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THE COMPREHENSION AND USE OF
PROJECTIVE SPACE SEMANTIC RELATIONS
DURING MIDDLE CHILDHOOD AND
PREADOLESCENCE: IMPLICATIONS FOR
THE ACQUISITION OF SPOKEN AND
WRITTEN LANGUAGE.

City University of New York, Ph.D.,
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1976

**THE COMPREHENSION AND USE OF PROJECTIVE SPACE
SEMANTIC RELATIONS DURING MIDDLE CHILDHOOD
AND PREADOLESCENCE: IMPLICATIONS FOR THE
ACQUISITION OF SPOKEN AND WRITTEN LANGUAGE**

by

ELAINE R. SILLIMAN

**A dissertation submitted to the Graduate
Faculty in Speech and Hearing Sciences
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1976

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CHAPTER I

STATEMENT OF THE PROBLEM

In 1908, a pioneer American psychologist, Edmund Burke Huey, wrote a classic book entitled The Psychology and Pedagogy of Reading (Huey, 1968). From his introspective experiments on reading with adults, Huey noted that when prepositions were encountered in the text, unlike other "little words," their presence frequently evoked the formation of visual images which functioned to convey meaning relating orientation of self to objects. Sixty-eight years later, Huey's description of still unexplained mental events, the reading process and its relationship to the formation of visual images, remains pertinent to the question of the nature of the correspondences existing between the visual-spatial system, the relationship of these correspondences to the definition of a learning disability, and the role of semantic relations in the set of behaviors described as a learning disability.

Traditional Approaches to the Problem

The Development of Perception of Three-Dimensional Space

Current accounts of spatial knowledge generally attribute the source of that knowledge to an active internal process by which the perceiver comes to "know" his environment in terms of the structured features of the environment to which he attends (Gibson, 1969; H. Clark, 1973; Kaufman, 1974; Arnheim, 1974). Within this model, then, it is the physical world which is structured for the perceiver on the basis of his perception of the structural equivalences among features. It follows that the primary function of the "knower's" perceptual organization is to detect environmental regularities or patterns, not to provide the structure for what would then be an unstructured world. According to Gibson (1969), perceptual learning functions adaptively, providing the child with a continuous means of modifying his perceptions in order to increase the correspondence between "the events and objects that are sources of stimulation as well as an increase in the capacity to utilize potential stimulation (Gibson, 1969, pp. 3-4)."

That the perception of space is a visual event which has biological, physiological, and psychological correlates has long been a matter for scientific inquiry (Lashley, 1961; Kaufman, 1974). But how

the child comes to perceive that space has length, width, and volume is not well understood. One attempt to explain the psychological aspects of child concepts of space has been proposed by H. Clark (1973). Clark surmises that the three psychological categories of space (length, width, and volume) originate in the constraints imposed by man's sense organs or perceptual apparatus. Because of these constraints, for example, his binocular vision and upright position which are thought to provide "optimal conditions for perceiving (Clark, 1973, p. 34)," three reference points become naturally defined: (1) one vertical plane of perceptual symmetry which separates left from right (which Clark views as a natural consequence of the bilaterally symmetrical sense organs); (2) one vertical plane of perceptual assymetry separating the front-back axis; and (3) one horizontal plane of perceptual assymetry, the natural ground level plane of reference, where objects perpendicular to ground level, that is, above ground level, are characteristically heard, seen, etc.

Since these reference points are natural, they lend themselves to formalization by means of a Cartesian coordinate or reference system: (1) in a uni-dimensional space, location is most easily defined as a directed distance from a zero reference point; (2) in bi-dimensional (Euclidean) space, location can now be specified with several reference points and several distances according to x and y axes of reference,

that is, length and width; (3) tridimensional space means that location can be specified by directed distance away from the three possible reference planes (x = length, y = width, z = volume (Clark, 1973, p. 32). Thus, spatial operations ultimately define directionality because of their function in coordinating the location of objects according to a system of reference points (one-dimensional), reference lines (two-dimensional), and reference planes (three-dimensional). Practically, the existence of these spatial invariants means that any object can be located in terms of distance up, for example, from a floor (x, y plane), distance into a room from a left side wall (y, z plane) (Clark, 1973, p. 32). Extending this analysis to the semantic structure of English spatial terms, Clark (1973) states that all prepositions serve as a reference location for locating other objects and, therefore, require a notion of 'point of reference (Clark, 1973, p. 36)' based on previous definitions of perceptual space.

Traditional explanations for how the child organizes and semantically encodes the three dimensions of space appear limited because of three theoretical restrictions. First, space is usually defined in terms of its Euclidean (linear) dimensions or in terms of the Cartesian axioms by which objects can be located. However, Euclidean space, while necessary for determining object location, remains insufficient as a full account since, as Kaufman (1974)

has noted "we move about in the world and do not view it always from a stationary position (Kaufman, 1974, p. 233)." Thus, a full account of spatial organization would have to include how the child acquires not only the Euclidean coordinates but also a system of perspective in order to operate on changes in relative position according to changes in his viewpoint.

Secondly, the "perceived" space model has not explained how the child reorganizes his perceptual notions of space into conceptual notions. The spatial "visualization" of simple geometric forms, for example, copying a circle or drawing a vertical line, appears to emerge in the early preschool years (Terman and Merrill, 1960) but "Little is known concerning the role that spatial-visual imagery plays in mature complex thought... (Maccoby and Jacklin, 1974, p. 64)." Furthermore, the fact that straight lines, circles, and angles are not found in pure form in the physical world (Page, 1959) would imply that the child must have a representation, or mental image, of those entities for which tangible, or perceivable, referents are unavailable.

Finally, Clark's (1973) model for the perceptual origin of English prepositions is correct in assuming that comprehension and use of particular prepositional categories presupposes prior knowledge about the three dimensions of space and the relationship of motion, or directionality, to defining position. However, he admits that Euclidean

explanations for such relational terms as "in front of-in back of," "beside," and "above-below" are unsatisfactory because their use is "complicated" due to the interpolation of self as the primary point of reference. In other words, relational terms cannot be explained solely on the basis of a Cartesian framework in terms of the intrinsic features of the target objects because, in these instances, the nature of the relationship between the subject's point of view and the objects relation to each other defines the meaning of the term.

Perceived Space and Learning Disability

Since the 1930's when Monroe (1932) and S. Orton (1937) first described a causal relationship among spatial disorientation, speech defects, laterality effects, and failure to read in the child with normal intellectual potential, the search for underlying causes has concentrated on two general but interrelated lines of inquiry: (1) the functional dependencies existing between the development of visual form perception and certain kinds of spatial abilities, the latter usually considered as a set of independent abilities (Maccoby and Jacklin, 1974) prone to selective disruption (Chalfant and Scheffelin, 1969) and usually tested by means of two-dimensional pencil and paper tasks (Koppitz, 1964, 1975; Frostig, 1966; Beery, 1967; Boehm, 1971) and (2) the issues of language lateralization and language processing (Harris, 1957; Zangwill, 1962,

1975; Myklebust, 1973; Semel and Wiig, 1975; Stark, 1975; Wepman, 1975). Despite the diversity of clinical and educational studies, two serious problems exist currently in defining the meaning of a learning disability. The first problem concerns who is learning disabled while the second involves how the learning disabled are defined empirically.

