. A representation of space is a spatial image or the "evocation of objects in their absence" (Piaget & Inhelder, 1967, p.17). In general, this major intellectual period in early childhood has been designated as the "preoperational thought" period. During this period of preoperational thought, which continues to about the age of 7 years, functioning in the representational mode replaces the sensorimotor mode of functioning. The child is freed from the restriction of only being able to deal with the immediate environment. During the preoperational thought period and specific to spatial representation, Piaget has distinguished between two successive stages. Stage I, lasting to approximately 4 years of age, marks the beginning in the young child´s capacity to make representations by symbolic functioning and thus mentally manipulate images and symbols. This stage corresponds with the preconceptual phase of preoperational thought. Stage II of spatial representation is observed in children between the ages of 4 - 6 years , and corresponds with the intuitional phase of preoperational thought. During this stage young children expand their collection of image symbols and take on the accomplishment of multiple classification, allowing them to deal with several attributes in a collection of objects (Robeck, 1978). Observing differences in spatial representational ability between these two stages (i.e. initial transition and more established ability), can add to our knowledge of the complexity of young children´s developing representation of spatial information.

A common thread appears to run through the major theoretical frameworks previously discussed, which points to spatial intelligence as well as a young child's reasoning to be less verbal and more visually imaging in nature. Measurement of this phenomenon therefore, calls for an assessment technique which can gauge spatial ability by nonverbal means. Utilization of such a measurement technique can then explore the factors associated with high or low spatial representational ability in young children. One aspect of the present research focused on the problem of designing an appropriate assessment technique which attempted to provide a new dimension for understanding children's development of intelligence.

Prior to an act of representing space, that is, imaging a visual array, perception of that array must take place. Sedgwick (1982), using Gibson's theoretical framework, defines visual perception as "the process of picking up the information that is available in the optic array". According to Piaget (Piaget & Inhelder, 1967), representation extends perception. In a review of the developmental literature on visual scanning, Day (1975) maintains that detailed perception of the visual environment requires movement of the eyes, with successive fixations or stabilized gazes about the visual field. Day (1975), in referring to the works of Engel (1971) and Sperling (1960), adds that visual scanning most frequently refers to the "sequential allocation of attention by successive eye movements". This "exploration of configurations by systematic eye movements, shifting one´s fixation point in a systematic way", is to Piaget, the most important among the perceptual activities (Piaget & Inhelder, 1969). The above described relationship of perception to movement behavior added another thought-challenging feature to this study of spatial representation in young children.

In the present study, the facilitation of attending behavior in young children to promote attention to relationships among objects in a visual display or array, involved the variable of movement to enhance the spatial representational experience. For a child in a stationary position, the fine motor activity of eye movements allows various fixations from point to point on a visual array from one perspective with respect to the relative distance of objects. Children engaged in gross locomotive movement around a visual array, therefore, would have the opportunity to perceive multiple perspectives of that array. According to Piaget (Piaget & Inhelder, 1967), movement may be regarded as a transformation of the perceptual field and every perceptual field is a group of relationships determined by movements. Young children tend to limit their amount of attention to single fixations. To this notion Piaget adds:

> ...absence of active exploration explains a characteristic that has been classically ascribed to the perceptions of children under seven years of age: namely, their syncretism (Claparede) or global character (Decroly), which is such that in a complex configuration the subject perceives only the total impression, without analysis of the parts or synthesis of their relations... this syncretism expresses a lack of systematic exploratory activity (Piaget & Inhelder, 1969, p.40).

Evidence of the influence of movement on spatial representation ability can also be inferred from a physiological standpoint. Through the action of the vestibular apparatus of the inner ear (balance), individuals are able to rotate the head, wherein a counterrotation of the eyes occurs which has the effect of holding the eyes stationary with respect to the environment. This response, known as the vestibulo-ocular reflex, suggests that a child in movement is not necessarily burdened with random rotations of the eyes when attending to a visual array. On the contrary, Sedgwick (1982) concludes that movement through an environment makes available new visual information in terms of changes in the optic array, (i.e., Gibson's term for the structured array of light converging on the observer's eye from the environment) and the opportunity to have portions of the environment, previously hidden, revealed to the observer. Potegal (1982) also finds that the combination of visual and vestibular input are compatible, which allows for a vestibular-visual convergence to occur when one actively locomotes through the environment. Furthermore, in a classic animal study of space perception Held (1965) compared active and passive kittens and their perceptual organizations. From this research, Held found that passive kittens did not develop normal sensory-motor reactions, suggesting that self-initiated movement is essential to assessing and interpreting the environment.

To date, current studies investigating the effects of movement, generally walking, on children's spatial representation ability have been limited to large-scale rather than small-scale space (Feldman & Acredolo, 1979; Herman & Siegel, 1978; Herman, Kolker & Shaw, 1982; Cohen & Cohen, 1982; Cohen & Weatherford, 1981; Herman, 1980; Hazen, 1982). Large-scale experimental spaces are frequently room or hallway areas bounded by walls or dividers, whereas small-scale experimental spaces are confined to table-top dimensions. Recognizing the importance of movement or mode of exploration in the acquisition of spatial knowledge in large-scale spaces it also appears important to investigate this variable in small-scale space. In the course of the typical day at a preschool or day care center, young children are constantly being engaged in table-top activities. Typically the presence of chairs at these activities, limits children's exploration from a stationary position in space. An aspect of this study contrasted a child's ability to "represent" an array of objects displayed on a small-scale space (i.e., table-top) under two experimental conditions or modes of exploration. One mode of exploration involved the child time-viewing an array of objects on a table-top from a standing, stationary position, while the other mode of exploration involved the child time-viewing an array of objects using movement by walking around the visual display of objects. Because facilitation of young, pre-operational children's knowledge should include learning experiences and planned activities that involve spatial cognition, a need exists to determine what modes of exploration can positively effect their abilities to image and represent space.

Purposes of Study

The major purpose of this study was to examine how certain selected variables were related to the accuracy of children's spatial representations. These variables included young children's stage of preoperational thought, sex, and mode of exploration. Boys and girls ranging in ages from about three to six years were used as subjects. Their cognitive levels were assessed through use of Piagetian preoperational thought tasks. All subjects were exposed to an array of objects displayed on an experimental, small-scale space (i.e. table-top), under two experimental conditions; one involved viewing the objects from a stationary position, and another involved movement by means of walking around the experimental space. Nonverbal spatial representation tasks were used to assess the accuracy of subjects' spatial representations. The tasks designed for this study were "gamelike" activities which involved the manipulation of objects in a bounded three-dimensional experimental space suggestive of table-type activities typically found in preschool learning situations. A new scoring procedure which utilized a computer-assisted strategy to quantify observations of children's direct performance on the spatial representation tasks was employed. Findings from this study were utilized to generate educational implications for facilitating the development of spatial cognition among three to five year old children in a preschool setting.

General Hypotheses and Data Analysis

The following general hypotheses were tested in this study, focused on how selected variables including children's stage of preoperational thought (Stage I vs. Stage II), sex (males vs. females) and mode of exploration (stationary vs. locomotion) are related to the spatial representation accuracy (eg. displacement, relation and order) of preschool children in small-scale space.

Hypothesis I: Children at Stage II of preoperational thought will outperform Stage I children on various representation accuracy tasks.

Hypothesis II: Males will not outperform females on various spatial representation accuracy tasks.

Hypothesis III: Children's performance on various spatial representation accuracy tasks will be better under the locomotive than under the stationary condition.

A 2 (Stage: I vs. II) X 2 (Sex: males vs. females) X 2 (Mode of Exploration: stationary vs. locomotive) factorial multivariate analysis of variance, with repeated measures on mode of exploration, was applied to the spatial representation accuracy scores of subjects. Spatial representation accuracy involved a threefold measure of displacement, relation and order. The main effects of stage, sex and mode of exploration, and their interactions, were studied.

Definition of Terms

To clarify the meaning of some terms used in this study, the following definitions are given.

Cognitive mapping: A process composed of a series of psychological transformations by which an individual acquires, codes, stores, recalls, and decodes information about the relative locations and attributes of phenomena in his everyday spatial environment (Downs & Stea, 1973).

<u>Experimental space</u>: A bounded surface area of defined parameter which is composed of several three-dimensional objects in a specifically designed arrangement or array.

<u>Fixation point</u>: A stabilized gaze about an individual's field of vision which may vary in duration, location and sequence to make up a visual scanning pattern.

<u>Haptic perception</u>: Perception of an object or shape by means of the sense of touch in the absence of visual clues.

<u>Preoperational thought</u>: The Piagetian period of cognitive development characterized by a child's evolution from functioning in primarily a sensori-motor mode to functioning in a conceptual and representational mode.

<u>Representational space</u>: The imaging, contemplating or taking as an object of thought either one's own or another's multi-dimensional visual environment (Eliot & Salkind, 1975).

<u>Space</u>: An abstraction derived from the relative intervals between and among objects requiring always a

referent and a terminal point (Barsch, 1967) or, relationships of objects in reference to each other and to the self, (Gerhardt, 1973).

Spatial cognition: The ability to interpret the environment requiring experience and perception, and as such, can be referred to as an individuals knowledge or cognition of space.

Visual scanning: The process by which the individual actively, and sequentially acquires information from the visual environment (Day, 1975).

REVIEW OF RELATED LITERATURE

The framework for this review of research includes discussions related to methodological features of previous studies which have posed questions concerning children's spatial representations. One of these methodological features includes the difference in the expanse of the environmental space under study which ranges from large- to small-scale space. The following review identifies studies relative to this expanse differential which provides the groundwork for the choice of the small-scale space used in the present experimental study. An additional methodological issue of previous research is the strategy used to evoke responses from children which act as indicators of their spatial representations. Supplemental to this strategy is the scoring procedures utilized in measuring the accuracy of children's responses.

A further issue addressed in this review is the mode of exploration utilized in various studies of spatial representation. A review of previous research related to this concern is vital to the central focus of this study, previously identified as "movement". Additional aspects of earlier research selected for discussion are the age and sex variables of the sample populations under consideration. The interpretation of results and their generalizability are related to these age and sex variables.

Significance of Experimental Space

Prior to discussing the significance of experimental space used in previous research, it is important to acknowledge that the concept of space is relative to the observer, rather than absolute, wherein the observer is regarded as irrelevant. This discussion proceeds with the understanding that space, as a relationship among objects, changes as the objects or the observer changes in position (Liben, 1981). This premise places children in an active role while they are in the process of gathering information about an environment, a task which is primary to spatial representation.

In the quest to observe and understand children's spatial cognition, researchers have employed a variety of types of spaces from macrospace (large-scale) to microspace (small-scale). Decisions regarding the size of experimental space utilized in various studies appear to be based not only on the interpretation of the term "spatial representation", but also on the question of whether size of space influences the ability to tap this process in children's thought. Recently, these issues have been discussed by a few researchers in an attempt to address discrepancies.

The interpretation of the concept of "spatial representation" was discussed in detail by Liben (1981), who identified three types of research problems related to spatial representation; spatial products, spatial thought and spatial storage. Spatial products, is characterized by research studies concerned with an individual's ability to describe an encountered space with an external medium such as maps and models. Spatial thought, focuses upon the problem of how individuals use their thinking processes to manipulate spatial images (e.g. rotating "in the mind's eye" a seen configuration in an effort to solve spatial problems). This second type of spatial representation research includes studies dealing with perspective problems. This includes the notion of egocentric thought in young children reviewed earlier in this paper. Research which focuses on perspective taking as a developmental phenomenon in the young child differs from spatial products in that models used in perspective studies are in full view at all times.

The third type of research problem related to spatial representation is spatial storage. This describes research efforts directed at tapping stored, but not cognizant, information about space (e.g. efficient movement through real environments). In discussing these different types of spatial representation research problems, Liben (1981) argues that "different methodologies may be needed to tap these different types of spatial representations".

Reflecting upon Liben's descriptions, the present study was aimed at tapping the ability of early spatial "representers" to describe the encountered space of an object array using the external medium of a like set of objects. This type of spatial representation research problem was previously referred to as spatial products. The ensued need to fit a design method which tapped children's spatial products suggested that a small-scale, table-top space would best provide the type of environment suited to observe this medium of modeled space. In addition, since the intention of this study was to provide an experimental space which was as naturalistic as possible in terms of children's play spaces, this small-scale strategy aided the generalizability of results to many other early childhood activity settings. Furthermore, use of an activity in a small-scale, table-top space provided a non-threatening, enjoyable and meaningful experience for the children.

The question of whether size of space influences the ability of researchers to tap the process of spatial representation in children's thought was addressed by Siegel, Kirasic and Kail (1978). They indicate that "statements regarding a child's competence in cognitive mapping in the large environment cannot be inferred merely from performance in small-scale space" and that "micro-spatial cognition may well involve processes different from those of macro-spatial cognition". Yet, with further empirical evidence, Siegel et al. (1979) later found that when children made trips through a large- and small-scale model town, either walking through the large space or pushing a toy car through the small space, constructions from memory of the layout of buildings in either space resulted in children's performances that were comparable.

Furthermore, Acredolo (1981), in an article that presented the issue of "small-scale versus large-scale space" specified the similarities and differences between these two types of spaces. In doing so, she pointed out that both types of experimental spaces involved spatial relationships among objects, and a developmental sequence from topological spatial concepts to projective and Euclidean concepts, both of which are important to the facilitation of spatial representation. For clarification, this latter notion of topological and projective concepts is the base assumption of Piaget's study of the psychology of space. To this, Piaget and Inhelder (1967) speak to the developmental nature of children's spatial representational thought, which mainly deals with figures or objects and how they are related to one another. Initially, representational thought reconstructs space from primitive notions of the relations of proximity, separation, order, continuity and enclosure. These relations are built in the process of organization. During this process young children analyze objects individually, such that each object is viewed or considered in isolation. Piaget referred to this early processing of object relationships as "topological". The use of this term in Piaget´s treatment is based upon geometrical concepts. The Oxford English Dictionary historically traces the term topological and refers to it´s introduction in usage as distinguishing qualitative from quantitative geometric relations. Likewise in Piaget´s theory, children developmentally at this period view situations without respect to size or shape in a measurable sense, and thus ignore metric, perspective and proportional relationships. The perceptual activity at this developmental period brings to mind the phrase, "what you see is what you get".

At about the age of 7 - 8 years, children begin to involve geometrical co-ordinate systems of vertical-horizontal relations, progressing them to projective and Euclidean relations. Spatial relationships are now among objects, and the isolated object analysis is replaced with a comprehensive system organized in terms of a common spatial structure throughout. These projective or Euclidean structures are complex in organization and require conservation; the cognitive notion that relationships persist throughout the course of transformation. For a more complete coverage of this latter concept, the reader is directed to The Child's Conception of Space (Piaget and Inhelder, 1967). The preoperational child developmentally utilizes the isolated topological relationship as a process of spatial representation. It was this stage of development upon which the focus of this study was intended.

In referring to the differences that may exist between small- and large-scale space, Acredolo (1981) suggests that response mode, number of vantage points and the fact that a small space actually exists within a large-space are points for consideration. With regard to mode of response, Acredolo cites studies that demonstrate that small- and large-scale spaces do not necessarily yield the same behaviors. It follows that a child uses different motor abilities in either small- or large scale spaces, suggesting a correspondence between small motor ability for small spaces and large motor ability for large spaces. The present study went beyond this structure in that large motor walking behavior was used in a small-scale space. Concerning vantage points, there is the differentiation that small-scale spaces enclose objects that can be seen from a single viewpoint, whereas this is not possible when one is located within a large space where a portion of the space to the rear of the observer is out of viewing range. The last factor that Acredolo mentions in differentiating between spaces is that a small space actually exists within a large space, thus contributing outside clues for representation. This notion calls to mind the phrase, "where do you draw the line?" All space is a system of matrices or "something within something else". However, to this regard, it is agreed that experimenters must report the nature of the larger environment for the purpose of research generalizability. In this study, to avoid possible outside clues, an encircling barrier was provided which surrounded the experimental small-scale space.

In an effort to treat the topic of spatial representation in a complete fashion and to present a total picture of this concept, it is necessary to review experimental research which has utilized both large- as well as small-scale spaces. The discussion above, which was concerned with the significance of size of space, provided the background information necessary to further discuss distinctions among the following reviewed studies as well as the strategies which were employed to evoke spatial representation responses from children.

Experimental Strategies

One feature of prior experiments that may have confounded results is the frequent inclusion of verbal information either during the viewing period or during the response period of spatial representation. Verbal confounding may confuse not only the children in the study, but also the research results. This supposition is grounded in Bruner's (1966) theory that preschool children rely on a stimulus bound visual mode of representation. He refers to this developmental stage as "iconic". Earlier in this paper additional scientific theory was reviewed which pointed to the nonlinguistic characteristic of spatial intelligence. This issue, (i.e., verbal input) poses a methodological concern in the examination of the accuracy of children's ability to make spatial representations.

Studies Which Include Linguistic Stimuli

In an early study of children's spatial representation, Olsen and Baker (1967) questioned "what the child would do when he is deprived of visual perceptual cues". Basing their study on evidence that representation of vertical space at about 3 years of age preceded that of horizontal space at about age 8 years, the researchers designed an experiment to test children's stored representations of directionality. Using a classic children's game, blindfolded children were asked to "Pin-the-Tail-on-the-Donkey". In each of two different conditions children were asked to first label the parts of the donkey while the picture was in view. In addition, to check for verbal knowledge of "left" and "right" the examiner asked the child to "put up your right hand" while facing the child with his right hand up creating a perceptual incongruity. Results showed that the preschool children's ability to represent space on the horizontal plane (head to tail relationship) was significant at the .01 level. However, "almost invariably" children could not correctly raise their right hand in the verbal check. This latter result supports the theory that spatial representation is not dependent upon a linguistic structure. Ramifications of the verbal input in labeling parts of the stimulus field (donkey) were not identified or considered in the report of results. Likewise, Herman (Herman & Siegel, 1978; Herman, 1982; Herman et al., 1982) in studies of children's memory for spatial location, included "encounter" procedures in which either children named toys or experimenters told "stories" concerning the stimulus objects as children viewed their locations. An explanatory remark was included which specified that stories were included to sustain children's attention.