Definition of learning disability

The general description of a learning disability is an exclusive one in that it applies only to children with at least average intellectual potential (Clements, 1966; Wender, 1971). By definition, specific neurological impairment, for example, cerebral palsy, mental retardation, sensory handicap, would not qualify for inclusion under the learning disability rubric unless it could be demonstrated that the primary handicapping condition failed to explain the nature of the child's learning difficulties.

As defined currently, a learning disability is usually considered as synonymous with reading failure or dyslexia (Sapir and Nitzburg; 1973, Critchley, 1975; Vogel, 1975). In the past several years, the meaning of a learning disability has taken on a particular definition, the "language-based" definition. Underlying the assumption that a learning disability is language-based is the premise that dyslexia is a principle symptom of a failure to process systematically oral language (Stark, 1975; Vogel, 1975; Semel and Wiig, 1975). A natural consequence

of this premise is the conclusion that disorders of spoken and written language are synonymous.

The problem of defining who is learning disabled cannot be dissociated from how learning disabilities are tested. Studies on the learning disabled child have tended to select their learning disabled sample using a combination of testing measures including performance on tests of reading achievement, verbal and non-verbal intellectual ability, psycholinguistic ability, auditory and visual perceptual functioning, visual-motor integration, and sentence repetition and comprehension (Kinsbourne and Warrington, 1966; DeHirsch, Jansky, and Langford, 1966; Klasen, 1972; Myklebust, 1973; Morency and Wepman, 1973; Wiig and Semel, 1973; Semel and Wiig, 1975; Vogel, 1975). However, these studies leave unclear whether their learning disabled sample actually presented a disturbance of spoken language. In fact, it appears that a disturbance of spoken syntax was not a primary criterion by which subjects were selected initially (e. g. , Kinsbourne and Warrington, 1966; Morency and Wepman, 1973; Wiig and Semel, 1973; Semel and Wiig, 1975; Vogel, 1975). If, as I. Liberman has commented "the spoken language of the child is 'generally good' (I. Liberman, 1970, p. 60)," then the criteria by which disorders of spoken and written language are considered synonymous are in doubt.

Another problem in the empirical definition of a learning dis-

abled sample involves differentiating between the truly dyslexic child and the slow reader (Elkind, 1975). Since standardized measures of reading achievement are defined as relative rather than absolute measures (Malmquist, 1958; Newbrough and Kelly, 1962; Dechant, 1968), use of such measures would predict that in a theoretically random sample some children would always fall "at the bottom." As Malmquist (1958) has pointed out, there is no qualitative criteria available to distinguish the "poor" reader from the dyslexic.

A third problem of empirical definition stems from the nature of the testing medium. Pictorial representation is used commonly as material for the eliciting of both verbal and non-verbal responses. Regardless of whether test content is designed to measure visual perceptual ability, visual-motor integration, or the ability to comprehend and produce specific syntactic structures, the graphic representation of space is an obligatory property of such testing material. As a consequence, it becomes unclear whether poor performance can be attributed to a failure to process the syntactic and semantic structure of the verbal instructions, an ability to integrate visual with motor modes to reproduce geometric forms, a deficit in visually perceiving the "gestalt" of the picture, or a problem in systematically reconstructing knowledge of a three-dimensional system of reference in a two-dimensional medium such as pictorial space. The latter has been seldom

considered as a variable in the testing behavior of either normal or learning disabled children (Schafer, Hellig, and Rubin, 1974).

Measuring perceived space by the use of
two-dimensional drawings

The linear plane is represented graphically by means of a redundant set of pictorial depth cues. Kaufman (1974) identifies two major categories of pictorial cues, Euclidean and non-Euclidean cues. The Euclidean cues, which have physiological correlates, are perspective and familiar size. According to Kaufman (1974), perspective, the most important cue to the pictorial representation of two-dimensional space, is represented by the convergence of parallel lines with the vanishing point at the horizon, and is a product of Euclid's constant object law, that is, a constant object of invariant linear size will have an angular size inversely proportional to its distance from the eye. The closer the object the larger its size. Conversely, the farther the object, the smaller it will appear.

Familiar size has both absolute and relative properties. Absolute distance, the relationship of the observer to the object, is defined as the distance between the observer and an object with the observer at point zero and objects located at specific linear distances from point zero. In contrast, relative distance, the relationship of object to object, becomes the distance between objects independent of the distance from

the observer to any one of the objects. Again, an inverse relation holds. As the retinal image becomes smaller, the observer judges distance as relatively greater.

Non-Euclidean cues are defined by Kaufman (1974) as aerial perspective (a distance cue important pictorially but not physiologically), relative brightness, light and shade, and superimposition, a critical cue for tridimensional representation. Arnheim (1974) cites the importance of superimposition, or overlap, as a pictorial depth cue because "As long as the contours touch or cross but do not interrupt one another the spatial effect is absent or weak (Arnheim, 1974, p. 248)."

In summary, the Euclidean cues function graphically to provide redundant information about relative distance on a terrain (Kaufman, 1974) while the non-Euclidean overlap cue, which also shows the "figure-ground" relationship, is important for the pictorial representation of three-dimensionality. Perspective, as a linear or perceptual cue, appears essential to establishing a correspondence between the content of the picture and the observer since it functions to make "the picture's central axis coincide with the viewer's line of sight (Arnheim, 1974, p. 294)."

That perspective as a depth cue in children's drawings is an event of late middle childhood has been recognized (Piaget and Inhelder,

1967; Arnheim, 1974). Furthermore, the acquisition of pictorial depth cues appears to be developmentally ordered, that is, the overlap cue becomes useable in interpreting pictorial content earlier than perspective (familiar size being an obligatory cue in any picture in which objects are depicted in connection with each other). The most extensive work on the acquisition of pictorial depth cues has been conducted by Hudson (1960, 1967), Mundy-Castle (1966), and Deregowski (1972) with African adults and children. However, with the exception of Deregowski (1972) few investigators have made the distinction between perspective as a perceptual depth cue and perspective as a conceptual relation which has as its referent the invariance of object position despite the changing viewpoint of the observer. In other words, conventional pictorial depth cues are external cues which provide information about surface relations such as relative distance; however, understanding that one object is "in front of" another would seem dependent not only on relative distance cues but also on the observer's viewpoint, or perspective, of the objects relationship to each other. In such cases, the child would need to coordinate both external and internal relationships.

This aspect of the graphic representation of space has not been investigated in either normal or learning disabled children.

An Alternate Approach to the Problem

The Development of Conceived Space

In contrast to the definition of perception as the process through which the perceiver inducts regular features of the environment, Piaget (1955, 1963, 1969) and Inhelder and Piaget (1969) have proposed that action, rather than perception, functions as the mediator between "what is known" and "how it is known." In this model, perceptual functions are continuously modified and reorganized by cognitive functions. It follows that while perceptions are necessary for the construction of such cognitive operations as spatial operations they are not sufficiently explanatory to account for the latter because it is surmised that the child does not perceive objects and actions independently, that is, "he perceives objects as things which are modified or are capable of being modified by his own actions (Inhelder and Piaget, 1969, p. 13)." In the Piagetian framework, then, perception cannot be the source of knowledge because its sole function is to serve as "signals" which enter into the construction of mental operations.