Although the report of a study by Kosslyn, Pick, and Fariello (1974) implied elimination of labeling stimulus objects, linguistic discourse accompanied the procedure employed to prompt memory for object placements. These researchers examined factors which systematically distorted children's and adults' memory for spatial relations in "real-life" space. Specifically, opaque barriers (hanging blankets) and transparent barriers (low wooden fences) were used to create four sections in an experimental space (a 17-foot square garage). Ten toys, such as a plastic boat and a stuffed animal were placed in the experimental space and used as stimuli to measure subject's accuracy in distance-judging of positions between pairs of toys. Suggesting a rationale that difference in adult to child body size, motor ability and conception of accuracy might produce differences in how closely toys would be placed in initial positions, the researchers chose not to utilize a method in which subjects would simply replace toys on a floor where they thought the toys initially had resided. Stressing that their goal was to gain information about spatial memory of relative relations between toys, the method designed required verbal interactive responses. In the distance-judging phase of the experiment, preschoolers and adults were asked to imagine where a certain toy placed in their lap was located in the experimental space. Subjects were then asked to point out the toy in a box of toys that had been "most near" on the floor to the toy in their laps. As children and adults receptively identified the closest toy, that toy was removed from the box and the question of proximity was repeated until all toys were removed from the box. Results of this rank- ordering process revealed that preschoolers exaggerate distances between objects separated by the barriers. A question that emerges from this study is how the requirement of verbal interpretation affected preschoolers' responses in making judgments of relative relations between toys. The procedure of the Kosslyn et al. (1974) study was repeated by Newcombe and Liben (1982) who used first graders and adults as subjects. Children were again asked to make judgments as to which toy was "most near" to a referent toy in a rank-ordering process. Citing results of the data, the researchers argued that "the rank-ordering task is quite difficult, especially for children", but do not offer the problem of verbal interpretation as a possible interference in children's performances.

At least one researcher addressed the issue of language in an experimental study to determine preschool children's ability to utilize language in spatial problem solving. Ives (1980) designed an experiment, based on the "three-mountain problem" developed by Piaget and Inhelder (1967), in which children indicated another's view of a spatial array from a series of visual alternatives. In Ives' (1980) study, children were trained to use the terms, "front", "back", and "side" correctly, then told the experimenter what view of an object (e.g. toy cars and people) a camera would take from various positions. In a second response condition, the same procedure followed but photographs of the front, back, and side view of objects were used in lieu of verbal responses. From data analysis, the verbal response mode lead to more correct responses, at least in solving spatial perspective tasks. Ives (1980) implied from these results that linguistic processes are accessible, and he questioned the notion that visual mode precedes a verbal mode in the preschool years. The limitation of this study lies in the fact that there was no comparison experiment to judge spatial representation in any aspect other than perspective taking. Ives clarified his ideas by noting that experimental paradigms based on visual-spatial cues, such as memory tasks are unsuited to tap linguistic skills and that the nature of the task determines the mode (i.e. linguistic or visual-spatial) utilized in problem solving. The nature of perspective taking tasks requires that the visual array is constantly in view which eliminates the need to access spatial memory. Further, associations of visual and verbal information were structured through the training involved in the experimental design. This study characterizes the type of spatial representation Liben (1981) refers to as "spatial thought", reviewed previously. It would be erroneous to generalize the results of this study to one focused on "spatial products", which requires the ability to describe an encountered space with an external medium when the experimental space is no longer in view.

In addition to language being used within a study to evoke children's representations, caution must also be applied to the choice of words used to initially introduce children to a spatial task. An example which demonstrates this concern is a very early study by Emerson (1931). To introduce nursery school children to a task aimed at determining memory for spatial placement of wooden rings on an easel, the examiner's directions were "This is my little house. Now I am going to put my ring right here in my house and I want you to put your ring just like mine in your house". This study suggested that simple closely related wording be used in directives, which would eliminate the possibility of semantic confusion.

One other example of a study with unqualified verbal input is an experiment designed to compare spatial knowledge of small- and large-scale spaces in which Siegel et al. (1979) asked children to construct from memory the layout of buildings in a large-scale space or pictures of the buildings in a small-scale space. This study, which was identified as a step towards a theory of spatial cognitive performance, suggested a perceptual rather than linguistic orientation; nevertheless, it included verbal stimuli. During an encountering phase of the experiment, the experimenter stopped at each building or picture in the experimental space and labeled it for the child.

Verbal information as well as translation, which requires a child to reinterpret an experimental space, were evident in another study by Siegal in collaboration with Schadler (1977), in which children were involved in the construction of a 3-Dimensional model of their kindergarten classroom. Using scale model objects of the classroom and its contents, children were asked to tell the experimenter some of the furniture that belonged in their actual classroom. Upon naming an item, the scaled object was given to the child to arrange in the model. Objects not named by the child were named by the experimenter, who then asked if it belonged in the child's classroom. This latter study introduces the issue of translation, which requires the child to mentally transform an experimental visual array to another scale or form, in the process of representation.

Studies Which Involve Translation

Typically, when researchers have directed their work toward tapping children's spatial representations, they have employed tasks which require a child to translate the stimulus visual scene to another configuration. Some methods requiring translation to evoke responses from children are to ask them to make a pictorial representation of an array of objects by either drawing a "map" or by arranging pictures that depict the visual display. Pictures were used in Piaget and Inhelder's "three mountains task". Ten color coded pictures of various viewpoints of a pasteboard model of mountains were shown to children to facilitate their imagining which perspective a doll would "see" in different positions. Shantz and Watson (1971) used 7 1/2 X 5 inch photographs of a landscape scene to assess the ability of children, ages 3 1/2 to 6 1/2 years, to predict the location of objects on a model landscape. As in the "three mountain task" a doll was used to designate "another´s" point of view or perspective. The task was reported to be very difficult for young children. To reiterate, it is necessary to discuss the issue of translation due to the effect it may have on research efforts to evoke children´s representations of space. The cognitive translation needed by children to comply to these demands for response poses a concern, especially in studies involving younger children. Another type of translation or transformation activity identified above and used to elicit an individual´s image of space is map drawing.

Downs (1981) traces the vital role cartography plays in our thinking about the form, structure and function of internal spatial representations. Mapping functions as a way in which "tacit knowledge can be rendered explicit for the purposes of expression and communication". The value of this technique is obvious, but its use with children is questionable. To support this assertion, Siegel (1981) points out that drawing a sketch map confounds the externalizing ability of young children in terms of their understanding and production of conventions and symbolizations. As empirical evidence, Wapner, Kaplan, and Ciottone (1981), in an article focused on life-cycle transitions in instrumental acts of representation, refer to the sketch maps of a child 4 1/2 years-old. The subject, translocated to a new and unfamiliar environment in Holland was asked to draw maps of the town visited over a nine month period. An initial map included "undifferentiated blobs" to represent objects and there was no evidence of coordination or integration of spatial regions. In a more recent study, map drawing was used to examine the relationships between children's memories for the sequence of locations and events, and their search strategies in a large-scale space (Anooshian et.al., 1982). Within the search environment, which consisted of hallways and rooms, seven locations were designated by children's games. At one of these locations the experimenter "lost" an object. In an effort to tap spatial representations of the experimental space, the children, who ranged in age from 3 - 6 years were asked to arrange seven photos of the game locations as well as draw a map of the search area. For the map drawing, each child was given a large piece of paper and a pencil and was asked to put small circles on the paper to indicate the places where they had played the first and last games. The child was then asked to draw a line to show the path walked from the first to the last location. The experimenter then provided descriptions of the remaining locations and the child marked these on the map. Correlation between the event recall of placing photos in order and map drawing was not significant in this study. A report of the children's map drawing behavior identified confusion and specified a low criterion level for success. Pilot testing by the present investigator also indicated children's difficulty in a map making task. Upon viewing a visual array of five toys arranged in a small room, under a stationary and free movement condition, six children with a mean age of 3 - years - 8 - months were asked to represent the visual array by a modified mapping technique. The technique involved children naming the toys viewed, then pointing to their placement on a colored construction paper "map". Children's responses were recorded by the examiner with the use of "pres-a-ply" paper dots, printed with names of the toys, which were then fastened to the pointed locations. Pointing behavior was observed to be haphazard in most cases and children's performance mean of 1.7 objects indicated low mapping accuracy of the five toys. The technique utilized proved insensitive to tapping differences between the two conditions of the study.

Piaget et al. (1967) recognized the limitations of using map drawings for spatial representation by young children. In a classic model village task children were asked to make drawings of objects arranged on a table or floor. Piaget identified the chief difficulty in this method as the role played by the child's own drawing, and stated that "it is therefore essential (especially with the younger children) to be able to replace the task by that of actual construction. The task was then replaced by the model village being arranged on a base and the child given a card and identical objects to arrange in the same way. With the recognition that drawing poses problems in spatial research with young children, many researchers have incorporated model construction into their investigation of spatial representation. The construction of a model display using identical objects to represent the previously seen display corrects the translation problem but can still contain a confounding element when a large-scale space is to be represented by small-scale objects.

In addition to the previously reviewed study by Siegel and Schadler (1977), in which children constructed small-scale models of their kindergarten classroom, Hazen, Lockman and Pick (1978) incorporated a similar strategy in their investigation of children's spatial knowledge. In that study, experimenters took preschool-aged children through a series of uniformly sized rooms arranged in rows. In each room a large toy animal was housed in the center as a landmark feature. Upon completion of the route through the rooms, the course was repeated and children were asked about the order of rooms entered and "Which animal lives in there?", which incidentally provided another example of the inclusion of a language variable. The representation testing condition consisted of a series of small boxes used to substitute for the rooms and small toy animals which resembled the large animals. Directions to children were as follows: "These are the same animals that were in the big house. Pretend these little boxes are little rooms. Can you make a house out of these animals and these little rooms so that it looks just like the big house?" This methodological factor of dissimilar sized spaces requires that children understand the complexity of transformation in their imagery. An additional issue which should be considered in these large- to small-scale model studies is that perceptually, children are viewing a fragmented image while in the large space but expected to represent a whole image in the construction task.

In further discussing the use of model construction to assess children's spatial knowledge it is necessary to once again refer to the categories of spatial representation offered by Liben (1981). The term, spatial products, was previously described as an external representation, and hence requires a medium for communication. Verbal descriptions, mapping, and miniature models used to represent large spaces are three types of mediums which have been argued to be inappropriate for young children. Liben (1981) adds that research focused on this category of spatial representation is concerned with "how spatial relationships are represented". Model construction in this case is highly central to competence, and the task is not "a superfluous performance variable". In relation to this study, the task of imitating the arrangement of objects seen in a model array was central to assessing the accuracy of children's memory for spatial relations. These relations have been previously identified as the proximity, separation, order, continuity and enclosure between objects. Liben's remaining two categories of spatial representation -- spatial thought and spatial storage -- can best be described as internal representations utilized, respectively, in spatial problem solving (e.g. mentally rotating objects) and maneuvering in an environment (e.g. way finding). Consequently, a further concern identified by Liben is whether a researcher is interested in determining specific spatial information children might possess, which enables them to maneuver in their environment, or abstract spatial information they might possess about the spatial relations referred to above, which was the focus of this study. Researchers interested in both types of information have utilized the task of model construction with children. As shown, inconsistency of the scale size of the model and the actual environmental space presents another situation where translation is a concern. Siegel et al (1979) used both small- and large-space variations of model construction to elicit memory for a layout of buildings and found that children's constructions were most accurate when they were tested in the same-scale environment in which they developed spatial knowledge of the layout. The methodological technique of using the same scale model as an experimental space further refines research attempts at tapping children's spatial representation.

Model Construction Studies Which Eliminate Translation

In a series of studies, Herman (Herman & Siegel, 1978; Herman, 1980; Herman, Kolker & Shaw, 1982; Herman, Roth, Miranda, & Getz, 1982) recognized that previous studies, which required children to encounter an environment on one scale and then tested on another scale, confounded children's cognitive mapping ability with the ability to translate and represent their knowledge of disparity. In each of the above studies, a large model town was used for both the encountering and testing phases of the studies. This imaginative model consisted of buildings each about 7 cm high, 11 cm long and 8 cm wide in size and were differentiated in terms of shape and color. Each building resembled those found in an actual town and included a hamburger stand, farmhouse, garage, one- and two-story houses, a bank, a school and a fire station. Children could walk through the town, and in the representation phase manipulate the buildings which were glued to masonite circles covered with green felt.

As demonstrated above, many of the recent studies purporting to tap children's spatial representation through model construction have concentrated on large-scale spaces, corresponding to the category specific spatial information, described earlier. It is Liben's (1981) supposition that due to arguments suggesting young children have particular difficulty in externalizing internal representations by traditional methods, researchers have turned to designing tasks in which children are asked to move through real environments. This study proposed that small-scale spaces represented by small-scale model construction should not be dismissed, and that it continues to offer practical utility for abstract spatial representation performance by young children. Educing children's spatial representation ability through small-scale spaces has the advantage of reducing interference time between the two events of viewing the stimulus display and representing it by model construction. Interference theory provides an explanation for "forgetting" and considers the effect of interpolated activities on learning (Kerr, 1982). As empirical evidence, Kerr cites a study by Pepper and Herman (1970), which shows that movement activities performed between the learning and reproduction have shown to cause interference in short-term memory experiments. Young children in this study were immediately engaged in the representation task following the stimulus task. The following paragraphs review studies which have used small-scale spaces and models in their investigation of children's spatial representation.

Huttenlocher and Presson (1973) employed an object array model to contrast the spatial representation problem of rotation (i.e. predicting the appearance of an array of objects when the array is rotated) with the problem of perspective (i.e. predicting the appearance of an array of objects when the observer has rotated). The array consisted of three colored blocks arranged in a line on a 6 1/2 inch platform and a toy horse situated in a position to "see" the blocks. In these experiments, either the horse or the platform were rotated to create the spatial problems. Results showed rotation problems to be easier for the school-aged subjects involved. Spatial perspective was also investigated through the use of a small-scale model in a study by Flavell et. al. (1981). The unique stimulus model created for that study was an abstract wire sculpture about 8 X 7 X 7 cm in size which provided a heterogeneous-sided object, and a 9 X 4 cm black wooden cylinder which provided a homogeneous-sided object. To test children's knowledge of three spatial perspective-taking rules [i.e. 1) objects appear the same to the self and another if both view it from the same position, 2) a heterogeneous-sided object will appear different to the self and another if viewed from different sides, and 3) a homogeneous-sided object will appear the same to the self and another if viewed from different sides] the examiner in a series of six different positions asked "Does it look the same to your eyes as it does to my eyes or does it look different?" Consistent with Piagetian inquiry techniques, children were asked to explain their answers. Conclusions reported that rules 1 and 2 were understood by 4 1/2-, 5-, and 5 1/2-year-olds, but only 5 1/2 year olds grasped all three rules.

Piaget and Inhelder's (1967) small-scale model village, referred to previously, was used in various experiments. It was designed to resemble an open country and was comprised of small-scale cottages, a church, trees, paths and streams. One experiment using this model investigated the problem of children's reference systems. Using two identical models, children were asked to place a doll on one model in a position which corresponded to the position of a doll on the original model. In order to test children's reference systems the child's response model was rotated 180 degrees, relative to the original model. As reviewed previously, young children disregard the reversal of the model until the age of 6 or 7 years. Pufall and Shaw (1973) examined the validity of Piaget's claim that children's spatial reference system is organized in terms of a self-reference system as opposed to an adult's objective reference system with the use of an experimental space composed of 2 ft. square boards containing a geometric form and pegs. As in Piaget's study, two identical model boards were used with one rotated 180 degrees. Instead of dolls, toy lambs were used for children to position according to the corresponding position of the examiner's board. Their findings supported Piaget and Inhelder's hypothesis that children organize representational space in terms of a self-reference system.

Studies which utilize scale models in order to tap memory for spatial location offer a more direct example, as was intended in this study, to tap children's memory for spatial relations. Anooshian and Wilson (1977) designed an experiment in which the effect of route extensity on the memory for locations of objects in a spatial array was examined in kindergarten and adult subjects. Specifically, the researchers examined encoding of functional distance in space, thought to be influenced by characteristics of routes that connect objects in space. The procedure involved two types of "routes" which were actually scale model train tracks on a table-top board. One route was direct while another was indirect created by elevation and looping of the toy tracks. The routes connected four small objects, a tree, gas station, log cabin and house. During the viewing period an examiner arranged the objects on the board as a small train stopped at points along the route. Kindergarten and adult subjects were then trained to place the objects at the correct locations as the train made it's stops. Upon placement of one object, it was removed to prepare for the next train stop which, unlike this study, eliminates the need to make relationships between objects. The need for training was described as an attempt to minimize differences attributed to attentional and learning differences between the child and adult subjects. During the representational aspect of the study, subjects seated in front of the board with one point of view were given duplicate objects and told to replace them on the response board, which at this phase of the experiment did not contain the train or train tracks. Children's accuracy of interobject locations showed, as predicted, that children distorted distance in terms of the nature of travel observed between objects. It is important to note that the nature of this study reduced the total awareness of relationships between objects in a perceptual sense, since the tracks were removed in the representation phase, resulting in a different topological structure.

In another study by Piaget and Inhelder (1967), using the aforementioned model village, children were tested on their accuracy of creating a topological schema. Eight objects were arranged on a display model in a specific layout, then children were given a board and like objects to arrange in the same way. The requirement of children to reproduce the arrangement of objects like the display model necessitated that they take into account the positions of the objects relative to one another. Reports of spatial correspondence, or the arrangement of an identical pattern, showed that children at Stage I (up to 4 years of age) displayed a few topological proximity relationships, while children at Stage II (from 4 to 6-7 years of age) began to make partial co-ordination among the group of objects. Jea (3;3), a child at Stage I, crowded objects together in one corner, suggesting an inability to distinguish between the concepts of relatedness and proximity of the objects. The question that emerges from Piaget's study is how young children would perform if they were not limited to one point of view? The present study went beyond the existing studies by incorporating locomotor movement around the display model. This feature would allow children to access several points of view, thus enriching their visual scanning patterns and allowing a more involved interaction with the stimuli.

In the following sections the discussion will focus on three variables of interest related to the accuracy of children's spatial representations. Initially, research which speaks to the question raised above, that of movement, will be addressed. Subsequently, the issues of sex differences and stage of preoperational thought will be raised.

Mode of Exploration

Movement has been recognized by researchers to be significant in spatial cognition. In a review of the development of spatial representation Siegel and White (1975) claim "actual locomotion in space appears to be an almost essential condition for the construction of spatial representations", and cite the argument of Lee (1968), that spatial representations arise and "jell" as a result of practical activity.

Walking in Space

Many studies designed to elicit aspects of children's spatial representation have incorporated walking into their designs. Siegel et al.'s (1979) study of large and small spaces included walking through a large-scale model of buildings and pushing a toy truck in the small-scale space which used 3 X 3 cm color photographs in place of the buildings. Frame of reference, defined as a system that controls what an individual uses to code location within an environment was examined in another study by having blindfolded children walk a route through a room (Acredolo, 1976). Cohen and Weatherford (1981) looked at the effect barriers have on spatial representations as children walked a path from object to object arranged in a school cafeteria. An encountering phase included walking through a large model space in a perspective study by Herman et al. (1982). A more direct treatment of mode of exploration is contained in the following review of current studies which have recognized the importance of movement in space and have attempted to measure it´s effect on children´s spatial knowledge learning. Results of the previously reviewed Held and Hein (1963) study showed that self-produced movement, with it´s concurrent visual feedback, is necessary for the development of visually guided behavior. That germinal study acted as a catalyst for researchers to examine children´s active (self-produced) and passive exploration of an environment.

Active vs. Passive Exploration

Feldman and Acredolo (1979) based their study not only on the theory of Held and Hein, but also on Piagetian cognitive development theory suggesting that, it is through active involvement with stimuli that a child's knowledge advances. Movement in that study involved 3- 4- and 9- 10-year-old subjects walking through an unfamiliar hallway in search of a hidden key under a cup which they were later asked to relocate. Half of the subjects were engaged in a passive condition which involved an adult holding their hand during the walk. The other half engaged in the active condition of walking on their own with an adult following behind. As predicted, active exploration of the environment significantly increased memory for the spatial location of the missing key, but only in the preschool-aged group. Results of that study support the hypothesis that self-directed activity serves to increase preoperational children's attention to topological cues in the environment. But, results differed in the 9- 10-year-old operational subjects who performed equally well in both the active as well as the passive condition. Likewise, Herman (1980) tested two groups of children (mean ages 5.9 and 8.9 years, respectively) on the effects of different types of exploration within his model town. Active and passive conditions were compared by measuring children's development of spatial relationships among the large-scale model's eightbuilding layout. In one experiment some of the children walked around the model town at it's perimeter, while other children walked through the model town. The spatial representation construction phase involved the removal of all the buildings and then asking the children to put each building in the place it had been during the walk. The walking activity in that study can be placed in the category of passive exploration in that the experimenter walked with the child and at each building both stopped, while the experimenter pointed to and labeled the building. Assessed placement of the buildings was more accurate when children walked through the model town rather than around it's perimeter. Herman's second experiment involved active, self-directed exploration in which children freely explored the model town. Motor activity and attention to buildings were not controlled, unlike the passive condition of experiment one. Children again reconstructed the town from memory and placements were assessed. Herman's results showed that children were less accurate in the self-directed condition, which is contrary to the results of the Feldman and Acredolo (1979) study. Herman suggested that type of environment (hallway vs. model town) and the nature of the representation task (one lost object vs. eight buildings) were explanations for these differing results. An unrecognized difference between the studies was the age of the subjects used in these studies. Feldman and Acredolo's younger subjects had a mean age of 4.3 years, while Herman's younger group had a mean age of 5.9 years. This age difference, although close, may have been responsible for the differing results. The present study which included subjects between the ages of approximately 3 and 6 years, provided further empirical evidence on the effects of active and passive exploration on young children's spatial representations.

Contrary to the results in Herman's (1980) study, Hazen (1982) explored the effects of active exploration and found it related to accurate knowledge of a spatial layout. Knowledge of spatial layout in this study was determined by route knowledge tasks through a playhouse (i.e. route reversal, detours and new route). Two groups of subjects, whose ages were 20 - 28 mos. and 36 - 44 mos. freely explored a large-scale playhouse prior to all subjects being taught a specific route through the playhouse. Results of the various route knowledge tasks indicated that active exploration prior to the task was related to more accurate knowledge of the spatial layout. Additional observational data noted that individual differences existed in children's ability to actively explore an environment. In the pilot version referred to earlier in this paper, children were also observed to vary greatly in the extent of movement engaged in when instructed to walk among objects within a room-sized experimental space. Children's exploring behavior ranged from standing still to walking briskly around and between the toys arranged on the floor. This evidence - that children's individual differences in quantity and mode of exploration may be predictive of differences in spatial representation abilities - suggests that controlling the mode and quantity of exploration can subsequently control this variable in a research design. Children in the present study walked slowly in a circular path, for a standard duration of time, around a displayed array.

Active and passive exploration was again addressed in a study, which examined the effect of increased motor involvement with an environment, on children's memory for spatial locations (Herman et al. 1982). Three conditions of motor involvement with the environment - standing, riding (non-self produced movement) and walking (self produced movement) - were compared to children's placement accuracy of a layout of buildings. Accuracy improved with increasing motor activity for only kindergarten children. In addition, the researchers tested an active as well as passive condition for spatial memory which compared intentional memory (i.e. children were given instructions on how to remember the locations of the buildings) with incidental memory (i.e. no specific memory instructions were provided). There was no significant difference between intentional and incidental memory in that study.

Cohen and Cohen (1982) expanded the movement component of walking through an environment and added two additional conditions of actually performing activities at various locations. They found that a functional theme such as writing and mailing a letter facilitated the acquisition of spatial representation better than the walking only or using isolated task conditions. Spatial representation strategy in this study required first and sixth grade children to perform a complex translation task of estimating distances between locations and placing color cards with printed names of the locations in a similar arrangement on the floor of another testing room.

How experience in an environment can affect spatial representation was reflected upon by Pick and Lockman (1981) in a chapter included in Liben, Patterson and Newcombe's (1981) Spatial Representation and Behavior Across the Life Span. They suggested that one may learn about a space in a variety of ways, and that these different experiences may result in different spatial representations. Stationary and motor-encoded representations are two types of varying experiences in space which can be thought to operate in specific ways. The authors concluded their discussion by stating that relatively little work has been done on how experience affects spatial representation. They suggested a call for research which can add to this knowledge by specifying the nature of representation. The present study explored two types of exploratory experiences in a novel activity and measured the resulting spatial representations.

To summarize, previous research on spatial representation and mode of exploration has been limited to studies of movement in large-scale spaces. The reviewed studies showed that young children's active exploration of space results in better mental representations. Explanation has also been given that the fragmented visual images of large-scale spaces cannot effectively test representations of whole configurations. Spatial representation of a whole array of objects which taps relational spatial knowledge should be preceded by the opportunity to view the whole array. A question which arises is whether movement influences children's spatial representations when the experimental space is small-scale. Movement was considered and incorporated into the present study of preoperational children's small-scale spatial representations.

Sex Differences in Spatial Representation

A discussion of sex differences requires a preliminary mention of hemispheric brain specialization. Brain research scientist Loye (1984) cites classic as well as recent findings from the fields of neurophysiology and psychology. Broca's (Teitelbaum, 1967) discovery demonstrated that damage to the left brain's frontal lobe caused the inability to speak; but damage to the same area in the right brain left speech intact, suggesting language processing to be a dominant function of the left brain. Analogously, Loye cites references which support the processing of visual and tactile spatial information as the major practical purpose of the right brain. Damage to the right brain frontal area (Nebes, 1977) produces behavioral difficulties that show a disturbed sense of spatial relations (e.g. misjudging the size, distance and direction of objects as well as difficulty in construction tasks). Loye points to further evidence in the works of Milner and Penfield. Milner's (1970) research supports the right brain's dominance in nonverbal memory, specifically for spatial configurations. Penfield's (1975) work also supported the right brain's role in image formation.

One proposed relationship of brain laterality to sex difference is that when boys' performance on spatial tasks is better than girls', which is predominantly the case, the better performance may point to a more functional right brain dominance. Kail and Siegel (1977) concur with such a sex difference in their description of the developmental course of right brain specialization. These considerations are important to the discussion of sex differences which have been reported in research on children's spatial representations.

Some of the previously reviewed studies have addressed the variable of sex in their research and have reported whether a difference was present between boys´ and girls´ ability to make spatial representations. These research reports will be discussed according to each studies´ results. Additional research which has contributed evidence to the question of sex difference in children's spatial cognition will also be discussed.

Representation Accuracy of Girls

Research which shows the superiority of girls on tasks of spatial cognition is practically nil. No studies were found which tapped the spatial products category of representation and identified girls performance to excel that of boys. One study which did show girls to have an edge, was Ives´ (1980) study on preschool children's ability to coordinate spatial perspectives through language and pictures. Children were asked to verbally identify another's view of a toy after being trained to use the terms "front" "back" and "side" accurately. Kail and Siegel (1977) refer to Maccoby and Jacklin's (1974) study of children's cognitive sex differences, which points to evidence that girls tend to show better performance when a task requires retention of verbal material while boys perform better in retention tasks which require the use of spatial skills. In Kail and Siegel's (1977) study, children in grades three and six as well as adults were tested for sex differences in recall for verbal and spatial characteristics of stimuli. A procedure was used which required the male and female subjects to view slides of sixteen cell matrices in which letters were placed in five of the cells. Subjects were asked to remember the name of a letter, its position, or both. Females were significantly more accurate in recalling letters, but their recall of position was less than males' recall of letters or positions.

Representation Accuracy of Boys

When research results have found boys to excel on tasks of spatial cognition, a notable characteristic is generally present. Differences emerge when there are subjects in the study's sample who are above the age of 7 years, which coincides with the end of the preoperational stage of development. For instance, when Newcombe and Liben (1982) asked preschoolers and adults to learn toy locations in a room divided into quadrants by barriers, only the adult sample showed males to be more accurate in the distance estimation measure between locations. Likewise, first- and fifth- grade boys estimated distances more accurately than girls in Cohen and Weatherford's (1981) study of the effect of barriers. This age characteristic can also be found in the results of Herman and Siegel's (1978) study which found second-and fifth- grade, but not kindergarten boys to be more accurate than girls in reconstructing a model town. Anooshian and Young (1981) judged spatial representation, in a truly large space (4 km neighborhood), by the performance accuracy of children engaging in pointing behaviors. Boys in three groups of children with mean ages of 7.8, 10.7, and 13.4 years pointed a telescope at neighborhood landmarks more accurately than girls in terms of both relative accuracy (i.e. walking a route and pointing to landmarks from various reference points) and absolute accuracy (i.e. standing in front of their homes and pointing at imagined reference sites of landmarks).

One exception to the characteristic identified above as age was shown in the study by Siegel and Schadler (1977) which found that among a sample of kindergarten age children, boys were consistently more accurate on three different measures of spatial representation. In the arrangements of scale model versions of their actual kindergarten room, boys´ performance was significantly greater in absolute accuracy (i.e. a given item´s position in the model compared to it´s position in the actual classroom), local relational accuracy (i.e. a given item´s position in the model with respect to items adjacent to it in the classroom), and global relational accuracy (i.e. a cluster of items´ position in the model in relation to other clusters of items). Recognizing the uniqueness of finding a sex difference in such a young sample the researchers noted, through observation, that no obvious differences in patterns of interaction with the environment occurred between the boys and girls. Their interpretations of the sex difference were either that girls show a relative inability to remember positional information in a large scale environment or alternatively, that girls show a relative inability to deal with the demand of spatial transformation needed to construct the small-scale model. Other studies which have focused on younger samples generally show the same performance results for both boys' and girls' representations of space.

Same Performance Representation Accuracy

Typically, when studies of spatial ability include children in the preoperational stage of cognitive development, results show a similar task performance by both girls and boys. Contrary to the results found in the Siegel and Schadler (1977) study above, Siegel found no sex differences in a later study (Siegel et al., 1979) which also involved kindergarteners. As in the former study, one condition of the experiment involved a small-scale model construction of a large-scale space. Subjects walked through the large-scale town three times then constructed the layout of the town from memory in the small-scale space, using pictures of the buildings. The researchers reported that the preliminary analysis indicated no sex difference in children's performance. Likewise, in the early study by Emerson (1931), which measured the effect of bodily orientation upon younger children's (2 - 5 years of age) memory for the spatial placements of wooden rings on an easel, no significant sex difference was found. The average number of correct placements for each sex was similar.

Very young children between the ages of 1.8 and 3.8 years were studied by Hazen (1982) with respect to their cognitive representations of a large playhouse space. Both boys and girls could reverse a known route, detour from this route and reach a goal from various starting positions equally well. It is noteworthy to report that in Hazen's (1982) study exploration of the playhouse as well as exploration data taken in a museum setting showed that boys and girls had comparable activity ratios. Activity ratio was computed by dividing the number of active movements by the total number of movements (active plus passive). Active movements were those designated as self-guided, while passive movements were those guided by the parents of the children. It is also interesting to note that, although activity ratios between boys and girls were similar, boys were significantly higher in total number of movements made. Pertaining to this exploration issue Herman (1980), in the previously reviewed study, found that kindergarten boys took more time than kindergarten girls (100 sec. vs. 60 sec.) to explore the model town on their first encounter with the novel experimental space. Nevertheless, all subjects in the study performed the construction task equally well in the self-directed condition.

From these research results, which generally show no sex difference among children at the preoperational stage of cognitive development, the aforementioned question of brain specialization arises. There is some evidence that right brain specialization is evident in boys but not in girls at 6 years of age (Witelson, 1976). However, in contrast there is also evidence to support this specialization for both boys and girls at 4 years of age (Etaugh and Levy, 1981). Etaugh and Levy (1981) looked directly at the development of right hemisphere specialization for spatial processing in girls and boys 4- and 5- years-old. Based on the tactile-spatial task devised by Witelson (1976), blindfolded children engaged in a haptic (tactile) exploration of meaningless styrofoam forms. With one shape in each hand, the children then selected the same shapes visually from a group of six shapes. Left hand performance, and alternately right brain functioning, was significantly better ($p < .005$) than right hand performance for both girls and boys in the study.

To summarize the issue of sex difference in spatial ability Harris, (1978, 1981) in an extensive review, offered both neurological as well as socioexperiential explanations from scientific research. However, he warned against a simple input-output relationship between neurological structure, life experience and spatial cognitive ability. He suggested that there are intervening steps that need to be considered, wherein further psychological work must be done in order to grasp the origins of individual differences in spatial cognitive ability. The present study which included the variable of mode of exploration in a small-scale space offered another investigation of spatial representation with a specific age group which typically, although not always, indicates an absence of sex difference. A second question emerged from the study of previous research and that was whether a spatial cognitive sex difference can be observed between young boys and girls under the exploratory mode conditions of this study.

Stage Differences in Spatial Representation

Research evidence which supports the developmental nature of spatial representation has it's roots in the work of Piaget (Piaget and Inhelder, 1967). In a series of experiments tracing the developmental course of the idea of space in children, Piaget and his associates observed as well as made direct inquiries into this ability among children. Summarily, according to Piaget, the evolution of spatial relations proceeds at the perceptual and representational level under the influence of motor and perceptual mechanisms. From birth, sensori-motor space develops into the symbolic function of representational space at which point mental imaging is possible. The periods and stages of sensori-motor space involve the gradual construction of perceptions of space which lead to the co-ordination of vision and grasping. At the transition point of development, from the sensori-motor to the preoperational stage, the need for direct perceptual contact with objects is advanced to the ability to reconstruct objects in the form of images, that is representational thought.

A distinction between the two levels of spatial representation offers a conceptualization of the developmental nature of this area of cognition. Based on the work of Hardwick et al. (1976), Anooshian and Young (1981) distinguish these two levels of representation as relative accuracy and absolute accuracy. Relative accuracy is the level of representation containing a wholistic coordination of the ordinal or relative relationships between objects in space. This can be measured as the degree to which a child maintains ordinal relationships among locations of objects in an array.

Absolute accuracy is that level of spatial representation directed towards specific points of view. Detailed information is needed about object sizes and distances between the objects in space. This ability requires the higher level logic of older children. A similar distinction was made earlier when the difference between topological and Euclidean space was considered. It follows that the latter specific absolute accuracy may not be acquired until the former more general representation level is reached. Empirically, Anooshian and Young (1981) found high relative accuracy scores among young children in their study which measured representation in a familiar naturalistic neighborhood area. Their analysis of performance data revealed the developmental trend noted above (i.e. young children displayed ordinal relationship accuracy, but the further development of the older children allowed for absolute accuracy in representing specific reference systems).

The ability of young children to maintain, in short-term memory, the order of objects in an array (i.e. relative accuracy) describes the focus of the present study. More precisely, one research question of interest is how this ability differs between children in Stage I and Stage II of the preoperational period of cognition. Previously, specific developmental distinctions were made between the stages of preoperational spatial representation. This developmental stance implies that children in Stage II (4 to 6-years-old) would perform at a higher level than children in Stage I (under 4-years old) on a task which involves spatial representation. A look at the findings from current spatial representation research in relation to age can provide information on the developmental nature of this aspect of spatial cognition.

School-Aged/Younger Child Studies

The examination of developmental differences is found in a number of spatial representation studies. These studies compare the performances of child subjects who are in the stage of preoperational thought with children who are in the next stage of cognitive thought, designated as the period of concrete operations (ages from about 7 to 11 years). During the period of concrete operations children's reasoning processes and decision making become more logical, distinguishing them from younger children who rely on perceptual decisions. Despite this fact, the concrete operational child still relies on observable objects and events in space reflecting an inability to solve abstract spatial problems. As concisely stated by Wadsworth (1979) "...the concrete operational period can be viewed as being a transition between pre-logical (preoperational) thought and the completely logical thought of the older child". Children in both stages of development mutually rely on the presence of concrete objects, a feature essential to the investigation of spatial thought at these two periods. The studies which follow have involved child subjects at these two identified stages of development (i.e. preoperational and concrete operational).