For Piaget and Inhelder (1967), visual perception, while necessary, remains insufficient in explaining how the child constructs what they term as a conceived space. According to them, space cannot be understood as the perception of a container in which objects are located

but as a conception of the relationships which hold among the contents of the container. They propose (Piaget and Inhelder, 1967) that the cognitive attainment of a three-dimensional system of spatial perspectives and Euclidean coordinates evolves from a mental representation of space progressively constructed by the child over the first eleven to twelve years of life.

In the organization of a perspective and Euclidean reference system, Piaget and Inhelder (1967) claim that topological relationships, which are essentially perceptual, function as prerequisites to the more complex three-dimensional structure. Topological relations pertain only to the internal spatial relations of a single object and, unlike perspective and Euclidean relations, they remain independent of transformation of shape because they do not involve conservation of straight lines, angles, curves, or distances. Thus, the only relationship topology is capable of establishing is that of structural equivalence, the major reason why topological relations are incapable of providing a comprehensive system of spatial reference in the locating and relating of different objects.

The system of spatial perspectives derives from what is described as a projective space. By projective space, Piaget and Inhelder (1967) mean that the child becomes aware of not only his own viewpoint but also the simultaneous awareness of the theoretical possibilities

for multiple viewpoints (perspectives) according to whether objects can be located in a relation of before to behind, left to right, and above to below--the three developmentally ordered projective relations corresponding to notions of length, width, and volume.

Implications for a Definition of Learning Disability

In place of traditional approaches to defining a learning disability, an alternate approach is to explore the manner in which a child with a learning disability constructs a representational spatial structure and the manner in which he uses words that refer to aspects of such a conceptual space. While traditional formulations have identified certain behavioral disturbances in the learning disabled child's use of space, they have failed to specify how this particular child organizes space and how this organization is itself reorganized over time perceptually, cognitively, and linguistically. If such differences in manner of organization do exist, then there is the implication that these differences may be described as qualitative. Moreover, qualitative differences suggest alternate criteria for considering disorders of spoken and written language as synonymous, particularly in the case of the child whose spoken language appears superficially intact.

Few studies have explored the acquisition of spatial knowledge

as a three-dimensional system of spatial coordinates and perspectives in the child with either a disorder of spoken or written language. Scattered throughout the literature are largely anecdotal reports that children with reading problems (but not a communication disorder) tend to have more difficulty with comprehension of terms which refer specifically to relative position or changes in perspective according to the subject's point of view, for example, "in front of," "behind," "left," "right," "above" and "below" (Kalinski, 1962; Frostig and Horne, 1964; J. Orton, 1966; De Hirsch, Jansky, and Langford, 1966; Wiig and Semel, 1973; Semel and Wiig, 1975). However, there has been little systematic attempt to relate these comprehension findings to the development of a system of conceptual spatial perspectives.

Purpose of the Study and Hypotheses

Purpose

The purpose of this investigation was to study the construction of a three-dimensional system of spatial perspectives in elementary school-age children in Grades 1 to 4 presenting difficulties in reading at expected levels of achievement. Specifically, the investigation was designed to evaluate how a randomly selected group of "poor" readers differed from their peers who were defined as "achieving" readers in (a) their organization and application of a three-dimensional projective

space structure within both the three-dimensional and two-dimensional mediums of representation and (b) their comprehension and spontaneous production of relational terms which encode projective space in both the three-dimensional and two-dimensional mediums.

Hypotheses

It is a reasonable supposition that prior to the time children "learn to read", they have begun to organize three-dimensional space systematically in terms of their own relationship to objects (Meyer, 1940; Piaget and Inhelder, 1967; Laurendeau and Pinard, 1970; Brown, 1973; E. Clark, 1973a, Kuczaj and Maratos, 1974). What is less well understood is the degree to which preschool and elementary age children can interpret projective spatial relations and their lexical counterparts in a two-dimensional medium such as pictorial representation. Although several studies have demonstrated the importance of exposure to pictorial material in the acquisition of early reading skill (for example, most recently, C. Chomsky, 1972 a; Briggs and Elkind, 1973; Gibson and Levin, 1975), little is known about how children encode pictorial representations in which relative position, as opposed to simple object identification, functions as the crucial variable. Furthermore, since the pictorial medium serves as a major method for instructional and assessment purposes, the child dependent upon a more elementary spatial strategy

for pictorial interpretation would appear to be at a distinct disadvantage within both the classroom and clinical setting.

Four hypotheses were predicated on an assumed conceptual relationship between organization of three-dimensional and two-dimensional projective space. Three hypotheses pertain to the normal developmental sequence in the structuring of projective relations in two-dimensional space while the fourth hypothesis concerns the nature of spatial organization in children who present academic learning difficulties.

Hypothesis 1

Previous research on the organization of a three-dimensional projective spatial structure (Elkind, 1961; Piaget and Inhelder, 1967; Laurendeau and Pinard, 1970) has indicated an invariant order of acquisition for the three projective relations. The before-behind relation emerges prior to the left-right relation while the above-below relation remains the most cognitively complex.

It was predicted that when pictorial space was used as the medium of representation, the three projective semantic relations would follow the same invariant sequence. "In front of-in back of" (before-behind relation) would be mastered before "left-right" and "to the left (right) of" (left-right relation) while comprehension of "closer to" (above-below relation) would be the most difficult.

It was predicted also that comprehension of the topological terms "closer to you," "looking at," and "pointing at," which refer to the surface relationship between self and an object or of one object to another in terms of their proximity, would be easier to comprehend in the pictorial medium than the projective terms.

Finally, the prediction was made that poor readers would manifest greater difficulty than good readers in the comprehension of the three topological and projective semantic relations in the context of two-dimensional (pictorial) space.

Hypothesis 2

Research on the developmental order of acquisition of the conventional pictorial perceptual relative distance and depth cues (Hudson, 1960, 1967; Mundy-Castle, 1966; Deregowski, 1972) has found that African children are first able to interpret the pictorial representation of familiar size followed by the overlap cue while perspective is mastered the latest.

It was predicted that American children in Grades 1 to 4 would follow a similar developmental progression in the recognition of pictorial depth cues: interpretation of overlap cues should precede interpretation of the perceptual perspective cue. Furthermore, in view of the redundancy feature of the pictorial cues, it was

predicted that when familiar size was presented as the sole cue for estimating relative distance, it would prove to be the most difficult cue to interpret. Conversely, inclusion of all three cues--familiar size, overlap, and perspective--should facilitate pictorial interpretation.

The final prediction was made that, when alteration of conceptual perspective was introduced as a factor in the interpretation of pictorial content, the presence of depth cues would not be sufficient to encode the picture.

Hypothesis 3

Except at high and low extremes, IQ as an individual variation, should be unrelated to the invariant sequence of acquisition of the three projective semantic relations in pictorial space.

Hypothesis 4

Based upon their performance on the comprehension of the three projective semantic relations when presented in the pictorial space medium, it was predicted that elementary school-age poor readers in normal classroom placement would produce performance patterns indicative of significant qualitative differences on tasks pertaining to the assessment of:

1. The sequence of emergence of the three projective relations in three-dimensional and two-dimensional space.
2. The understanding of projective spatial relations in structuring a three-dimensional projective space.
3. The use of projective semantic relations in the verbal encoding of relative spatial reference in three-dimensional and two-dimensional mediums.

CHAPTER II

REVIEW OF THE LITERATURE

The review of the literature is divided into three major sections.

The first section summarizes cognitive and linguistic prerequisites for the normal acquisition of written language.

The focus of the second section is on a review of two approaches to the traditional study of disorders of written language: visual perceptual deficits and language lateralization and processing limitations.

The final section emphasizes an alternate approach to the study of disorders of written language, the representational space model, and examines the psychological reality of the model in the context of both normal and abnormal development. Lastly, the effect of the two-dimensional medium on the comprehension and use of projective spatial relations is reviewed.

Developmental Prerequisites for the Acquisition of Written Language

In the past several years, many investigators have recognized that the acquisition of reading and writing is dependent upon certain

cognitive processes (Lieberman, 1970; Elkind, 1974, 1975; Limber, 1974; Gibson and Levin, 1975; Wepman, 1975; Stark, 1975; Smith, 1975). According to Gibson (1975), only within the last ten years can reading research be characterized as "theory-based" with respect to "a psychological analysis of cognitive development in general and of the processes involved in learning to read in particular (Gibson, 1975, p. 288)."

While acceptance may exist that the capacity to acquire written language evolves from the progressive development of cognitive functions, what remains less well defined is the nature and the priority of specific prerequisites. As Limber (1974) notes, reading and writing involve a complicated set of coordinated activities that simultaneously include controlled hand and eye movement as well as cognitive and linguistic analyses of the linearly represented conventional graphic symbols. Furthermore, written language can probably be understood as a more complex level of the semantic, syntactic, and phonological aspects of spoken language since written language seems to offer a new method of operating upon spoken language (Ajuriaguerra and Auzias, 1975). Although, intuitively, spoken and written language appear to share similar constituent elements in terms of grammatical structure, the exact developmental relationship between the two symbolic communication systems and their dependence on, or independence from, the

more general cognitive system remains unclarified. What follows is a brief summary of current assumptions about the nature of the cognitive and linguistic prerequisites for the acquisition of written language.

Cognitive Prerequisites

In viewing reading as "a highly complex cognitive process involving much more than perceptual skill (Gibson and Levin, 1975, p. 11)," Gibson and Levin have specified five organizational strategies which the child must be capable of using in order to effectively operate on written language.

The first strategy permits the child to anticipate relevant features, for example, the "distinctive features" which are said to differentiate among graphemic shapes (Gibson, Gibson, Pick, and Osser, 1962). The second strategy pertains to the ability to search effectively for a desired target, a strategy involving the systematic visual scanning of a two-dimensional medium. The application of this strategy implies that notions of dimensionality (e.g., top-bottom, left-right) must be available. Third, the child must be capable of organizing and using simple structural relations holding among classes of objects, a strategy demanding the ability to utilize class membership. Fourth, effective strategies for problem-solving with verbal material, which has as its precondition knowledge of words, are

necessary. Lastly, the child must be capable of using effective strategies for "intentional remembering" in order to organize material for recall and to search for meaningful relations in what has to be remembered.

Gibson and Levin term the first three strategies skills basic to the beginning stages of reading, skills which appear to emerge between the ages of four to seven, while the last two strategies, which seem to pertain more to comprehension of written material, are products of late middle childhood.

By contrast, Elkind (1974, 1975) argues that in order for the child to achieve use of the Gibson and Levin basic strategies, he must be first capable of thinking about the relations which hold among classes of objects. In other words, he must initially provide evidence that he has attained the stage of concrete operational thinking (Inhelder and Piaget, 1969).

Elkind also distinguishes between the prerequisites needed for beginning reading and those necessary for advanced reading. In terms of the conceptual obstacles presented by beginning reading, Elkind (1975) states that the concept of grapheme is more complicated than the concept of a number. Like number, the grapheme has an ordinal property, its position in the alphabet, and a cardinal property, its name (A, B, C) which is shared with all the other graphemes of the

same name (for example, all B's are B). Unlike number, the grapheme has phonemic contextual properties, that is, one grapheme can stand for one or more sounds and one phoneme can be represented by different graphemes. Therefore, to understand the properties of graphemes, the child must be capable of mapping between phonemes and graphemes through use of combinatorial operations, the latter involving knowledge of classes and relations between classes. The Elkind thesis is buttressed by findings (Briggs and Elkind, 1974) that early readers are distinguished from non-early readers by virtue of the fact that they attain operational thinking at a faster rate than their peers.

Despite the different theoretical orientations of Gibson and Levin and Elkind, it seems a viable assumption that the capacity to systematically map invariant relations is a cognitive priority for beginning reading.

Linguistic Prerequisites

It is clear that by the time the child enters school, he has developed a relatively sophisticated use of the semantic, syntactic, and phonological aspects of spoken language. Because he can be considered a mature language user, traditional reading approaches have erroneously assumed that the formal teaching of reading involves only the decoding of the symbols of written language to sound (Aukerman, 1971). Gibson and Levin (1975) and Smith (1975) both agree that such a conception is an over-

simplification. "The argument is not whether written language can (author's italics) be decoded into speech, which is obviously the case, but whether such decoding is necessary for comprehension (Smith, 1975, p. 348)." Given the argument that the mapping of phonemes onto their graphemic correspondences fails to account sufficiently for how written language is acquired, the issue of developmental priorities for the comprehension of printed text has been addressed primarily in the context of possible hypotheses and strategies underlying the child's processing of speech.

The role of the developmentally ordered abilities to explicitly segment syllables and phonemes as a precursor to beginning reading acquisition has been explored by I. Liberman (1970, 1973) and I. Liberman, Shankweiler, Carter, and Fisher (1974). On the basis of research findings in speech perception which has specified the relationship between the acoustic signal and the phonetic message (Studdert-Kennedy, 1975), I. Liberman and her associates have argued that explicit segmentation is crucial to the acquisition of written language because it implies an analysis of the relationship between the component parts of spoken and written language. In contrast, speech perception does not demand as explicit awareness of phonemic structure because of the availability of acoustic cues which simultaneously transmit information regarding manner, voicing, and place of production

(I. Liberman, 1970). Thus, the syllable package, the basic unit of speech perception (A. Liberman, 1973), allows for efficiency of function in that each phoneme need not be perceived independently.

Liberman et al.(1974) found that syllable segmentation was easier than phoneme segmentation at the end of first grade. The necessity, however, of explicit segmentation for acquiring beginning reader in alphabetic systems of orthography remains undocumented. More fundamentally, as Liberman et al. (1974) note, syllables and phonemes are "meaningless" segments of speech. Limber's (1974) comment that analyses of the reading process which focus on speech tend to ignore the issue of meaning is a valid criticism of the developmental importance of explicit segmentation in the comprehension of written language.

An alternate theory, based on the work of Chomsky and Halle (1968), is found in the developmental model proposed by C. Chomsky (1972 b). Similar to Liberman et al. (1974), C. Chomsky stresses that speaking and reading are not equivalent operations. Spoken language, which includes other speech activities such as reading aloud, demands operating on both deep (lexical) and surface structure (phonetic) levels of language with the application of phonological (transformational) rules mediating between the two levels. Thus, while speaking, when defined by pronunciation, is dependent on the phonological processing of regular

phonetic variations (for example, pronunciation shifts as realized by stress placement and vowel reduction), written language, including silent reading, more directly represents the "meaning-bearing" elements of the abstract phonemic lexicon. Chomsky reasons that English orthography indicates how words are related in meaning independently of their phonetic, or sound, configuration because the function of the abstract lexical spelling of words (in which letters represent "segments", not sounds) is to maintain phonological invariance. Essentially, phonological processing while important for speaking becomes irrelevant for reading, because "part of learning to read rapidly and well is learning to dispense with the application of phonological rules (C. Chomsky, 1972 b, p. 71)." Although there are little data to support this formulation, Chomsky views the readiness of the child to abandon his "phonetic" hypothesis as a prerequisite for written language acquisition, a readiness which appears not to emerge until after age six years. Almost parenthetically, Chomsky comments that good readers and spellers "seem to rely on an underlying picture of the word that is independent of its varying pronunciation (Chomsky, 1972 b, p. 75)."