Previous sections throughout this review refer to a series of studies which utilize a "model town" to tap children's spatial representations (Herman & Siegel, 1978; Siegel, Herman, Allen & Kirasic, 1979; Herman, 1980; Herman, Roth, Miranda & Getz, 1982; Herman, Kolker & Shaw, 1982). All of these studies examined developmental differences in kindergarten-aged children (preoperational) and school-aged children who ranged in ages from 7 to 11 years (concrete operational). Each of these studies, using a similar strategy of asking children to reconstruct an arrangement of buildings in a model town, attempted to examine how a variety of variables influenced performance accuracy. Results showed that children in the concrete operational period consistently outperformed the preoperational stage children. For instance, Herman (1980) found third graders to be more accurate than kindergarteners in constructing the town from memory across four types of exploratory conditions including directed walking within a space, directed walking around the perimeter of a space, walking within combined with direction of attention toward specific spatial relationships among buildings, and the free exploration of a space. From a developmental point of view, differences in performance between the two groups were recognized by Herman as a function of speed of acquisition and storage of spatial information, referred to as "metamemory". Herman et.al. (1982) again found third graders to be more accurate than kindergarteners when the experiment entailed the recall of toy locations from the same or different perspectives. As in the previous study, changes in performance over age were attributed to the increasing ability to process spatial information in working memory. In another experiment, Herman and his colleagues (1982) studied the effects of motor activity (standing, walking and riding) on spatial representation. Third graders were more accurate than kindergarteners in the stand and ride condition, but not in the walking condition. Equivalency in the walk condition suggested that the younger preoperational child is more dependent on motor activity than the older operational child.

"Model town" studies which examined other variables such as repeated walking vs. repeated construction and bounded vs. unbounded space conditions (Herman & Siegel, 1978) found fifth graders to be more accurate than both second graders and kindergarteners, but the latter groups were not significantly different, suggesting equivalence at the transition between the developmental periods. One feature which specifically improved the performance of the youngest children was the boundedness of the experimental space. The bounded space of a classroom facilitated accuracy of construction more than the unbounded space of the gymnasium-size environment. This points out the previously discussed importance of topological relation cues in an experiment for young children. The present study offered younger children the boundedness of a small-scale space to tap their spatial representation abilities.

Influences on children's spatial representation, and the performance comparison between preoperational and concrete operational stage children, have been studied elsewhere. Of particular interest to the present study, Feldman and Acredolo (1979) investigated the influence of active versus passive exploration on memory for spatial locations of an event, and found 9- and 10-year-old subjects more accurate than 3- and 4-year-olds, regardless of the mode of exploration. As noted earlier in reference to that study, the 3- and 4-year-olds improved accuracy from the passive to the active condition ($p < .01$) but 9- and 10-year- olds' accuracy was the same in both conditions. Examining Piaget's notion of the ontogenetic order of the influence of spatial reference systems, Pufall and Shaw (1973) found 4-year-olds unable to copy the location of an object under two perspective conditions. Six- and ten-year-olds in the same study performed significantly better, showing the ability to conceptualize space in two dimensions (i.e. left/right and far/near). Frame of reference, defined earlier as "a system or strategy that underlies and controls what an individual uses to code location within an environment", showed a developmental trend as well in the work of Acredolo (1976). Ten-year-olds in that study were better at returning to a position in space, a specific spot in a room, under experimental conditions of body orientation. Acredolo (1976) also looked directly at the developmental difference between 3- and 4-year-olds in the same experiment and one other experiment which differed in terms of the size of space. The results of that study, which follows, focused on comparing the performance of two groups of children within the preoperational stage of cognitive development.

Preoperational Children Studies

Acredolo (1976) did find a difference in the spatial representation performance of 3- and 4-year-old subjects in her study, but only in a large 10 x 15 foot space. In that size space 3-year-olds relied on a coding system based on the relation of objects to their own body (i.e. egocentric), while the 4-year-olds were most influenced by the advanced coding system based on an object (a table) as the central feature in the space (i.e. nonegocentric). Utilizing the same procedure but in a smaller experimental space (e.g. a 7 x 12-foot space), no differences were found between the performances of 3- and 4-year-olds, and neither group relied on an egocentric frame of reference. Other studies of spatial representation which focus on the preoperational age period show inconsistent evidence of developmental differences within this cognitive period. Stage II children do not always excel on performance measures in various studies. But, an interesting phenomenon occurs in a few studies showing that children in Stage I (between the ages of 3 and 4 years) show greater increase in spatial ability than children in Stage II (between the ages of 4 and 6 years). Perhaps the early part of preoperational thought is a sensitive period for the development of spatial representation.

Results differed in studies which examined spatial representation in terms of perspective problem solving in young children. No significant difference was found between the performance of 3- and 4-year-olds in Ives' (1980) study of perspective taking, (i.e. the ability to select pictures of another's view of a spatial array from a set of alternative views). Likewise, contrary to the expectation that children's ability to correctly predict object locations would improve with age, Shantz and Watson (1971) found no significant difference between three age groups including 3.8 - 5 years, 5- 5.11 years, and 6 - 6.5 years.

Flavell et. al (1981) also examined the development of perspective taking within this developmental period. These researchers did find developmental progress in knowledge of perspective taking rules in children between the ages of 4 1/2 - 5 1/2 years. They studied three perspective taking rules, and in two of these three rules, a definite developmental trend was seen. However, in the case of the third rule (i.e. a cylinder will appear the same to two individuals who view it from different sides) 4 1/2-year-olds performed better than the 5-year-olds. Anooshian et al (1982) did find a developmental progression in spatial representation identified as sequence recall in their study of children between 3 and 6 years of age. However, there was no relationship between age and event recall or search scores in that study concerning recall of the order of locations along a travelled route.

Age was not significant as a main effect in Etaugh and Levy's (1981) spatial representation study of hemispheric specialization in preschool-aged children. Interestingly, additional analysis resulted in an age X sex interaction which showed that 4-year-old boys performed most accurately, while 5-year-old boys performed least accurately on the task of matching a visual display of a shape with one explored haptically (i.e. perception of an object by means of the sense of touch in the absence of visual stimulation).

Two studies (Emerson, 1935; Hazen et al., 1978) revealed evidence that there is more progress in spatial cognitive development at the beginning of the preoperational period than at the end of that period. Results of Emerson's (1935) research of children's memory for the spatial placement of pegs on a display followed a general curve characterized as "negative acceleration". Although there was a general increase in the average number of total correct placements from age group to age group, the increase was greater between the ages of 3 and 4 years than between the ages of 4 and 5 years. Emerson (1935) indicated that possibly the "ability to make proper placements develops early and rapidly and does not show a constant increase." Hazen et al. (1978) also found that performances on their landmark-reversal and model building tasks significantly increased between the ages of 3 and 4 years, but not between the ages of 4 and 5 years.

The wide variety of results reviewed above point to the need for further investigation of the relationship between age and spatial ability during the preschool period of cognitive development. Particularly, further study is warranted which explores developmental differences within the preoperational period of thought so that the question of stage specificity in spatial representation might be more directly examined. The present study offered such an examination of stage specificity.

Scoring Procedures

In order to more clearly examine the development of children's spatial representations, an accurate means to quantify the task responses of children must be present. Measurement techniques logically vary according to the specific indicators of children's spatial representation. These methods which have included: arranging photos, constructing models and map reading have been described previously in the section labeled "Experimental Strategies". Model construction was inferred to be one direct method suitable for use with young children. This section reviews the measurement techniques utilized by a number of studies which directed their interest towards children's ability to arrange objects in an experimental space in order to tap their spatial representation ability.

Correct/Incorrect Scores

In Emerson's (1931) early study, child subjects placed wooden rings on an easel which included 42 peg "sites". Correct responses were tabulated for each condition in the study. This correct/incorrect scoring procedure failed to measure the degree of accuracy of the child's placement in relation to the actual position. This correct/incorrect strategy was also used in a highly subjective manner in Olsen and Baker's (1969) study of children's placement of a tail on a picture of a donkey. Scores for each subject were determined by the evaluator's judgement as to whether the placement was towards the head or near the rear of the donkey.

Accuracy by Observation

The general procedures in the perspective studies, cited earlier in this review, involved children placing one mono-oriented (i.e. appears upright in a particular orientation) shape, usually a doll or toy animal, on an experimental space. Based on the examiner's decision, the object was checked for accurate orientation representation. Pufall and Shaw (1973) measured perspective not only with an orientation measure but also with a location measure as well. In that study, location was not scored in an all or nothing fashion. A toy lamb's orientation was analyzed at three levels including: quadrant location, peg location, and position location, within the experimental space. Locations were coded and defined as near/far and left/right according to a set criteria (e.g. far was defined as a position location which fell within an area set off by degrees). Two judges independently scored each position location by classifying the orientations. This practice of utilizing observers to judge the accuracy of children's placements has been extensively used in spatial representation studies.

The measure of spatial representations was made more precise in Alexander and Schadler's (1977) study, wherein children constructed a model of their kindergarten classroom. The scoring procedure involved three different accuracy measures including: absolute accuracy (i.e. one point for each item placed within two inches of where it belonged), local relational accuracy (i.e. one point for each of four predetermined inter-item relations such as crayon tables adjacent), and global relational accuracy (i.e. one point for each predetermined cluster of objects present in the construction). An observer recorded each item's placement on the child's model by manually converting the placement to a position on a grid map. Photographs were made of the final model to facilitate the above scoring procedure.

Accuracy by Measurement

In a number of studies designed by Herman and his associates to understand children's memory for a layout of buildings, absolute placement values were calculated by observers who recorded and scored the model arrangements (Herman and Siegel, 1978; Siegel et al., 1979; Herman, 1980; Herman et al., 1982). Each study used metric measurement scales placed on two adjacent edges of the large model town space to derive the metric accuracy of each child's construction. Observers then recorded the X - Y coordinates of each building's placement. A score of one point was given to each building placed within one foot of the actual position. Proportion correct was calculated by dividing the number of buildings judged to have met the criterion above by the total number of buildings present. These proportions were then subjected to an arc sine transformation before analysis. Additional calculations in the Herman (1980) and Herman et al. (1982) studies included a Spearman rank order correlation coefficient to determine the extent to which the sequence of building placements approximated the sequence in which the buildings were encountered. Herman et al. (1982) included a distance deviation score calculated by plotting the placement coordinates of the 7 toys on a sheet of graph paper, then dividing the total distance deviation by 7.

When children reconstructed the environmental configuration in Cohen and Weatherford's (1981) large-scale study, interpoint distances were calculated as a measure for the dependent variable. Specifically, fifteen interlocation distances were measured for each child's placements. Proportion of under and overestimation of the fifteen distances were then calculated and averaged to determine a score. Further development of this scoring procedure occurred in a later study by Cohen and Cohen (1982). In the interest of studying children's ability to estimate distance between objects in a room, as in the former study, ten interobject distance locations were again estimated. Proportion of under- and overestimation was initially used as a score, but further examination revealed that the averaging of scores was misleading. As a result, overall error in estimates was then calculated and converted into an absolute value of percentage of error. One other study utilized interobject distance as a measure between landscape objects in a small-scale spatial array (Anooshian and Wilson, 1977). When children placed objects on a response board, distances between centers of the objects were measured and recorded. Measurement distance means were then calculated and analyzed.

Data on accuracy of model construction in Hazen et al.'s (1978) study involved categorizing the model into sequence (i.e. the order of toy animals in the experimental space) and overall shape (i.e. the arrangement of houses in the space). Model building scores were assigned according to categories such as "house shape right, but animal order wrong" equals a score of 1 point, or "model completely right" which was scored 3 points. Two other studies focused their scoring procedure on measuring sequence or ordinal relations. Kosslyn et al.'s (1974) study of spatial representation of a model array included a training phase of placing toys in remembered locations, but actual scoring procedures involved a task in which children imagined where the toys were placed on the floor and then pointed to a toy in a box of toys that was "most near" to a selected toy. From this ranking procedure ordinal relations in the set of proximity data was measured and represented by another spatial configuration. This response spatial configuration was then compared to the model stimulus configuration, and a degree of congruence was calculated. A unique aspect of that study was the fact that the researchers made use of a computer program, CONGRU (Oliver, 1970) to assist them in the measurement procedure. Computer programs such as the one described above provide a more efficient and precise technique to derive scores on dependent measures in studies of children's spatial representation of objects in an array.

Previous studies have varied in their attempts to derive scores for children's representation responses, and have often used a degree of subjectivity. Some plotting, measuring and recording was time-consuming and increased the possibility of miscalculations. The criteria for judging accuracy has been shown to be an important concern in studies of spatial representation. Evans (1980) has noted that studies have been vague in describing both the judges who scored the model arrangements, and the exact criteria used to establish judgement accuracy. In addition, he notes that research data is lacking in aggregate descriptions of model constructions. The need exists to further develop strategies to quantify individual's model constructions for a more complete analysis of this cognitive process. This point is especially essential to the measurement of relative object placement, which was a major concern of the present study. This study introduced a measurement strategy which utilized a computer calculated scoring procedure to compare more objectively object placements of a stimulus model to object placements of children's response models. This programmed system called KIDSPACE (Fuhrer, 1985) was designed to calculate relative object placement scores for each child's performances in this study. For a more detailed description of this program refer to Appendix A.

Summary

The purpose of this chapter was to consider certain important aspects of research in the area of children's spatial representation. Initially, the significance of the size of space used in experimentation was given full attention. It was concluded that decisions regarding size of space be based on the specific research question of interest related to children's spatial representation ability.

The present study is concerned with spatial products which are utilized to describe or represent an encountered space and act as an indicator of children's spatial representation. In addition, this research study is concerned with children's relational accuracy in placing objects in a space encountered previously. With these interests in mind, it was concluded that a small-scale space provided the most suitable environment.

Next, a review of experimental strategies in spatial representation research pointed to the methodological concerns of verbal input and translation requirements. These two concerns posed demands on young children which are unrealistic and restrict direct inquiry into spatial ability. Consequently, a nonverbal measurement procedure was chosen for the current study.

Another key area of discussion was the mode of exploration in experimentation and it's relationship to children's ability to recall an encountered space. It was shown that studies which compared active versus passive exploration found the former to significantly increase children's accuracy on spatial tasks. These previous studies were limited to large-scale spaces, therefore, it was the intent of the present research to investigate the question of whether locomotion was a significant condition for memory of a spatial array in a small-scale space.

The issue of sex difference in spatial ability was also addressed. Research results indicated that boys perform better than girls on spatial tasks, but generally not before the age of seven. At least one research study did find a difference in favor of boys in a kindergarten (preoperational) sample of children. However, the research question, "At what age do sex differences in spatial representation emerge?" still remains to be explored.

The issue of sex difference was followed by a discussion of age difference related to children's spatial representations. Past research supports a developmental progression most clearly when school-aged and younger children are compared. Developmental difference within the preoperational period was not well established, therefore, investigation of the development of spatial representation among children during this intellectual period seemed warranted.

Finally, the methodological issue of measurement was reviewed. Progress was seen in the refinement of accuracy in techniques which measure children's responses on tasks of spatial representation. It was suggested that a more advanced technological approach to measure children's spatial representations should include the use of computer assistance. A computer program designed to "score" spatial representations can provide researchers with a more objective and accurate means to quantify children's spatial representations.

Collectively, the issues, concerns and research questions presented directed the purpose of this study which focused on the spatial ability of young children. Moreover, they guided the development of an inquiry strategy to tap children's spatial representations of an encountered small-scaled space. Specifically, the research questions posed concern differences in preschoolers' ability to represent space by stage of cognitive development, sex, and mode of exploration.

METHODOLOGY

This section describes the procedures utilized to address the previously raised questions concerning the effects of stage of preoperational thought (Stage I vs. II), sex (female vs.male) and mode of exploration (stationary vs. locomotive) on children's spatial representation accuracy.

Design

The strategy of the present factorial experiment offered a systematic study of the phenomenon of spatial cognition and the variables that may influence it. Snedecor and Cochron (1980) pointed out the important advantages gained by combining the study of several factors in the same experiment. Not only is it highly efficient, due to the fact that every observation supplied information about all factors, but also that it provided a method to investigate relationships between the effects of these factors. Likewise, Neale and Liebert (1980) stressed the benefits of the factorial design in terms of the economy it afforded to sample size and it's ability to detect the presence of interaction. More specifically, this is a mixed design which included the classificatory independent variables of stage of preoperational thought and sex as well as the manipulated experimental variable of mode of exploration. Notation for this system of factors and levels taken from Cochron and Cox (1968) is as follows: the factor of stage of preoperational thought (A) is at two levels; stage I and stage II (a), the factor of sex (B) is at two levels; girl and boy (b) and the factor of mode of exploration (C) is at the two levels; stationary and locomotive (c). The 2 X 2 X 2 factorial treatment combination is displayed in Table 1. Table 2. shows the resulting table of contrasts.

Table 1. Treatment Combinations

1. first level of all factors	(1)
2. stage II	a
3. boy	b
4. stage II + boy	ab
5. locomotion	c
6. stage II + locomotion	ac
7. boy + locomotion	bc
8. stage II + boy + locomotion	abc

Table 2. Table of Contrasts

Contrast	(1)	a	b	ab	c	ac	bc	abc	L	MS
A	−	+	−	+	−	+	−	+		
B	−	−	+	+	−	−	+	+		
AB	+	−	−	+	+	−	−	+		
C	−	−	−	−	+	+	+	+		
AC	+	−	+	−	−	+	−	+		
BC	+	+	−	−	−	−	+	+		
ABC	−	+	+	−	+	−	−	+		

Dependent Variables

The dependent variables in this study of children's spatial representation are the subjects' accuracy scores in reconstructing the configuration of a table-top model array of toys. Subjects' reconstructed model arrangements are measured following the manipulation of the independent variable, mode of exploration. That is, accuracy was measured following exploration of the model array in both a stationary (standing) condition and in a locomotive (walking) condition. This accuracy measurement operationalized the cognitive process of interest in this study which was young children's ability to retain in short term memory the relative placement of objects in a spatial array.

Accuracy scores were calculated through the use of a computer program designed for this study, KIDSPACE (Fuhrer, 1985). This computer program analysed childrens' model configurations for three elements; displacement, (i.e. child's location of each object compared to the actual locations), order, (i.e. ranked order of objects in the response model from array center compared to actual ranked order of objects from array center), and relation, (i.e. response model proximities of items compared to actual proximities). In concert, these spatially interrelated subscale measurements: displacement, relation and order formed a threefold measure of spatial representation accuracy.