If little is known about the nature of cognitive prerequisites for the acquisition of written language, then it would appear that even less is understood about linguistic preconditions. The only conservation conclusion that can be reached is one similar to that summarized for

cognitive factors -- the capacity to maintain semantic, phonological, and phonetic invariants plays a role in defining the state of the linguistic knowledge the child must bring to acquiring written language. Moreover, if the criterion for mastery of written language is to be established as one involving comprehension, then it follows that reading and writing cannot be understood in purely linguistic terms but as an interaction between cognitive and linguistic domains.

Traditional Approaches to Disorders of Written Language

This section will review studies which have stressed the relationship of disorders of written language to developmental restrictions in the acquiring of spatial knowledge. Two conventional approaches will be covered: (1) the correspondence between "deficits" in visual form perception and spatial disorientation in poor readers and (2) the role of incomplete cerebral dominance and language processing limitations in poor readers. The limitations of traditional approaches will be discussed in the final portion of the review.

Visual Form Perception and the Development of Spatial Orientation

Historically, and from a theoretical perspective, spatial knowledge has been approached as an independent set of visual perceptual

factors. In their review of research on spatial factors conducted from the late 1940's to late 1960's, Chalfant and Scheffelin (1969) concluded that minimal evidence was available to support a general factor hypothesis. In their analysis, factorial studies of normal adult populations had isolated at least six separate factors: (1) a perceptual speed factor; (2) the ability to perceive and compare spatial patterns accurately; (3) the ability to recognize the identity of an object when viewed from different angles; (4) the ability to think about spatial relations in contexts in which the observer's body orientation is crucial; (5) the ability to comprehend imaginary movement in three-dimensional space; and (6) the necessity of kinesthetic imagery in order to represent left-right discrimination in reference to the subject's body. Although not discussed in such terms, the third and fourth factors appear to involve a "perspective" factor while the fifth factor can be interpreted as an "ability" which could equally necessitate the representation of objects in motion by means of a visual mode of representation. Chalfant and Scheffelin note that, while factorial studies have failed to demonstrate a strong correlation between spatial abilities and reading competency, a specific relationship has been demonstrated between spatial factors and mathematical "aptitude" in terms of the subject's capacity to perform numerical operations and the handling of the structure, measurement, and transformation of space configurations in regard to left-right

orientation.

A more recent analysis of spatial knowledge as a cumulative set of factors is found in the large-scale review by Maccoby and Jacklin (1974) on sex differences in intellectual abilities and cognitive styles in childhood. In the Maccoby and Jacklin taxonomy, spatial ability consists of both visual-nonanalytic and visual-analytic factors. Non-analytic abilities are applied in such tasks as the reproduction of geometric forms, matching of forms to a standard under different orientations, choosing two-dimensional drawings to represent three-dimensional objects, determining directionality, and selecting a path through a maze. In contrast, analytic abilities are responsible for the ability to "disembedd" features on such tasks as the Kohs Block Designs, the Visual Closure Subtest of the ITPA, and the Hidden Figures Tests. In employing this classificatory criteria, the authors conclude that, contrary to earlier research findings, sex differences do not exist in childhood on visual-spatial task performance; however, male superiority does begin to emerge in early adolescence and is maintained throughout the high school years.

Historically, the study of the relationship between spatial knowledge and disorders of written language has utilized two different types of population settings, the clinical and the educational. The

general objective of clinical studies has been to delineate patterns of performance which differentiate the disabled reader from the competent reader. On the other hand, studies using school populations have as their general purposes the description of possible prerequisites predictive of early academic achievement and the development of instrumentation which could be used subsequently for intervention purposes. Results from both types of settings have found consistently that the reading disabled population is a heterogeneous group. According to Vernon (1969, p. 11):

Deficient visual perception is one of the characteristics of severely backward readers, though there are many others. Performance on copying shapes--the Bender Test, Draw-a-Man, memory for form, certain WISC subtests, and left-right discrimination--may all be inferior. Learning of verbal material is slow... Recall of order may be affected. A general maturational lag in visual perception, language development, and personality characteristics may be the underlying cause of severe backwardness.

This performance heterogeneity has resulted in the creation of two distinct and separate categories: (1) disorders of written language attributable to deficiencies with spatial abilities, the "spatial disorientation" hypothesis and (2) disorders of written language attributable to specific linguistic deficits, the "processing limitation" hypothesis. The latter hypothesis will be discussed under the language lateralization and processing sections.

Two forms of the spatial disorientation model are found in the literature. The first derives from the administration of global test

measures and the second originates from specific measures of spatial knowledge.

General studies on the spatial orientation model

One commonly employed clinical method for evaluating which category a learning disabled child best fits is the Wechsler Intelligence Scale for Children (Wechsler, 1949) (hereafter referred to as the WISC). Thus, children whose verbal scores exceeded their nonverbal, or performance scale, scores by at least fifteen to twenty points on WISC subtests with high spatial loading (Kinsbourne and Warrington, 1966) were believed to be spatially impaired. The validity of this criterion for the differential diagnosis of the spatially disoriented from the linguistically impaired has been challenged by Klapper (1968) who reported that twenty-point discrepancies between verbal and performance IQ's in either direction were not uncommon. More recently, Klasen (1972) conducted a large-scale retrospective study, examining the files of 488 children previously referred for clinical evaluation because of serious reading problems. In selecting subjects for retrospective analysis, Klasen excluded those whose evaluations provided evidence of "general learning disturbances," behavioral disturbances, or a correspondence between intellectual performance and achievement in the "language areas." All subjects had previously received the identical test battery including the full-scale WISC, the Goodenough

Draw-a-Man, the Bender version of the Bender-Gestalt Test, the Harris Tests of Lateral Dominance, and various reading and achievement tests. In analyzing the results of the WISC subscale patterns for her clinical sample and for six other studies which found that "slow readers" performed better on the performance scale, Klasen found no specific pattern leading her to conclude that the language deficit-visual perceptual deficit constructs are conjectural since firm data did not support the dichotomy.¹

While administration of the WISC has been a common clinical procedure by which children are matched on some variable or theoretically different groups are distinguished on the basis of a fifteen to twenty point discrepancy between verbal and performance scales, the Kohs Block Designs of the WISC performance scale has been independently investigated for its value in differentiating reading versus non-reading disabled subjects. Lovell, Shapton, and Warren (1964) administered several of the WISC performance tests, including the Kohs Block Designs, to a sample of one hundred English children, matched for non-verbal intelligence, social class, age, sex, and membership in the same school. The fifty "normal" readers and fifty "poor readers" ranged in age from CA 9-4 to 10-4. Only the Kohs distinguished between the two groups with respect to a single criterion, the number of completed designs incorrect because of reversals. In discussion of their results, the

authors concluded that reading disability may be related to problems in constructing "a spatial frame of reference," a statement not further elaborated.