Presentation of the Task

The presentation of the spatial representation task involved two experimental stimulus conditions: stationary and locomotive, each with two phases: encounter and response. Each child subject was run in both of these conditions and phases.

Equipment

In each of the two conditions referred to above, the stimulus model consisted of a 30" diameter, 1/4" thick circular white foam core board, which acted as a field, and a configuration of seven objects. The portable board and objects were displayed on a 22 3/4" tray. To facilitate the procedure of counterbalancing in the presentation of the two experimental conditions (i.e. stationary and locomotive) two stimulus configuration arrays were utilized. The configuration of objects in these two arrays: array A and array B are shown in Figures 4. and 5. found in Appendix A. Stimulus objects in each array consisted of seven unrelated "toys" each approximately 3" in dimension. In the effort to control for the possible effects of orientation, these objects were chosen for their poly-orientation and did not have a logically favored position.

In a classic study, Miller (1956) presented evidence that there are 7 objects in an individual's span of attention. Miller's (1956) concept of channel capacity of 7 plus or minus 2 bits described the maximum number of items that can be attended to at one time. Subsequent research has suggested an absence of age differences in visual intake capacity in subjects 5-years-old to adult (Sheingold, 1973). In Sheingold's (1973) research, when both children and adults were presented with eight stimuli, the mean number of items in visual memory was 5. The seven household and nature objects selected for the study comprised two experimental sets: j and k. They are listed in Table 3. .

Table 3. Experiment Object Sets j and k

Set j	Set k
colored block	clear plastic box
wood cross-section	crayon
metal washer	metal bolt
snail shell	fan shell
silver dollar	large button
cloth flower	colored basket
rock	toy egg

Two 30" diameter clear plexiglas templates, with 3" diameter cutouts which corresponded to the configuration of array A or B, facilitated standardization of the arrangement of either set j or set k on the circular display board. Preparation for each subject's performance included the use of these templates to "set up" the stimulus model.

Prior research has indicated that outside reference clues may interfere with results in small-scale studies (Acredolo, 1977). To reduce possible reference clues from the large-scale environment of various preschool sites, a cardboard screen which was 3 feet high surrounded the circular array and provided a neutral background and enclosure. In addition, a pair of paper footprints taped to the floor provided a standard standing or starting position in space for each child. These footprints were located precisely one foot from the 0 degree mark on the circumference of the circular array and consistently faced east.

The following section describes the directives given to child subjects participating in the study. These directives promoted intentional memory for the spatial location of experimental objects. Results of studies which have examined children's intentional and incidental memory for spatial location have demonstrated that memory is better with instructions to remember than in the absence of such instructions (Acredolo, Pick & Olsen, 1975; Herman, 1981).

Instructions

Stationary Condition: Encountering Phase

As each child entered the large-scale environment which surrounded the small-scale experimental space, s/he was directed to stand facing the examiner with his/her back to the screen surrounding the circular array. The examiner said:

> We are going to play a remembering game with some things on a table: When you turn around stand on the footprints that are on the floor. We won't touch the things on the table we'll just look at them [Child is directed to the footprints]. Stand here and look at all these things. I want you to remember where all the things are on this table. When a bell rings I'll take the things off and you'll have a turn to put them all back in the right places.

Stationary Condition: Response Phase

The examiner then set a bell timer for one minute. When the bell signaled, the examiner lifted the board from the display tray and allowed the objects to fall randomly into a large wicker basket. The examiner said:

> Now it is your turn to put all the things in their right places.

The child proceeded in the untimed task of arranging the objects on the circular board. Children were given the opportunity to change the positions of objects if desired. When all the objects were placed the examiner said:

> Thanks for playing the game, you put all the things back on the table.

Locomotive Condition: Encountering Phase

As each child entered the large-scale environment which surrounded the small-scale experimental space, s/he was directed to stand facing the examiner with his/her back to the screen surrounding the circular array. The examiner said:

> We are going to play a remembering game with some things on a table. When you turn around stand on the footprints that are on the floor. We won't touch the things on the table we'll just look at them [child is directed to the footprints]. Now, walk around the table and look at all these things. I want you to remember where all the things are on this table. Keep walking around the table and when a bell rings I'll take the things off and you'll have a turn to put them all back in the right places.

Locomotive Condition: Response Phase

The examiner then set a bell timer for one minute. When the bell signaled, the examiner lifted the board from the display tray and allowed the objects to fall randomly into a large wicker basket. The examiner said:

> Now it is your turn to put all the things in their right places.

The child proceeded in the untimed task of arranging the objects on the circular board. As in the stationary condition children were given the opportunity to change the positions of objects until all were arranged. When the child had completed the task the examiner said:

> Thanks for playing the game, you put all the things back on the table.

Record of Responses

During the encountering and response phases of the task, a 30" diameter circular piece of transparent tracing paper rested on the circular field. Upon completion of the response phase, at which time all the objects had been arranged by a child subject, the examiner outlined the placements of the objects before they were removed. The midpoint of each object's outline is recorded by placing a mark at this point. In addition the zero degree mark was recorded on the tracing paper response sheet. This response sheet acted as a cognitve map of each child's spatial representation. This response sheet was then placed on a 30" diameter circular grid which had visible X and Y coordinates marked off in inches. A 16" plastic, 90 degree right triangle was utilized to represent the perpendicular lines which established the locations of the objects on the X and Y coordinates. Locations of all objects were recorded as coordinates on the data sheet shown in Table 4.

Subjects

The three factor mixed design involved the assignment of 48 child subjects to both conditions of the experimental variable and was essentially a combination of factorial and repeated measures designs. As such, it

Table 4.

Data Sheet: Record of Placement Coordinates

Subject Code #____________ Project Data #_______

FIRST TRIAL OBSERVATION

Condition (circle one) stationary locomotive

Array (circle one) A B

ORDER OF PLACEMENT	set j	Coordinates X	Coordinates Y
	1. colored block		
	2. wood cross-section		
	3. metal washer		
	4. snail shell		
	5. silver dollar		
	6. cloth flower		
	7. rock		

	set k		
	1. clear plastic box		
	2. crayon		
	3. metal bolt		
	4. fan shell		
	5. large button		
	6. basket		
	7. toy egg		

SECOND TRIAL OBSERVATION

Condition (circle one) stationary locomotive

Array (circle one) A B

	set j	X	Y
	1. colored block		
	2. wood cross-section		
	3. metal washer		
	4. snail shell		
	5. silver dollar		
	6. cloth flower		
	7. rock		

	set k		
	1. clear plastic box		
	2. crayon		
	3. metal bolt		
	4. fan shell		
	5. large button		
	6. basket		
	7. toy egg		

permitted the evaluation of the overall experimental effect and the examination of subjects' performance variations during the experiment (Bruning & Kintz, 1977). The procedure of repeated measures was utilized chiefly as a control for individual differences among subjects. Each subject became his or her own control. Due to the nature of this within-subjects comparison a procedure of counterbalancing was employed to guard against carryover effects from one measurement to the next. To minimize the influence of a practice effect from one mode of exploration to the other, the order of the conditions was counterbalanced such that half the subjects chosen at random were measured in the stationary condition first (A -> B) while the remaining half were measured in the locomotive condition first (B -> A). Balancing the order in which the treatments were given avoided bias in the comparison of the performance means during statistical analyses. In addition, both the randomized configuration arrays (A and B) and object sets (j and k) were counterbalanced to minimize carryover effects.

This procedure is illustrated in the design for the collection of data shown in Table 5. .

Table 5. Design for Collection of Data

Group1 (Stage I/Boy)			Group2 (Stage I/Girl)		
	stationary	locomotive		stationary	locomotive
Subject			Subject		
S1	O1aj	O2bk	S13	O1aj	O2bk
S2	O1aj	O2bk	S14	O1aj	O2bk
S3	O1aj	O2bk	S15	O1aj	O2bk
S4	O1ak	O2bj	S16	O1ak	O2bj
S5	O1ak	O2bj	S17	O1ak	O2bj
S6	O1ak	O2bj	S18	O1ak	O2bj
S7	O2aj	O1bk	S19	O2aj	O1bk
S8	O2aj	O1bk	S20	O2aj	O1bk
S9	O2aj	O1bk	S21	O2aj	O1bk
S10	O2ak	O1bj	S22	O2ak	O1bj
S11	O2ak	O1bj	S23	O2ak	O1bj
S12	O2ak	O1bj	S24	O2ak	O1bj
Sum			Sum		

Group3 (Stage II/Boy)			Group4 (Stage II/Girl)		
	stationary	locomotive		stationary	locomotive
Subject			Subject		
S25	O1aj	O2bk	S37	O1aj	O2bk
S26	O1aj	O2bk	S38	O1aj	O2bk
S27	O1aj	O2bk	S39	O1aj	O2bk
S28	O1ak	O2bj	S40	O1ak	O2bj
S29	O1ak	O2bj	S41	O1ak	O2bj
S30	O1ak	O2bj	S42	O1ak	O2bj
S31	O2aj	O1bk	S43	O2aj	O1bk
S32	O2aj	O1bk	S44	O2aj	O1bk
S33	O2aj	O1bk	S45	O2aj	O1bk
S34	O2ak	O1bj	S46	O2ak	O1bj
S35	O2ak	O1bj	S47	O2ak	O1bj
S36	O2ak	O1bj	S48	O2ak	O1bj
Sum			Sum		

O1 = 1st trial observation
a = array configuration a
j = object set j

O2 = 2nd trial observation
b = array configuration b
k = object set k

This 2 X 2 X 2 factorial design is an 8 cell arrangement as illustrated in the following design matrix (Table 6.).

Table 6. Design Matrix

A = Stage	B = Sex	C = Mode of Exploration: Stationary	C = Mode of Exploration: Locomotive
	Boys	12	12
	Girls	12	12
	Boys	12	12
	Girls	12	12

N = 12
Repeated Measure
----------->
Total subjects = 48

The subjects in the study were male and female young children between the ages of 3 and 6 years of age who were enrolled in middle-class day care centers, preschools, and kindergartens in Bellingham, Washington. Bellingham, Washington is a mid-sized city of 46,000 in the northwestern corner of the state near the Canadian border. A listing of sites which have approved the experiment and agreed to have children participate in the study can be found in Appendix C (Information and Consent Form). In addition, a parental approval form can be found in Appendix C (Parental Consent Form).

Prior to the collection of data, contact was made with the Oregon State University Board for the Protection of Human Subjects. From a review of the project this research was deemed "exempt" from further review since it involved the use of an educational cognitive test. 1981 regulations lists the following categories as exempt:

> 5. Research involving the use of educational tests (cognition, diagnostic, aptitude, achievement) is exempt, if information taken from these sources is recorded in such a manner that subjects cannot be identified, directly or through identifiers linked to the subjects.

Complying with the Board's recommendation, children's names did not appear on data collection sheets, and code numbers replaced actual names.

In order to ensure a representation of subject characteristics primary to this study a stratified random sampling procedure was utilized. Two classificatory variables were involved in this study, stage of preoperational thought and sex. In addition to the actual age range of children, stage of preoperational thought was determined through the use of a haptic perception evaluation originated by Piaget (Piaget & Inhelder, 1967) and later replicated in the research of Laurendeau and Pinard (1970). In brief, this test involved a nonvisual presentation of increasingly complex objects and cardboard shapes to children who manipulated these with haptic exploration. Children were then required to "match" the handled shapes to a group of visually displayed shapes. Piaget's experimentation and Laurendeau and Pinard's later replication demonstrated that stage I children (under four years) can recognize and distinguish between objects but not between geometric shapes. Whereas, stage II children (4 to 6 years) can distinguish between curvilinear and rectilinear shapes. A detailed description of this test can be found in Appendix B (Stereognostic Recognition of Objects and Shapes Test).

RESULTS

In this section, the results of the application of a 2 (Stage: I vs. II) X 2 (Sex: males vs. females) X 2 (Mode of Exploration: locomotive vs. stationary) multivariate analysis of variance (MANOVA) with repeated measures on mode of exploration on child subjects' spatial representation accuracy scores are reported. Spatial representation accuracy involved a threefold measure of "displacement", "relation" and "order". The measure of "displacement" was the subjects' locations of each object compared to the location of each object in the model display, "relation" was the relative proximities of the total display of seven objects compared to the total display of the model, and "order" was the rank order of each object from the center of the circular display. Results of accompanying, separate univariate analyses of variance on these measures are also reported. The $p<.05$ level or below was used as the significance level for all analyses.

Main Effects

Stage: Table 7. summarizes the means and standard deviations of subjects' spatial representation accuracy scores for displacement, relation and order by stage level. A significant multivariate main effect was found for stage, $F(3, 42) = 4.35$, $p<.01$. Additional analyses for stage demonstrated a significant univariate effect for the subscale displacement, $F(1,44) = 10.26$, $p<.01$. Subjects' in stage II of the preoperational thought period placed objects more accurately than subjects in stage I on the displacement spatial representation task.

Table 7. Means and Standard Deviations for Subjects' Spatial Representation Accuracy Scores by Stage Level

Accuracy Score/Stage Level	$\bar{X}$	SD
Displacement[a]		
Stage I	165.20	33.08
Stage II	136.91	27.51
Relation[a]		
Stage I	675.19	77.67
Stage II	659.27	63.47
Order[b]		
Stage I	2.58	1.86
Stage II	3.29	1.63

[a] Lower scores represent better performance

[b] Higher scores represent better performance

Sex: Table 8. summarizes the means and standard deviations of subjects' spatial representation accuracy scores for displacement, relation and order by sex.

There were no significant main effects for sex on subjects' spatial representation accuracy scores. Males and females were not significantly different in their performances on the spatial representation accuracy tasks.

Table 8. Means and Standard Deviations for Subjects' Spatial Representation Accuracy Scores by Sex

Accuracy Score/Sex	$\bar{X}$	SD
Displacement[a]		
Males	147.13	27.23
Females	154.98	38.66
Relation[a]		
Males	651.82	74.03
Females	682.64	64.94
Order[b]		
Males	2.75	1.19
Females	3.13	2.21

[a] Lower scores represent better performance

[b] Higher scores represent better performance

Mode of Exploration: Table 9. summarizes the means and standard deviations of subjects' spatial representation accuracy scores for displacement, relation and order by mode of exploration. There were no significant main effects for mode of exploration on subjects' performances on the spatial representation tasks. Mode of exploration whether under a locomotive or stationary treatment condition did not lead to significantly different performances of children on the spatial representation tasks.

Table 9. Means and Standard Deviations for Subjects' Spatial Representation Accuracy Scores by Mode of Exploration

Accuracy Score/Mode	$\bar{X}$	SD
Displacement[a]		
Locomotive	78.77	18.34
Stationary	72.28	22.70
Relation[a]		
Locomotive	335.06	47.19
Stationary	332.17	49.49
Order[b]		
Locomotive	1.48	1.07
Stationary	1.46	1.24

[a] Lower scores represent better performance
[b] Higher scores represent better performance

Interaction Effects

Table 10. summarizes the means and standard deviations of subjects' spatial representation accuracy

scores by stage X sex X mode of exploration. A significant multivariate interaction effect emerged for stage X mode of exploration, $F(3, 42) = 3.75$, $p<.05$. Each of the subscales revealed a significant univariate interaction effect: displacement, $F(1, 44) = 5.41$, $p<.05$; relation, $F(1, 44) = 4.53$, $p<.05$; and order, $F(1, 44) = 5.30$, $p<.05$. Figures 1., 2., and 3. present these interaction effects graphically.

Post hoc comparisons using the Scheffe test revealed different patterns for each spatial representation accuracy score. For displacement scores, Stage II subjects performed better than Stage I subjects in the stationary mode of exploration ($p<.05$). Also, Stage II subjects performed better in the stationary than the locomotive mode of exploration ($p<.05$). No significant differences were found between Stage I subjects in the stationary and locomotive modes or between Stage I and Stage II subjects in the locomotive mode.

For order scores, subjects in Stage II performed better than Stage I subjects in the stationary mode of exploration ($p<.05$). Following the pattern of displacement scores, no significant differences were found between Stage I subjects in the stationary and locomotive modes, between Stage II subjects in the stationary and locomotive modes or between Stage I and Stage II subjects in the locomotive mode.