Regarding the predictive value of the Kohs, Koppitz (1964), in her standardization of the Bender for children, found a relationship at the third and fourth grade levels between performance on the Bender designs and performance on the Kohs. Koppitz accounts for the causal relationship by relating the reduction of well-defined perceptual cues in the Kohs designs administered above the age eight years level to the type of performance demanded on the Bender designs in which the salience of perceptual cues are also reduced. Maccoby and Jacklin (1974) would probably account for this putative relationship on the basis of their finding that both tests require similar analytic functions. However, it is doubtful that neither the Koppitz nor the Maccoby and Jacklin explanations are an adequate account of content similarity. Rather both tasks would seem to require "non-analytic" functions. An analysis of developmental prerequisites indicates that the child would need to possess at a minimum: (1) the ability to translate a two-dimensional representation of a three-dimensional model into a three-dimensional replication in the presence of the two-dimensional model (Kohs); (2) elementary knowledge of horizontal and vertical axes of reference (Bender and Kohs); (3) some degree of mastery in understanding the relativity of the

diagonal (Bender and Kohs); (4) the capacity to deal with increasingly complex rotational transformations (Kohs); and (5) the ability to derive a whole from the sum of its parts (Bender and Kohs). As Gibson (1969, p. 346) notes "The question of whether children perceive parts or wholes depends on what units are being considered for there are subordinate and superordinate units in any display."

What remains unanswered in the case of both the Bender and the Kohs is the extent to which content validity, as opposed to predictive validity, correlates with prerequisites critical for the achievement of written language. Schafer, Hellig, and Rubin (1974) suggest that one characteristic common to the learning disabled child is the inability to easily form "associations and generalizations" from three-dimensional to two-dimensional (pictorial) space, to "make the jump from the concrete to the abstract (Schafer, Hellig, and Rubin, 1974, p. 81)." It is feasible, therefore, that the content validity of the spatially loaded WISC Performance Scale subtests, the Bender, and the Kohs may involve a form of the Schafer et al hypothesis.

Supportive evidence for their hypothesis is found in the longitudinal study conducted by DeHirsch, Jansky, and Langford (1966) on high risk behavioral attributes considered predictive of reading failure. Following fifty-three prematurely born and fifty-three normal birth-weight subjects from kindergarten through second grade, DeHirsch et al administered a test battery at the beginning of kindergarten which

included the Human Figure Drawing (body image knowledge), visual-perceptual patterning (the Bender), auditory-perceptual patterning (five subtests of "receptive language") and five oral language measures (sentence complexity, simple word definitions). A total of thirty-seven measures were incorporated into the diagnostic battery including six reading readiness tests. At the end of second grade, positive correlations between test battery performance and reading failure were found only for body image as measured by the Human Figure Drawing, performance on the Bender, and the five oral language measures. The effect of a possible disturbance of the "body scheme" on less adequate school achievement was not explained except insofar as it may have derived from deficits of visual form perception.

Studies of this genre raise several serious issues. First, in viewing spatial knowledge as a set of independent functions, the results fail to elucidate how the various abilities are related to each other and, in turn, how they function as preconditions for early academic achievement. Secondly, excepting the five oral language measures which were scored according to traditional surface structure criteria, the strongest correlations were obtained from "pencil and paper" tasks, tasks hypothetically involving some degree of proficiency in mapping knowledge of three-dimensional relationships on to a two-dimensional medium; thus, the nature of the medium for performance may have influenced

the results. Finally, the effect of broad scoring criteria for these pencil and paper tasks cannot be dismissed as another possible test artifact. DeHirsch et al. administered and scored the Bender according to Bender's (1946) procedures and norms both of which were standardized primarily with adults. In contrast, the Koppitz (1964, 1975) versions of the Bender were standardized on children; therefore, the scoring procedures of the Bender and Koppitz versions were not comparable. For example, in the Koppitz (1964) edition, many errors do not attain significance until after age six to seven years, an age span beyond that of the DeHirsch et al. subjects at the time of initial testing. A positive Bender may not have reflected a "maturational lag" but, simply, a testing artifact. In a similar manner, DeHirsch et al. scored the Human Figure Drawing using semi-psychoanalytic criteria (cohesiveness and differentiation). The work of Harris (1963), Koppitz (1968), DiLeo (1970) and Golomb (1974) on the developmental changes associated with both the form and content of human figure drawings and the sculpturing of human figures after age five years suggests serious limitations on the adequacy of the DeHirsch et al. body scheme disturbance explanation.

Studies on the systematic reversal of left-right space

No area has been more thoroughly investigated as a possible

source of failure with written language than the patterns obtained in identifying left-right laterality on self. Since the child's own body functions as the obligatory reference point in defining space and its units, it becomes logical to assume that disruption or disorganization in the integrity of the body scheme (a probable symptom rather than a source of reading failure [Klapper, 1968]) will result in a certain degree of "spatial disorientation" in terms of reference to self and self in reference to object orientation. Despite the range of studies exploring this stronger version of the "body scheme hypothesis," findings have been confounded by variability in test construction and methods of analyses and sampling biases (see pp. 96-102) for discussion of the normal developmental sequence underlying the acquisition of left and right).

The relationship of seemingly abnormal acquisition of left and right to reading disability has been investigated traditionally in the context of own person (or absolute) laterality and as a product unrelated to a more unitary system of spatial organization.

One of the most frequently explored hypotheses has been one proposed by Benton (1958, 1959). Based upon his own research with the normative aspects of the development of "somatic" left-right (Swanson and Benton, 1955) and variable patterns of its development (Benton, 1958, 1959), Benton has argued that a systematic reversal of left-right

space is the shared factor underlying reading disability. According to his definition, a systematic reversal tendency is marked by a consistent identification of own person left and right, that is, right and left are discriminated accurately but the performance pattern is characterized by a complete reversal of designation for both own person and opposite person. Benton further distinguishes between confusion or hesitancy in identifying left and right and the systematic reversal of left and right. The former pattern indicates that full mastery has not been attained while the latter, by definition, implies mastery.

The systematic reversal hypothesis has been pursued by several investigators in order to determine whether systematic reversals differentiated readers from non-readers.

Coleman and Duetsch (1964) using Benton's test of right-left discrimination (Benton, 1959) with a sample of lower socio-economic black children, ages nine years five months to twelve years three months, classified as normal and "retarded" readers, found that according to Benton's criteria all three groups demonstrated complete mastery of own person schema. They noted only five cases (4 percent) of systematic reversals (one case was found in the normal reader group). In contrast, independent of group assignment, all subjects had the most difficulty with other person transformation of left-right but the differences among groups were not statistically significant. However,

Coleman and Deutsch did not analyze results according to intra-age order of difficulty within and across groups, a serious limitation in accepting their conclusion that knowledge of one's own body schema by age eleven or twelve is independent of reading ability. Furthermore, they tested only absolute (own person and other person) left-right which is restricted to self in reference to a single object.

Relative aspects of left-right (self in reference to the relative position of a series of objects) were not investigated. Similar to Swanson and Benton (1955), Coleman and Deutsch found a mental age effect which is equivalent to stating that differences in IQ act selectively on the rate of acquisition within certain lower and upper IQ boundaries.

The previously cited study by Lovell, Shapton, and Warren (1964) using a slightly younger sample than the one used by Coleman and Deutsch (1964), ages spanning nine years four months to ten years four months, included all thirty-six items from the full-scale Benton test. All items related to the child's own body scheme either in terms of self-reference or self in reference to the front view picture of a man. The latter was the only task demanding a transformation of left and right. The authors apparently did not analyze for systematic reversals. Results are stated only in terms of correct/incorrect responses with the poor readers performing slightly less well on tasks involving self-reference and equally well on the pictorial task. No inter-item analyses

were made of performance differences, e. g. , designating own body parts versus own body designation in a crossed command context (right hand on left eye). Again, negative findings may be accounted for solely on the basis of the age of the sample and the relative ease of the task for all children over age nine years irrespective of reading achievement status.

In a well-designed study, Belmont and Birch (1965) included tests of both absolute and relative aspects of left-right following the question format initially developed by Piaget in 1928 (Piaget, 1968). Their sample was composed of only boys, fifty normal and one hundred and fifty "retarded" readers randomly drawn from thirty different English public schools, ages nine years four months to ten years four months. Within the one hundred and fifty sample poor reader group, twenty-nine subjects were found who had not yet achieved full mastery over own person relations. Of these twenty-nine, twenty exhibited an inconsistent identification pattern while nine subjects consistently reversed left and right. Further statistical comparison found that the total reversal group were the poorest readers of the poor reader group when performance on four standardized reading tests was used as an independent variable, suggestive evidence that within the "poor reader" category qualitative differences may exist. On the relative left-right tasks, proportionately, the poor readers did less well than the normals

although the relative tasks continued to be difficult even for the normals. Belmont and Birch argue that when results are combined with the poor readers performance on the WISC performance scale, the "body scheme" hypothesis assumes great potency.

More recently, in a large-scale study of four hundred children, ages two to twelve years, Laurendeau and Pinard (1970) found that 6 percent of their subjects (24/400) exhibited a systematic reversal of own and other person left-right relations but such cases were usually restricted to their younger subjects (under age five years six months). By ages five years eight months to seven years nine months, only 4 percent of subjects still continued to demonstrate systematic reversal tendencies. According to Benton's criterion (Benton, 1959), 6 percent of any experimental sample can be found to systematically reverse. In a recalculation of Belmont and Birch's data, it was discovered that their nine systematic reversers constituted exactly 4 percent of the total two hundred sample. Based upon these findings, one could expect, then, that after age seven years nine months, the presence of systematic reversal behavior in designating own and other person left-right may be suggestive of a deviant pattern in organization of self as the obligatory reference point.

The exact developmental implications of not only systematic reversals but also the relationship of systematic reversals to reading

disability remain an enigma, Laurendeau and Pinard (1970)² argue that, contrary to the Benton thesis, systematic reversals need not automatically restrict the child from understanding the relative aspects of left-right since the child may still construct the notion that an object can be located simultaneously to the left of one lateral object and to the right of the other. Although Belmont and Birch (1965) were the only investigators to administer Piaget's (1968) relative left-right tasks, they failed to analyze separately for both inter-and-intra-group performance. The only stated finding concerns the generally poorer performance of the poor reader group in contrast to the normal readers. While valid to assume that the developmental progression of left-right proceeds from self-reference to other person reference to self in reference to the relative position of a group of objects, the questions remain unanswered concerning the degree to which the construction of relative left-right may evolve independently of its absolute form and whether a systematic reversal of the absolute form mandates an identical construction of the relative aspects of left-right.

Language Lateralization and Processing

That the right hand side of the body knows what the left hand side is doing, and vice versa, is clearly a function of the bilaterally symmetrical cerebrum, each half the mirror image equivalent of the

other. Although the evolutionary and functional significance of the cross-over of inputs and outputs has never been explained, it does appear to represent a common pattern in all vertebrate brains (Rose, 1973).

There also seems to be little doubt that, at least in the adult brain, the notion of equal cortical control is violated to the degree that language becomes fully lateralized to the left hemisphere. Geschwind (1973) notes that although 93 percent of human beings are right-handed, approximately 96 percent are left dominant for language. Citing research with neonates on possible anatomical asymmetries which may account for the development of cerebral dominance, Geschwind has found some evidence that, at birth, the left hemisphere is larger than the right. Because of this finding, Geschwind finds it plausible that the left hemisphere not only is capable of acquiring language but also "because of its larger size, it leads the opposite side (Geschwind, 1973, p. 70)," a finding which Bever (1975) interprets as indicating that the left hemisphere is more adaptable at birth for the processing of analytic input such as language while the right hemisphere is more adaptable for holistic processing. An example of the latter would be the perception of simple visual figures.

The relationship between hemispheric specialization and preferred hand use has been also explored as a possible extrinsic mechanism

by which cerebral asymmetries occur (Gazzaniga, 1970; Corballis and Beale, 1972); however, their ontogenetic evidence is primarily inferential based on adult studies in which the commissural fibers of the corpus callosum have been surgically severed functionally creating a "split-brain" (Gazzaniga, 1970).

With the advent of more refined testing techniques such as the auditory rivalry, or dichotic tasks, recent research has focused on possible mechanisms underlying the lateralization of language (Kimura, 1967). Using the dichotic method, Knox and Kimura (1970) employed both verbal and non-verbal response patterns with forty males and forty females, ages five to eight years, all of whom were right-handed. Results indicated that, regardless of the method of report (verbal or non-verbal), perceptual asymmetries were readily apparent by age five to six years suggesting that "speech representation" was established in the left hemisphere. Knox and Kimura found further that males were superior on the non-verbal task (in which "environmental" sounds served as stimuli) which led them to posit a superiority of spatial abilities in males. Bryden (1970) challenged the general results of this study by pointing out order of ear report was not adequately controlled. When order of ear report was controlled, Bryden found a marked developmental trend in his sample of one hundred forty-four Grade 2, 4, and 6 subjects unlike the ceiling effect claimed by Knox and Kimura. With respect to

the sex differences found by Knox and Kimura, Maccoby and Jacklin (1974) argue that the "package" of skills located in each hemisphere does not correspond to known sex differences in abilities.

A theory that purports to account for female superiority on verbal tasks and inferiority on spatial tasks, in terms of stronger or earlier lateralization of the left hemisphere, would have to expect that the other functions controlled by this hemisphere would also be superior in girls (Maccoby and Jacklin, 1974, p. 127).

In view of their finding of an absence of sex differences in either verbal or spatial thinking during early and middle childhood, they suggest that such differences, when found, may be the result of test artifacts, that is,

what appears to be needed is examination within sex (authors' italics) of the relationship between the rate of early language development and later spatial skills. If boys who talk late have better spatial ability in later childhood than boys who talk early, this would be good evidence for the inhibiting effects of early left-hemisphere functioning on right-hemisphere functions (Maccoby and Jacklin, 1974, p. 127).