Table 10. Means and Standard Deviations for Subjects' Spatial Representation Accuracy Scores by Stage X Sex X Mode of Exploration

Mode of Exploration	Locomotion		Stationary	
Accuracy Score Stage X Sex	$\bar{X}$	SD	$\bar{X}$	SD
Displacement[a]				
Stage I	81.90	20.78	83.31	19.96
Males	78.57	18.13	79.12	16.47
Females	85.22	23.42	87.50	23.44
Stage II	75.65	15.02	61.26	20.01
Males	73.18	11.19	63.38	19.22
Females	78.12	18.85	59.13	20.79
Relation[a]				
Stage I	329.17	48.18	346.02	50.02
Males	309.84	50.19	332.20	57.41
Females	348.50	46.17	359.83	42.63
Stage II	340.95	43.39	318.32	44.89
Males	348.61	44.99	312.98	46.23
Females	333.29	41.78	323.65	43.55
Order[b]				
Stage I	1.54	1.14	1.04	1.27
Males	1.58	1.38	.83	.94
Females	1.50	.90	1.25	1.60
Stage II	1.42	1.04	1.88	.98
Males	1.42	1.08	1.67	.65
Females	1.42	1.00	2.08	1.31

[a] Lower scores represent better performance

[b] Higher scores represent better performance

Figure 1. Stage X Mode of Exploration Interaction Effects for Displacement Means

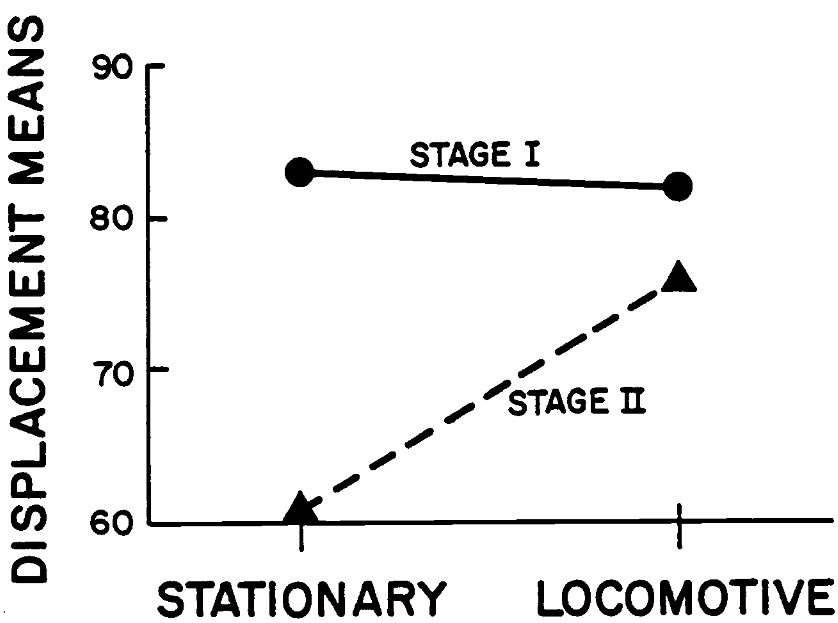


Figure 2. Stage X Mode of Exploration Interaction Effects for Relation Means

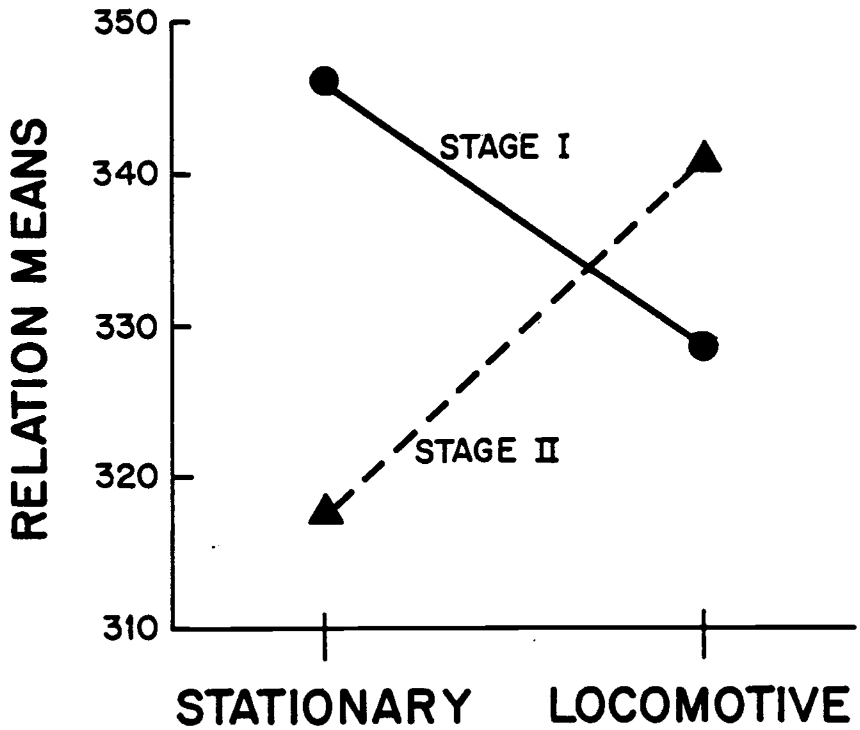
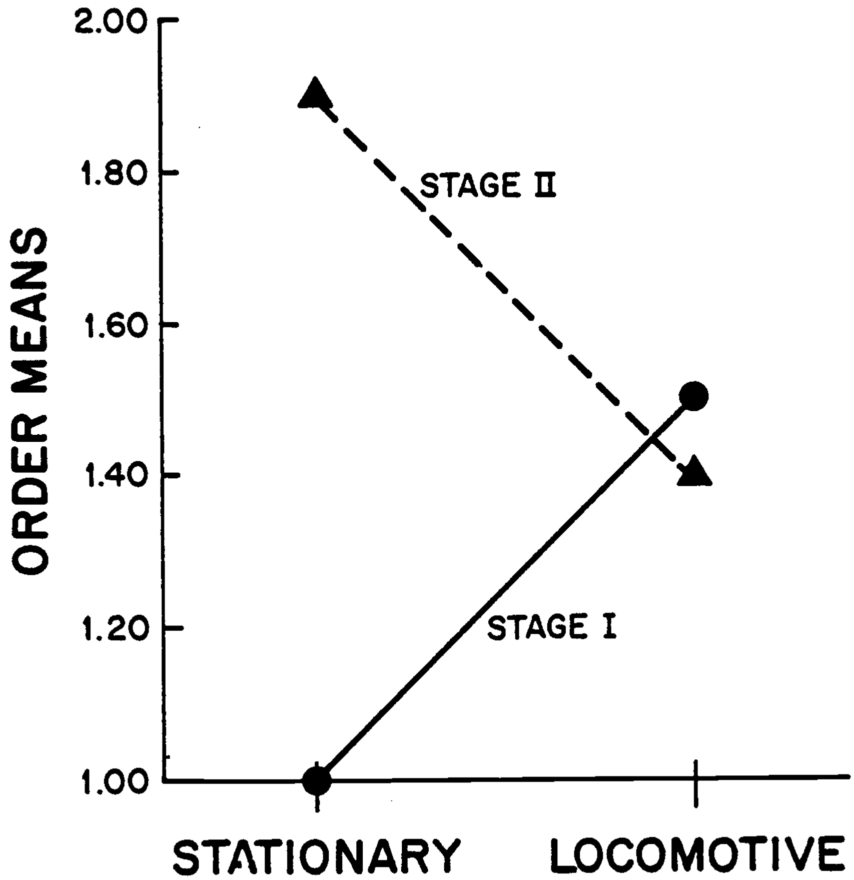


Figure 3. Stage X Mode of Exploration Interaction Effects for Order Means



Summary

In summary, results of this study revealed that stage of preoperational thought produced a significant effect on the displacement performance of subjects. Stage II subjects outperformed Stage I subjects in the displacement spatial representation accuracy test. However, when subjects' relation and order performances were considered, stage of preoperational thought failed to produce any significant effects. Furthermore, results also indicated that sex as well as mode of exploration failed to produce any significant main effects on any of the subjects' spatial representation accuracy scores.

Significant stage X mode of exploration interaction effects were also obtained for subjects' displacement, relation and order performances. However, post-hoc comparisons using the Scheffe test only revealed Stage II subjects outperforming Stage I subjects on the displacement and order tasks in the stationary mode of exploration, and Stage II subjects performing better on the displacement task in the stationary rather than the locomotive mode of exploration. Although the stage X mode of exploration interaction effects for subjects' relation performance was significant, post-hoc comparisons revealed no significant interaction effects for this variable.

DISCUSSION, LIMITATIONS AND SUGGESTIONS

In this chapter, findings of the present study are discussed and related to previous research. In addition, limitations of the study and suggestions for future research are made. Finally, implications of the findings and methods used in this study for educational practice are discussed.

Discussion

The organization of this discussion is based on the study's three independent variables: stage, sex and mode of exploration. Each variable is discussed in light of the research results obtained and described in the previous chapter.

Stage

In this study subjects were classified into either Stage I or Stage II of preoperational thought based on their performance on Laurendeau and Pinard's (1970) Stereognostic Recognition of Objects and Shapes Test (See Appendix B). The mean age of subjects in Stage I was 2.9 years, while the mean age of subjects in Stage II was 3.7 years. Results of this study provided support for some stage specific skill levels of spatial representation accuracy among very young children. The results of the analyses for the measure of displacement revealed that children in Stage II performed significantly better on object displacement than children in Stage I. However, results of the analyses for relation and order revealed that stage failed to have a significant effect on subjects' performance. This does not mean that Stage II children had the same level of performance as Stage I children on these spatial representation tasks. The means achieved by the Stage II children on relation and order, although not statistically significant, also indicated that they did, slightly, outperform children in Stage I.

Few studies have attempted to analyze the spatial representation skill level difference between groups of children within the stage of preoperational thought. Of those that have used very young children as subjects, specialized spaces and measures of spatial accuracy, unique to each study, limit a researcher's ability to make direct comparisons. However, certain observations provide justification for relating the results of this study to previous research. The significant difference in displacement found between subjects in Stage I and II in this small-scale space study is in contrast to findings of earlier studies. In two spatial location experiments with young children, Acredolo (1976) found a difference between the performance of 3- and 4-year-olds when the experimental space was large-scale. However, no difference was found when a small-scale experimental space was employed. Similar results were obtained by Ives (1980) in his small-scale study of spatial perspective taking among 3 and 4 year olds. Likewise, Shantz and Watson (1971) found no significant difference between 4 and 5 year olds in their small-scale study of spatial object locations. However, the results of this study does support the developmental nature of spatial representation in young children found in the research of Flavell et. al (1981) and Hazen (1982). Flavell et. al (1981) found a significant difference in small-scale spatial perspective taking performance between 4 1/2 and 5 1/2 - year olds. Hazen (1982) obtained similar findings with even younger children. Three year olds scored significantly higher than two year olds on three different measures of spatial knowledge involving a playhouse layout.

The question which arises from the above review of various stage difference studies in spatial representation is why results show a developmental trend in some studies and not in others? An important point to consider in this discussion is the differences in the nature of the various studies conducted. Previously, it was noted that under the umbrella of spatial representation knowledge a variety of distinctions can be made. One possible reply to the above question concerns the distinctiveness of both the specificity of the experimental space used and the corresponding nature of the ensuing accuracy measures. Two differential features in the composition of experimental spaces are their exact circumscriptions of area and their individual arrangements of materials. These features influence the complexity of the experimental space and so present different problems to child subjects. Resulting accuracy measures are also unique to each study. It follows that if the task differs in complexity so too would the particular interpretation of obtained scores. Each study differs with respect to these features and this dissimilarity could affect the ability to detect developmental trends.

The other possible reply relates to the precise age period during which spatial representation knowledge is being considered. The significant results obtained in Hazen's (1982) and the present study involved very young children as subjects. Perhaps, this initial period is a more sensitive time for the development of spatial thought than at later ages. A line of research stemming from this study could involve experiments designed to investigate further the developmental course of spatial knowledge and representation during the early period of preoperational thought.

Sex

The present research findings clearly indicated that there was little difference between early male and female performance on the small-scale spatial representation tasks designed for this study. Male subjects did not perform significantly better than female subjects on all three spatial representation tasks including displacement, relation and order. The lack of significant differences between male and female spatial representation performances early in development supports findings of previous research in this area. In studies conducted by Emerson (1931), Siegel at al. (1979), Herman (1980), and Hazen (1982), results indicated similar spatial ability task performance among girls and boys at the preoperational stage of cognitive development.

One explanation which might account for this lack of sex difference in spatial representation ability may lie in studies related to the development of brain specialization. Clearly, reviews of hemispheric brain specialization by Teitelbaum (1967), Milner (1970), Nebes (1977), and Loye (1984) point out that a right brain specialization does exist for spatial ability. Previous research in sex differences on spatial ability, which involved child subjects above the age of seven, consistently supports the finding that boys outperform girls on spatial tasks. If consideration is given to functional right brain development and sex, a positive relationship between spatial representation ability and right brain development among boys seven years or older appears plausible. Among children under seven years of age, however, in the preoperational stage of development, since brain specialization has not as yet developed, no sex differences in spatial representation ability would be expected. Further research is needed to varify this proposition.

At this point, it is also important to consider the possible socio-experential explanations for the nonsignificant sex findings obtained in this study. How young boy's and girl's social environments and experiences provide or inhibit their involvement in a variety of spatial experiences may markedly influence their spatial task performances. For example, during the early years, sex role norms may not inhibit children's involvement in various spatial activities as in later childhood or adolescence. On the basis of these findings, therefore, sex differences in spatial representation ability would not likely occur until later childhood, due to a variety of socio-experential sanctions. Future studies in this area, in addition to the neurological studies previously suggested, would be extremely worthwhile.

Mode of Exploration

On the basis of results obtained in this study, it appears that mode of exploration had little impact on children's spatial representation ability. This nonsignificant effect was true for all three measures of spatial representation accuracy studied. These nonsignificant results compared to the results of previous research will be discussed below. However, further evidence regarding the significant stage by mode of exploration interaction effect will also be discussed since it contributes additional information to our understanding of the effects of mode of exploration on children's spatial representation accuracy.

The lack of significant difference between the locomotive and stationary modes of exploring stimulus arrays to facilitate aspects of children's spatial representation obtained in this study is in contrast to findings obtained by Feldman and Acredolo (1979) and Hazen (1982). In relating the results of this study to these two previous studies, the concern of scale of space and nature of spatial representation tasks used once again become critical issues. The researchers mentioned above conducted their studies in large-scale spaces which accomodated unrestricted, more variable movement activity. The dimension of an area and the accompanying movement activity within it's bounds have a direct influence on research findings. So, while results obtained in previous studies may be accurate for large-scale space, they may not be for more concentrated small-scale space and movement. Measuring the effects of movement on children's ability to represent small-scale space is a relatively unapplied research strategy. Siegel at al. (1979) in another study did incorporate movement in a small-scale space by requiring subjects to push a toy truck through a table-top space. However, Siegel did not subject the data to probability analysis which compared that condition to a stationary condition of exploration, so a direct comparison of modes cannot be made.

The scale of an experimental space, which acts as a provision for movement activity in spatial tasks, is a salient point to consider when discussing the differing findings for the significance of movement on tasks of spatial cognition. In this study, the enclosed 8.5' diameter area provided a concentrated space for the specialized movement of walking in a circular path around an elevated table-top display. Attention to the effects of movement on children's ability to represent an encountered small-scale space is worthy of further investigation. Experimental strategies might vary in movement direction (eg. moving toward the display) or visual distance (eg. floor level displays). Considering the limited number of studies focused on the effects of movement on young children's representations of small-scale space, this research might lend a framework for replication studies so that inquiry into this variable might be further explored.

Although mode of exploration as a main effect was found not to be significant, further analysis revealed a significant stage X mode of exploration interaction effect. Post-hoc comparisons revealed that it was in the stationary mode of exploration that Stage II subjects significantly outperformed Stage I subjects on the displacement and order tasks and that Stage II subjects performed significantly better on the displacement task in the stationary rather than locomotive mode of exploration. When previous researchers investigated both stage differences and the effects of movement on children's ability to represent space they found, contrary to the results of this study, that all children either excelled in the active rather than passive condition or else performed equally well in both conditions (Feldman and Acredolo, 1979; Hazen, 1982; Herman et. al., 1982; Cohen & Cohen, 1982). Although comparable in terms of factors under consideration, these previous studies and the present study differ with respect to the mean age of the young subjects. This age difference is one possible explanation for differing results. The findings in this study appear to indicate that children in the latter period of preoperational thought improved their ability to perform spatial representation tasks when visual scanning of the stimulus array occurred while they were standing rather than walking.

Despite the absence of significant findings related to Stage I subjects and mode of exploration, inspection of the differences between the means related to the interaction effects revealed that, although not statistically significant, Stage I subjects consistently perform better in the locomotive mode. The reverse is true for Stage II subjects. This tendency toward active exploration having a greater effect on younger subjects under study was found in two of the previous studies cited above. Feldman and Acredolo (1979) found that active exploration of their experimental environment increased memory for spatial location only in the preschool-aged group of subjects and not in the group of 9 - 10- year old subjects. Also, Herman et al.'s (1982) study found that memory for spatial locations improved with increasing motor activity for kindergarten children only. As an adjunct to the previously stated suggestion that the period of preoperational thought is a sensitive time for the development of spatial thought, it may be feasible that very early in this period of representational thought the modus operandi is an important consideration. Further research results in this direction are necessary before a developmental stance can be introduced.

Concluding interpretations of these results are that, if indeed, an imposed condition of movement during visual scanning impedes the spatial representation performances of subjects in the latter period of preoperational thought, the possibility exists that perceptual activity which includes locomotion limits attending behavior towards a stimulus array for this group of children. Analogous to this idea, locomotive movement may have facilitated attention and prolonged the visual fixations of younger subjects in the initial period of preoperational thought. The interaction results discussed above suggest, however preliminary, the contention that an active or locomotive mode of exploration is one strategy that might enhance the assimilation of spatial information in very young children.

Limitations

The applicability and generalizability of the findings must be considered in light of the sample and the experimental features used in this study. The target population was restricted to all children enrolled in middle-class child care centers in the city of Bellingham, Washington during the Spring and Summer of 1985. Random assignment was made at the children's center level. Additionally, to accurately equate the four treatment groups on the important variables of stage and sex, the necessary sampling condition of stratification was employed.

In order to obtain the stage characteristic primary to the study, the Stereognostic Recognition of Objects and Shapes Test (Piaget and Inhelder, 1967; Laurendeau and Pinard, 1970) was employed and administered to all subjects prior to conducting the study´s spatial representation experiments. All possible steps were taken to replicate the materials and procedures used in the original test. As is the case with any preassessment used in experimental studies, it is conceivable that the use of this test with it´s specific techniques used may have prompted one treatment group to possess unique characteristics that were uncontrolled for, thereby influencing the results of the study, thus threatening internal validity.

An additional issue to acknowledge in the use of this test as a procedure to classify subjects into stage characteristics is that an overlap exists between stages in the criteria established for stage classification. According to the test´s quantitative analyses, Stage III begins around six years and is fully attained by eight years. This designation of Stage III as an overlap of the last period of preoperational thought and the beginning period of operational thought may have eliminated some subjects who were in transition to operational thought yet, for classificational purposes were still representative of preoperational thought. A few older preschoolers and all kindergarteners assessed with the test were designated as Stage III and subsequently not included in the study. Consequently, the sample of Stage II classified subjects in the study may not represent those subjects who are advanced in the stage but still preoperational in their thought processes.

The external validity, categorized by Bracht and Glass (1968) as "ecological validity" of the experimental spatial task, must also be questioned. The type as well as the number of objects selected for the task are issues which warrant attention. The seven household and nature objects were chosen for the attributes of mono-orientation, familiarity, and the ability to engage children in the task. It is feasible that the features of the objects influenced children toward selecting one object over another during the representation phase of the experiment. A system of observation was included in the study to assess this idea. An examiner recorded each subject's order of object selection during the representation phase and a frequency count was tabulated (see Table 11). Results of the selection frequency tabulation, calculated as percent of total selection, generally show no great disparity which might suggest

Table 11. Selection Frequency Tabulation

Subjects' Order of Object Selection

	Set J	Set K		Set J	Set K
S1	7316425	3267514	S25	2647351	4173562
S2	4251673	7452613	S26	4165237	2743561
S3	6431275	1634725	S27	7426153	4357612
S4	5471362	2765431	S28	4571236	1725346
S5	6514237	1245736	S29	1246573	6354721
S6	5234761	4652731	S30	2463715	6574312
S7	6451273	1463572	S31	5364721	3567421
S8	3526714	4573621	S32	5621374	2475631
S9	7256431	7625413	S33	1276435	1724356
S10	7246513	1647352	S34	4275631	2576431
S11	2645317	1653724	S35	1235476	4652731
S12	4317265	5476132	S36	4273615	2517643
S13	7651432	2564731	S37	2473615	6374215
S14	1263475	1674523	S38	7165324	5172643
S15	3741562	3672514	S39	5263174	5763412
S16	2376415	2376451	S40	7315264	1547263
S17	2563471	3475612	S41	3426751	7351246
S18	6271435	5324761	S42	4375216	2576431
S19	4325167	2634751	S43	1245637	1674532
S20	7356142	3462751	S44	5172634	4563721
S21	5462713	2765134	S45	6723415	1674532
S22	3165742	2574631	S46	1356247	1345627
S23	2471536	3672451	S47	4672513	2764531
S24	3146527	2456731	S48	2341567	7643521

Object Selection Frequency

	Percent of Ordinal Frequency						
	1st	2nd	3rd	4th	5th	6th	7th
Set J							
1. colored block	12.5	10.4	8.3	22.9	8.3	22.9	14.6
2. wood section	16.7	27.1	12.5	6.3	18.8	8.3	10.4
3. metal washer	10.4	20.8	6.3	14.6	10.4	22.9	14.6
4. snail shell	18.8	18.8	16.7	6.3	20.8	6.3	12.5
5. silver dollar	14.6	8.3	12.5	20.8	14.6	6.3	22.9
6. cloth flower	10.4	10.4	18.8	25.0	12.5	14.6	8.3
7. rock	16.7	4.2	25.0	4.2	14.6	18.8	16.7
Set K							
1. plastic box	25.0	4.2	2.1	2.1	4.2	18.8	43.7
2. crayon	27.1	4.2	8.3	14.6	6.3	18.8	20.8
3. metal bolt	12.5	14.6	4.2	16.7	8.3	31.3	12.5
4. fan shell	12.5	14.6	12.5	27.1	16.7	8.3	8.3
5. large button	8.3	20.8	16.7	16.7	20.8	12.5	4.2
6. basket	6.3	27.1	20.8	10.4	18.8	8.3	8.3
7. toy egg	8.3	14.6	35.4	12.5	25.0	2.1	2.1

object preference. In three cases a selection frequency of over 30% was recorded. The highest percentages calculated involved the plastic box which was selected seventh 43.7% of the time, the toy egg selected third 35.4% of the time and the metal bolt selected sixth 31.3% of the time. It is unclear whether these high percentages were influenced by the object itself or it's position in the experimental model array.

Of greater concern is the number of objects presented in the visual array. Although the number seven was chosen, based on previous research in visual channel capacity (Miller, 1956; Sheingold, 1973), young children may have become frustrated with the quantity of objects. Although anecdotal information taken during subjects' performances did not cite any obvious behavioral indicators of frustration, such states may have been masked by children's eagerness to cooperate with the task. Such states of frustration certainly could have affected the accuracy results. By using the specific type and number of objects, the experimental task could have been measuring something other than the subjects' level of representation. Therefore, the generalizability of the study's findings must be considered in view of this possibility.

In conclusion, subsequent studies might employ an alternative procedure to accomplish the stage classification of subjects to include a broader range of substages in the period of preoperational thought. Also, a replication study which decreases the number of stimulus objects may provide additional information on performance accuracy during the early development of spatial representation. Further research might also include the documentation of the length of time each subject used to assemble the objects in the experimental space. The use of a stopwatch could easily facilitate this additional documentation.

Future research might examine factors which could influence spatial representation during specific substages of the preoperational thought period. This study identified locomotion as an activity which facilitated some increase in the performance accuracy of very young children. It was suggested that this movement variable influenced the attending behavior of children classified as Stage I in the period of preoperational thought. In contrast, children classified as Stage II significantly increased performance accuracy under the stationary condition. In order to effectively identify further conditions, which facilitate spatial representation in the latter group, it might be useful to concentrate a study on factors which influence that particular stage of cognitive thought.

Future research might also include the examination of general factors which influence performance on small-scale spatial representation tasks.

With a controlled methodology, socio-experential determinants such as play materials found in the home, levels of tactile exploration, frequency and duration of active play, or home play spaces might be examined for their correlation with performance accuracy on a spatial task such as the one designed for this study. An intervention study which includes a series of movement experiences might also be attempted to further investigate the relationship of movement to performance on spatial tasks.

Implications

Current recognition of the importance of promoting spatial knowledge in young children is evidenced by the trend in curriculum development to include experiences directed toward exploring "space". A number of these experiences are focused on gross motor movements which encourage body awareness and orientation in space. An issue recognized in this study was that the area of spatial knowledge must also include an awareness of children's capabilities to relate to the small-scale spaces and materials they encounter in their educational environments. The research review, the experimentation and the results obtained in this study offer a number of directives toward evaluative and curricular practices.

Evaluative Practices

The ability to identify and measure children's spatial knowledge, specifically their spatial representation accuracy, has been elusive as evidenced by the scarcity of evaluative tools. In the development of such tools the following recommendations might be given consideration:

1. Spatial intelligence has been characterized as a nonlinguistic processing mode. Therefore, reliance on children's verbal responses should be avoided. Informal anecdotal records identified only 3 children in the sample of 48 who verbally named the objects during either the exploration or representation phases of the experiment.

2. Children should be given time to "stand back" or "move around" the small-scale space to facilitate attending behavior toward the test stimuli.

3. Children's mental images of test model arrays cannot be assumed. Therefore, during a response phase they should be given an autonomous choice towards which test items they will act on, and in what order.

4. Scoring procedures must be both standardized as well as efficient. A computerized program, such as the one developed for this study meets these essential requirements.

5. In small-scale space assessments it is necessary

to shield the space from outside visual influences. A portable visual barrier which totally encloses the testing space accomodates this need.

Curricular Practices

Young children spend a great deal of time engaged in activities which require small table-top spaces. These activities which include a variety of manipulative materials for small construction, puzzles, animal and doll house miniatures, and art materials all involve spatial knowledge. Children are constantly processing information about placement, orientation, direction, order, and sequence. Recalling, visualizing, and reproducing the positions of these objects in space, referred to in this study as spatial representation, is an active mental process. To facilitate this development in young children, curricular planning might include the following considerations:

1. The development of spatial representation proceeds in stages. As evidenced by results obtained in this study young children's skills vary within the periods of preoperational thought. Planned spatial activities should have the ability to accomodate various levels of skill development.

2. From data gathered in this study, it appears that children's spatial representation performances vary

as the mode of exploration varies, sometimes significantly as in the case of stationary Stage II children. Since at this point, a definite pattern can not be shown for all young children it would be wise to allow children to explore spaces freely in the mode which they choose. Perhaps children should not be encouraged to maintain primarily a stationary position, for example in chairs, throughout table-top spatial activities.

3. Some activities might include exposing children to a movement experience during a playful spatial task. For instance, an array of objects might be arranged on a small floor space. Children might then locomote in variations around or through the array. A task could follow which includes "reorganizing" the objects in their original positions.

4. As suggested above, children's visual representational images cannot be assumed to follow a particular series or order of difficulty. Handing children puzzle pieces or other manipulative objects to assemble should be avoided.

5. Reliance on language stimulation during spatial activities might be limited considering that there is some evidence that the spatial processing mode is nonlinguistic in nature.

In conclusion, it is hoped that the preceeding discussion encourages further observation and exploration of children's spatial cognition.

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APPENDICES

APPENDIX A

Description of Computer Program (KIDSPACE; Fuhrer,1985)

The development of a computer program to assist in quantifying children's spatial representation of a viewed configuration (i.e. an array of 7 toys) was completed by Oregon State University programming consultant, Dave Fuhrer (KIDSPACE; Fuhrer, 1985). A computer software program was developed which computes "scores" for children's performances. Support for the development of this program was funded by a grant for the support of unsponsored research from the Oregon State University Computer Center, Corvallis, Oregon.

One specialized aspect of the study was the generation of computer randomized configurations for the stimulus model arrays. The randomization of these arrays protects against experimenter bias which might occur in placements arranged by the investigator (See Figures 4. and 5. for 80% reduced illustrations of array A and B).

Technically, the calculations for subjects' locations of objects in their response configurations make use of a mathematical polar coordinate system. In that system, X and Y coordinates locate each point on the plane, (i.e. the circular table-top display) in which a child subject has placed an object. These numerical

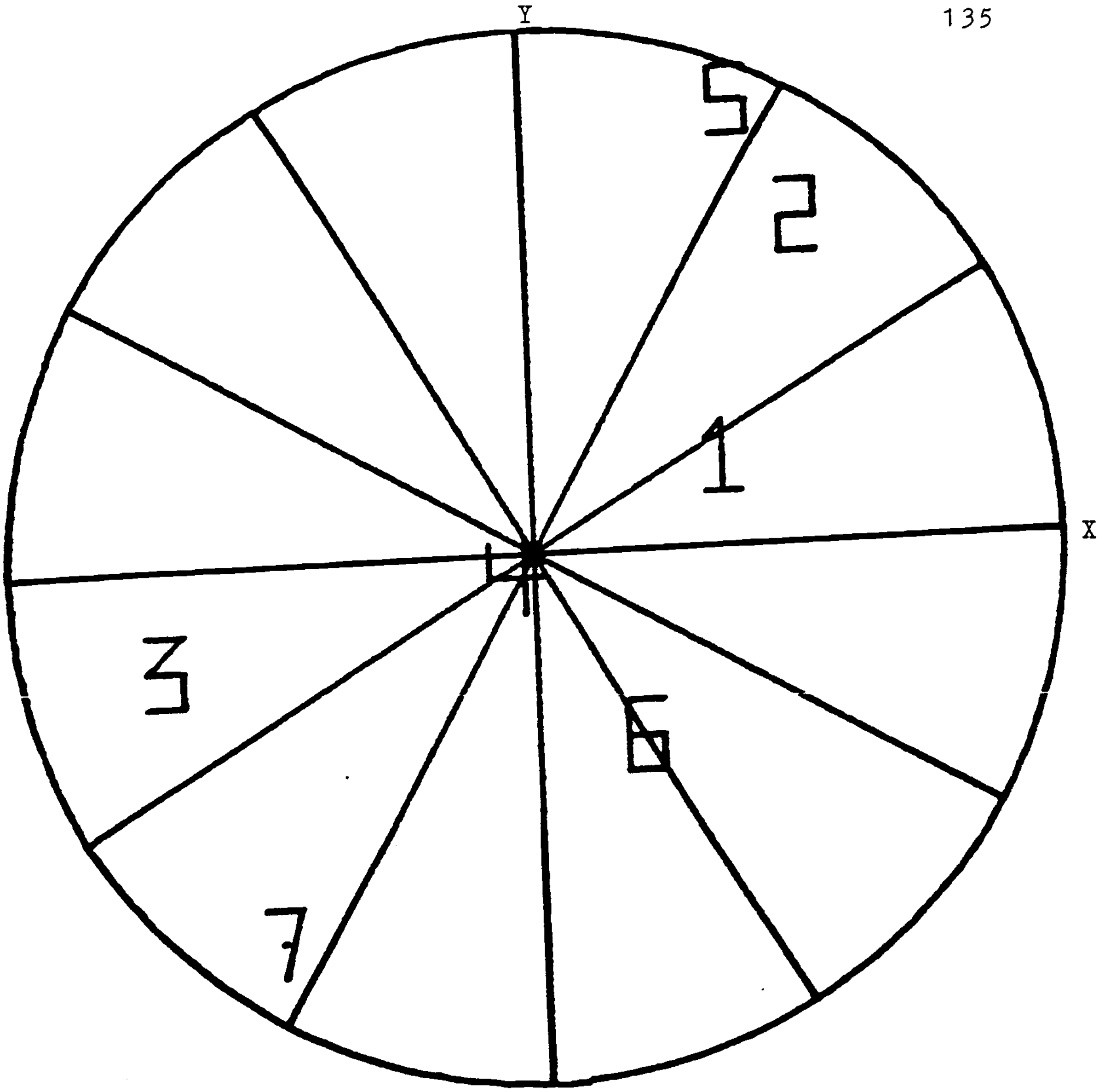


Figure 4. Computer randomized array (A). 80% reduction of actual tabletop array. Location of objects calculated from X and Y coordinate table shown below.

1	6	INCHES	25	DEGREES	X=	5.4	Y=	2.5
2	12	INCHES	50	DEGREES	X=	7.7	Y=	9.2
3	11	INCHES	195	DEGREES	X=	-10.6	Y=	-2.8
4	1	INCHES	220	DEGREES	X=	-.8	Y=	-.6
5	14	INCHES	65	DEGREES	X=	5.9	Y=	12.7
6	6	INCHES	300	DEGREES	X=	3.0	Y=	-5.2
7	13	INCHES	235	DEGREES	X=	-7.5	Y=	-10.6

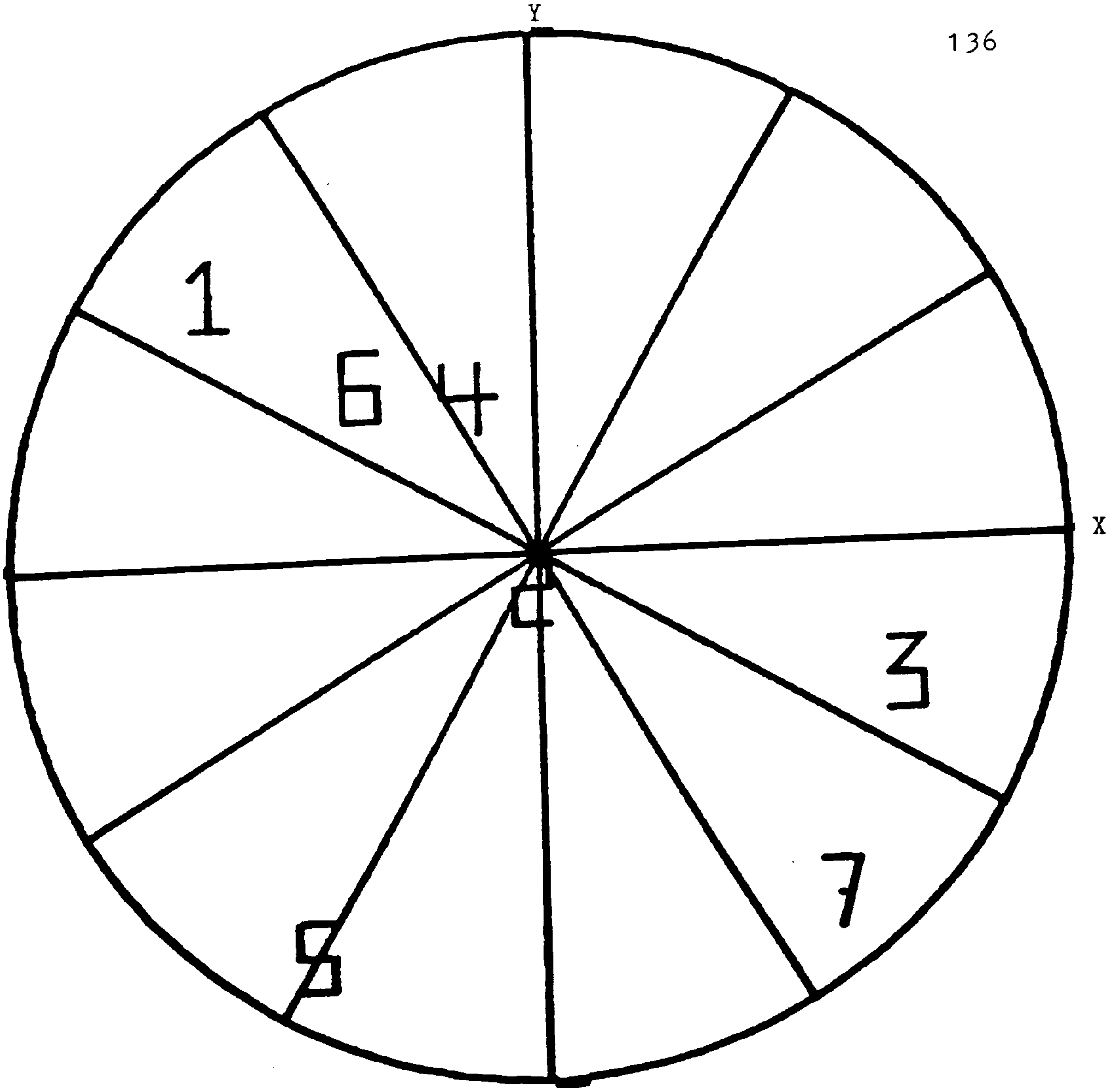


Figure 5. Computer randomized array (B). 80% reduction of actual tabletop array. Location of objects calculated from X and Y coordinate table shown below.

1	12	INCHES	140	DEGREES	X=	-9.2	Y=	7.7
2	1	INCHES	260	DEGREES	X=	-.2	Y=	-1.0
3	11	INCHES	340	DEGREES	X=	10.3	Y=	-3.8
4	5	INCHES	115	DEGREES	X=	-2.1	Y=	4.5
5	13	INCHES	240	DEGREES	X=	-6.5	Y=	-11.3
6	7	INCHES	135	DEGREES	X=	-4.9	Y=	5.0
7	13	INCHES	310	DEGREES	X=	8.3	Y=	-10.0

points are then compared to the points of the original model object locations to calculate differences and thus quantify scores for "displacement". These X and Y coordinates form radius vectors and further establish an angle with a fixed line. In addition to direct displacement of object locations in children's representations, computations for "relation" or an object's placement in comparison to adjacent objects and "order", or the rank distance from the center of the circular display are also parts of a subject's total measured spatial representation accuracy.

In detail, the descriptions of these measures are as follows (KIDSPACE; Fuhrer, 1985):

Displacement is the child's location for an object compared to the original location. Given the two X and Y coordinates, this is the linear distance between the two for each of the seven stimulus objects. A sum is then computed to quantify the total overall displacement of objects.

$$c = \sqrt{a^2 + b^2}$$

Relation is computed as a measurement to show the relative proximities of the child's placement of an object to each of the other objects' original locations. This is computed by calculating the differences in distance between the child's placement of an object and the actual original placement compared to (or in relation to) all other objects including itself. These seven delta distances are summed for each object.

Order is the ranked order from the center of the circle. This is computed by calculating the distance from the center (X=0, Y=0) for each object and ranking them from closest from center to farthest from center. The distance from the circle center is computed for each child's placements. The number of objects placed in correct ranked order is calculated as each subject's score for "order".
A sample subject's set of calculations for each score is

shown in Table 12..

Another distinctive feature of the computer program is the ability to create graphic depictions of each subject's spatial representations of the viewed configurations. For each subject two graphic illustrations depict the stationary and locomotive response configurations and superimpose these on the original encounter configurations. These graphics provide an efficient method to both view the subjects' configuration patterns and to visually compare performances under the two experimental conditions (See Figure 6. for a sample graphic illustration). This aspect of the computer program, KIDSPACE (Fuhrer, 1985) is defined as follows:

This subroutine (DRAWIT) draws a circle which represents a table top. Within this circle the actual original location of each of the seven objects are shown with the numbers 1 thru 7. The child's placements are indicated with a line drawn from the actual locations to the child's placement (red star).

Table 12. Set of Score Calculations

SUBJECT = S1 CODE = 1 S A J

DISPLACEMENT MEASURE

1	7.2	OL=(5.4, 2.5)	CP=(4.3, 9.6)
2	3.3	OL=(7.7, 9.2)	CP=(7.1, 6.0)
3	20.4	OL=(-10.6, -2.6)	CP=(9.3, 1.7)
4	10.6	OL=(-.6, -.6)	CP=(5.4, 6.0)
5	14.9	OL=(5.9, 12.7)	CP=(10.5, -1.5)
6	5.8	OL=(3.0, -5.2)	CP=(7.5, -1.5)
7	15.2	OL=(-7.5,-10.6)	CP=(6.6, -5.4)
----	------		
TOTAL	77.4		

ORDER MEASURE

ORIGINAL		CHILDS PLACEMENT	
4	1.0	6	7.6
1	8.0	7	8.7
6	6.0	2	9.3
3	11.0	3	9.5
2	12.0	4	9.7
7	13.0	1	10.5
5	14.0	5	10.6

SCORE = 2

RELATION MEASURE CP=CHILDS PLACEMENT, OL=ORIGINAL LOCATION

	CP 1	CP 2	CP 3	CP 4	CP 5	CP 6	CP 7
OL 1	7.2	2.4	1.3	3.1	4.1	4.1	5.5
OL 2	.2	3.3	3.6	1.3	10.3	9.6	9.5
OL 3	8.6	18.3	20.4	3.2	6.0	6.5	9.2
OL 4	.2	9.0	6.6	10.6	.7	1.6	1.9
OL 5	1.5	.3	1.1	.7	14.9	9.6	8.1
OL 6	.7	11.9	4.8	6.0	3.6	5.8	4.1
OL 7	11.1	21.6	9.6	.6	12.6	6.5	15.2
-----	-----	-----	-----	-----	-----	-----	-----
TOTAL	29.6	66.9	47.4	25.4	54.5	43.9	53.4

RELATION SCORE = 321.2

SUBJECT = S1 CODE = 2 L B K

DISPLACEMENT MEASURE

1	2.4	OL=(-9.2, 7.7)	CP=(-11.0, 6.1)
2	1.3	OL=(-.2, -1.0)	CP=(1.1, -.9)
3	3.3	OL=(10.3, -3.6)	CP=(12.5, -1.3)
4	15.6	OL=(-2.1, 4.5)	CP=(1.3,-10.9)
5	3.5	OL=(-6.5,-11.3)	CP=(-8.9, -6.7)
6	3.0	OL=(-4.9, 5.0)	CP=(-2.0, 5.9)
7	2.7	OL=(6.3,-10.0)	CP=(9.3, -7.5)
----	------		
TOTAL	32.1		

ORDER MEASURE

ORIGINAL		CHILDS PLACEMENT	
2	1.0	2	1.4
4	5.0	6	6.2
6	7.0	4	11.0
3	11.0	7	11.9
1	12.0	5	12.4
7	13.0	3	12.6
5	13.0	1	12.6

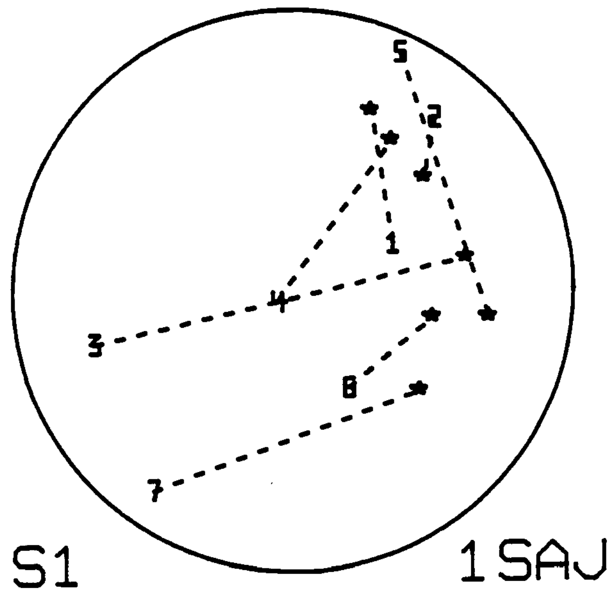
SCORE = 1

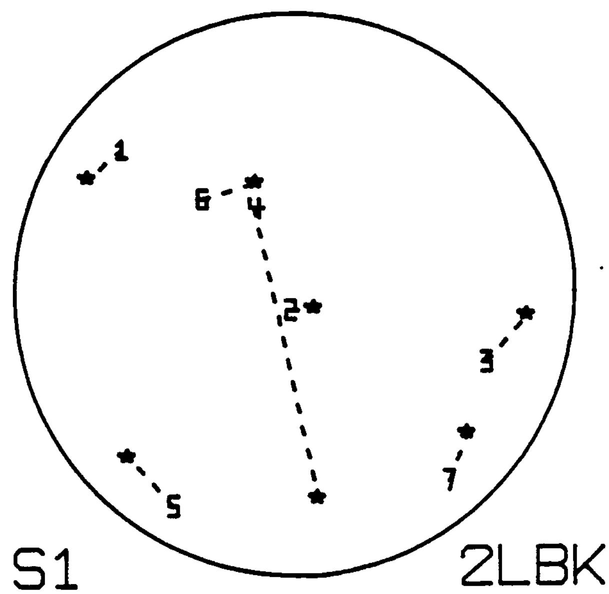
RELATION MEASURE CP=CHILDS PLACEMENT, OL=ORIGINAL LOCATION

	CP 1	CP 2	CP 3	CP 4	CP 5	CP 6	CP 7
OL 1	2.4	1.7	1.2	10.0	14.0	1.1	5.4
OL 2	2.1	1.3	1.3	9.9	4.0	1.6	4.8
OL 3	.9	1.8	3.3	6.3	.8	.1	1.6
OL 4	2.8	4.3	5.6	15.8	8.2	3.4	10.4
OL 5	17.6	3.4	1.0	.4	3.5	12.3	2.5
OL 6	2.3	5.6	5.0	12.6	11.2	3.0	9.4
OL 7	8.3	2.9	3.6	1.3	1.2	5.8	2.7
-----	-----	-----	-----	-----	-----	-----	-----
TOTAL	34.4	21.2	21.2	56.3	42.9	27.3	36.8

RELATION SCORE = 240.1

Figure 6. Spatial Representation Configuration Patterns





APPENDIX B

Stereognostic Recognition of Objects and Shapes Test

Laurendeau and Pinard's (1970) development of the Stereognostic Recognition of Objects and Shapes Test replicates Piaget's (Piaget & Inhelder, 1967) "haptic perception" task. Haptic perception involves the translation of tactile-kinesthetic perceptions into visual perceptions as well as constructing a visual image which incorporates the tactile data and the results of exploratory movements (Piaget & Inhelder, 1967). In Piaget's quest to trace the successive steps in the developmental process of conceptual space the effects of perceptual activity were examined. During the course of development the phenomenon of haptic perception becomes more sensitive and stage specific. Piaget's experiment in haptic perception was simply to present children with a number of objects or flat geometrical shapes to feel, then directing them to point out the object from a collection of visible objects. Piaget explains the results of these tests as follows:

> During the first stage, extending on an average up to 3; 6-4 years, one finds familiar objects more or less easily recognized, but not geometrical euclidean figures. During the second stage (4; 6-6 or 7 years) euclidean figures are progressively differentiated. (Piaget & Inhelder, 1967, p. 20).

These stages, initially recognized by Piaget, were subsequently verified through the more rigorous methodological framework of Laurendeau and Pinard's (1970) research. These researchers augmented Piaget and Inhelder's experiments by requiring a standardization of the materials and testing conditions, forming subject groups representative of the general population, considerably increasing the sample size (N=50 per age group) and analyzing the data statistically. The present study utilizes the test developed by these researchers in order to classify subjects according to their stage in the period of preoperational thought. The employment of this test is adapted to include the trials which are nonverbal and which eliminate the requirement of translation from actual objects to a pictorial display.

Table 13. summarizes the numerical criteria of successes required for classifying subjects in stage I or II (Laurendau & Pinard, 1970).

Table 13. Criteria for Assignment of Subjects' Stage

	Assigned Stage		
Section of the test	I	II	III
1. Common objects	3-11	8-11	8-11
2. Abstract shapes (set 1)	0-4	5-12	9-12
3. Abstract shapes (set 2)	0-6	0-6	7-12

Presentation of the Test

Materials

Materials in each section of the test differ in regard to the complexity of each shape. Section 1 consists of 11 pairs of common household familiar objects (eg. comb, key, etc.). Section 2 consists of pairs of the first series of nonpliable foamboard shapes which are distinguished from each other by topological (i.e. form) or Euclidian (i.e. metric) characteristics. Section 3, included to distinguish stage II children from the more advanced stage III (operational period of thought), consists of the second series of geometric shapes with Euclidian characteristics. Figure 7. shown below illustrates the shapes utilized by Laurendeau and Pinard (1970).

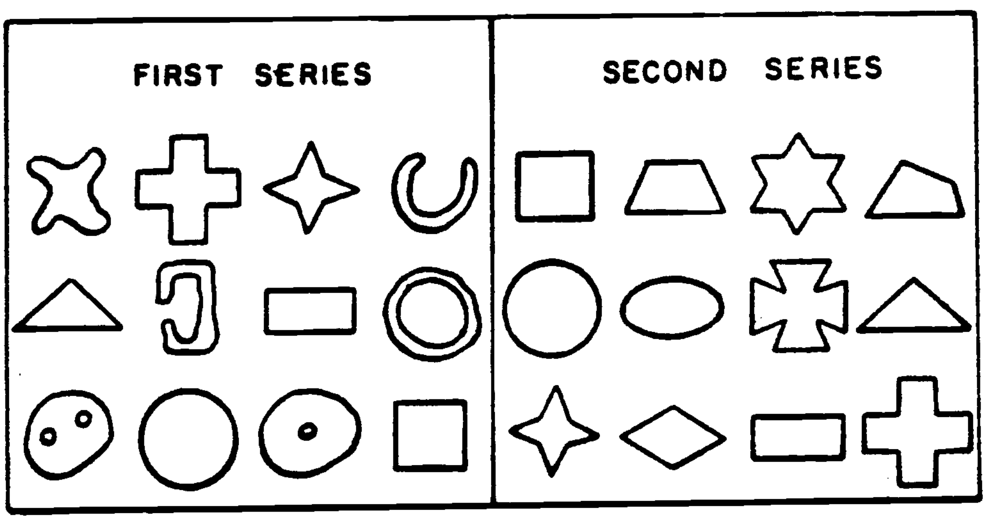


Figure 7. Shapes used in Stereognostic Recognition of Objects and Shapes Test. Actual dimensions are proportional to the circle, diameter: 7.5 cm.

Each section of the test requires a screen to occlude the vision of the child subjects. The screen is a rectangular piece of cardboard (28 X 36 cm.) held in place by a plexiglas holder. During the test this screen is placed between the subject and the examiner. Another examiner notes each subject's responses and records these on the data sheet shown in Table 14.

Instructions

The screen is placed vertically on the table in front of the child. Objects in each section are glued to a display board. The examiner says:

> We're going to play a game with this. Listen carefully, you must stay behind it and you must not look. You just have to put your hands on the other side, like this [the child's hands are placed behind the screen]. You see, I have put all of this on the table. I am going to put things in your hands and then you are going to show me things just like them on the table. You are only going to touch them, you are going to tell what they are only by touching them with your hands; then you are going to show me the ones just like them on the table.

Section 1

Examiner puts the comb in the child's hands and says:

> Okay, take this in your hands, don't look, and try to find the same thing on the table as you have in your hands. Is there something just the same on the table? Where is it? Point to it with your finger.

Examiner removes the object and keeps it hidden.

Section 2 and 3 proceed in the same way as section 1.

Table 14. Data Sheet for Sterognostic Recognition of Objects and Shapes Test

ITEMS	Subjects							
SECTION 1								
1. comb								
2. penny								
3. pencil								
4. glass								
5. button								
6. key								
7. ball								
8. scissors								
9. safety pin								
10. spoon								
11. wooden block								
SECTION 2								
1. square								
2. open rectangle								
3. closed ring								
4. triangle								
5. disk (2 holes)								
6. open ring								
7. 4-cornered star								
8. disk (center hole)								
9. irregular cross								
10. rectangle								
11. circle								
12. Greek cross								
SECTION 3								
1. circle								
2. triangle								
3. square								
4. Maltese cross								
5. rectangle								
6. 6-cornered star								
7. trapezoid								
8. Greek cross								
9. ellipse								
10. 4-cornered star								
11. rhombus								
12. irregular quadrilateral								

APPENDIX C

Consent Forms

Parent Consent Form

Dear Parent,

I am studying the ways in which young children remember or store information about the space surrounding them. In my study, children will be shown a group of toys arranged on a table, then they will be given a set of the same toys to arrange in the same manner on another table. Children will play this game two times. During one time children will stand on a set of paper footprints and look at the array for one minute, then arrange the toys themselves as they remember or "picture" their placements. During another time, they will walk around the table of toys for one minute, then again arrange the toys as they "picture" them.

I am studying two age groups of children, those under 4 years of age and those over 4 years. Because children are developmentally different at these ages, I will play a game with all children prior to the study to determine their "stage" of development. This game simply consists of having children match objects and shapes by handling these behind a screen and then pointing to duplicate objects presented in front of the screen.

I would greatly appreciate your child's participation in this study.

Thank-you for your cooperation,
Stephanie A. Kozick
Ph.D. Candidate, Oregon State University

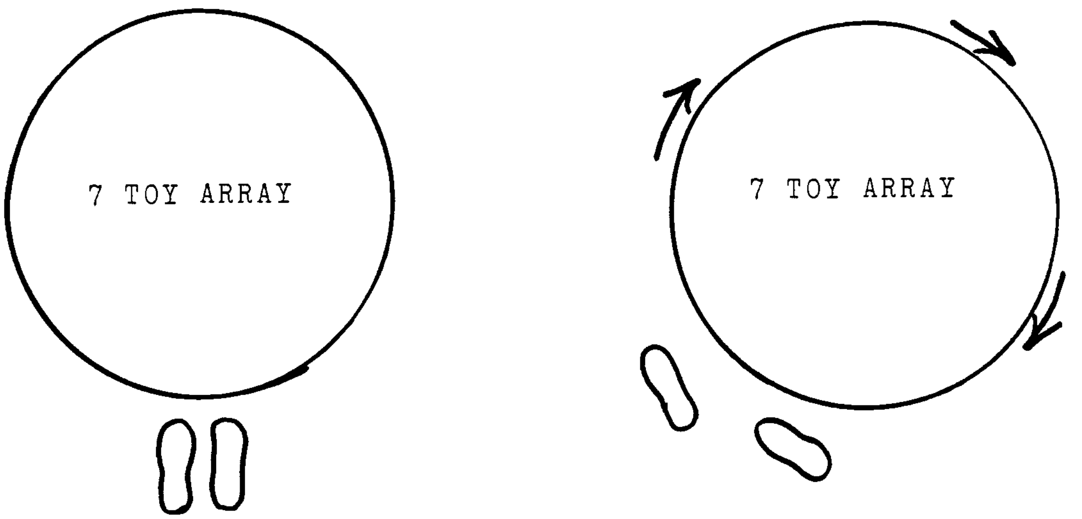
Child's Name ____

Parent Signature_______________________Date_________

Sample Space Game

Standing

Walking



Information and Consent Form

Research in children's cognitive functioning is a fascinating endeavor. One area of children's cognition or thinking is the way in which young children store information about the space surrounding them. I am proposing a research study to explore the relationship between spatial awareness and children's movement. Specifically, the study will involve assessing how a group of about 40 children between the ages of three and five remember or "picture" a group of previously seen toys arranged on a table. In one condition the children will be viewing the table of toys from a stationary position; in another condition, they will move around the table as they view the toys. My hypothesis is that children will remember more of what they saw in the movement condition. I am requesting that the children at your center or school serve as subjects in this study. If this is practical in your setting, I will provide the "game", instruct the children individually, and obtain prior approval from each participating child's parent. Thank you for your consideration.

Stephanie A. Kozick
Ph.D Candidate
Oregon State University

I consent to the children at this center or school participating in this study.

Signature of Director/Principal_____________________

Name of Center/School______________________________

Address____

____

Number of children enrolled 3 years old______________

Number of children enrolled 4 years old______________

Number of children enrolled 5 years old______________