In terms of the normal course of cerebral specialization, two issues appear to remain unresolved. First, the exact contribution of preferential hand use in the acquisition of spatial knowledge as well as its function in language acquisition is not understood. Shifting the focus of inquiry from asymmetrical function (e. g. , Knox and Kimura, 1970; Geschwind, 1973) to the self-organizing activity between structures of

the brain and structures of the mind (Lashley, 1961; Piaget, 1963; H. Clark, 1973; Bever, 1975), may explain more readily why preferential hand use, as a neurophysiological product, is intrinsically unrelated to the acquisition of either spatial location and direction or the particular semantic relations which formalize the underlying conceptual relations. Secondly, as Maccoby and Jacklin (1974) suggest, it is unknown whether there exists a critical period when the degree of cerebral lateralization may influence the development of particular modes of thought, for example, spatial and linguistic, or whether, the degree of cerebral specialization determines the skill with which one can utilize certain spatial and verbal styles of thinking.

Studies on lateral dominance and preferential hand use

The classic approach to investigating the putative relationship between lateral dominance and spatial orientation in disorders of written language has consisted of testing hand and eye preferences and then relating the pattern of performance to left-right awareness of the body schema and other independent variables such as delayed onset of speech and dyslexia. Strong claims have been made (Orton, 1937; Harris, 1957; Zangwill, 1962, 1975) that failure to acquire reading and writing is related to incomplete, or weak, left hemisphere representation of speech. According to Zangwill (1975):

...there is some indirect evidence in support of (Orton's view that speech, reading, and spelling problems may, in some cases at least, be related to the imperfect lateralization of speech... The most conservative conclusion seems to be that children with weak or mixed lateral dominance or those with left-handedness in their family histories appear to be at risk in regard to the developmental disorders of language (Zangwill, 1975, pp. 144-145).

The empirical evidence to support this conclusion is tenuous.

The clinical research conducted by Harris (1957) on eye, hand, and foot preferences in 316 cases of clinically defined reading disabled males with a median age of ten years led him to suggest that tests of lateral dominance could function as indicators of "directional confusion."

Harris found that when hand dominance results were combined with eye dominance results, the resulting hand-eye preference distinguished between his experimental and control groups. It should be noted that Harris made no effort to exclude children with reading problems from the control group and did not control for IQ differences. Because the dyslexic group at both ages seven and nine years demonstrated an increased incidence of mixed hand-eye patterns (mixed hand preference-right eye preference or mixed hand-left eye), Harris interpreted cases of mixed dominance as diagnostically significant. In contrast, he considered cases of crossed dominance, for example, right hand-left eye, a pattern which decreased with age in the experimental sample, as not significant diagnostically. The critical index, then, pertains to mixed

handedness independent of eye dominance.

The Harris study has been criticized by both Coleman and Deutsch (1964) and Belmont and Birch (1965). Both of these latter studies failed to find significant differences in dominance patterns after age nine years six months in samples of normal and poor readers obtained randomly, that is, from a school population. Belmont and Birch argued that the Harris clinical sample biased results since such a sample fails to be representative of the general population while Coleman and Deutsch argued that clinically defined samples of dyslexia were not comparable to reading problems found in the general school population. However, inspection of the testing procedure employed by Belmont and Birch and Coleman and Deutsch found that neither used the complete Harris battery. Belmont and Birch used one test of hand preference which includes ten items, and five tests of eye preference. Not included was the simultaneous writing hand preference subtest, a test which Harris (1958) termed as the "best" for determining both directional confusion and mixed hand dominance. Therefore, the Belmont and Birch classifications are based only on one test of hand preference which appears to be less selective in defining incomplete dominance. Secondly, Belmont and Birch seemed not to have made a distinction between mixed and crossed dominance classifying incidences of either under the category "Mixed."

Harris (1957) clearly distinguishes between the two citing cases of crossed dominance as non-significant. In contrast, Coleman and Deutsch utilized a modified Harris battery omitting only designated optional tasks. While they fail to specify use of the Harris classification criteria, an inspection of their Table 4 (Coleman and Deutsch, 1964, p. 47) indicates a separation of crossed from mixed patterns for the purpose of data analysis.

Although the Coleman and Deutsch findings fail to substantiate a sustained relationship between delayed establishment of lateral dominance and reading proficiency when IQ is controlled (earlier differences tending to "wash out" by age ten), the fact remains that such differences apparently do exist at younger age levels (neither Belmont and Birch [1965] nor Coleman and Deutsch [1964] used subjects younger than age nine and a half). Furthermore, these differences tend to be found more often in children encountering serious problems in acquiring written language given equivalent IQ levels. It seems clear, however, that what is symptomatic at age seven is not necessarily equally significant at age ten years. In this regard, Wender (1971) has proposed that some children may manifest such symptoms as mixed dominance across all developmental stages while others may follow an irregular developmental sequence with a particular symptom "dropping out," perhaps replaced by another. Wender notes, without documentary

evidence, that many "negative" symptoms frequently abate by puberty.

A final issue concerns the relationship between the establishment of laterality preferences and mastery of own person laterality (see discussion under "Spatial Disorientation Model," pp. 39-45). An earlier study by Belmont and Birch (1963) on normal school-age children found that own person left-right mastery stabilized earlier (at approximately seven years) than full stabilization of eye and hand preferences which may not occur until ages nine to ten years. This result seems consistent with that reported by Bryden (1970) (see p. 54) who found a developmental trend through age ten years on dichotic tasks. Lastly, Coleman and Deutsch (1964) found no basis for a relationship between reading failure, establishment of laterality preferences, and mastery of own person left-right relations; however, their testing procedure was not as rigorous as was the procedure used by Belmont and Birch (1965).

Dichotic studies

An alternate form of the "weakly lateralized for language" hypothesis has been proposed by I. Liberman (1970) and Shankweiler and I. Liberman (1972). Questioning whether handedness is an adequate indicator for assessing cerebral dominance, they suggest that, to the extent that reading "taps" into the linguistic process,

children who cannot read well are weakly lateralized for language. The limited use of auditory rivalry techniques in exploring this hypothesis has produced equivocal results.

Bryden (1970) investigated the relationship between dichotic listening performance and reading ability in the 144 Grade 2, 4, and 6 subjects cited earlier. His less than unequivocal findings may be related to the criterion used to classify differences in reading ability. Poor readers were defined as those subjects whose reading level, as determined by previous performance on standardized reading tests, were below IQ. Differences were obtained in the incidence of crossed dominance (different hand and ear) and uncrossed dominance (same dominant hand and ear) only when subjects were dichotomized on the basis of relative reading scores, that is, the five best, five poorest, and five intermediate readers, at each of the three grade levels. The relationship held for males at all three grades and for Grade 2 females only. Because reading failure is most often defined empirically by assessing achievement along a continuum measured against an independent variable as mental age (Dechant, 1968), Malmquist (1958) has suggested that this "relative" definition of reading failure makes it virtually impossible to differentiate the truly dyslexic child from the plain poor reader. Thus, Bryden's "poor reader" category may have reflected only normal relative differences in reading ability rather than

absolute differences.

Recently, Rosenbloom (1975)³ screened over seven hundred kindergarten subjects ranging in age from five and a half to six and a half years. Screening procedures included articulation testing and a simple hand preference task for three common activities. Twenty experimentals with "high" articulation scores and twenty controls with "low" articulation scores were selected for in-depth testing on a battery which included a dichotic task (using syllables), tests of hand preference and relative manual dexterity, the Beery Developmental Test of Visual-Motor Integration (Beery, 1967), a sentence repetition task, and a test of sentence comprehension. None of the handedness tasks differentiated between the two groups while the dichotic and sentence repetition tasks did differentiate. Differences were also found for the copying of individual shapes (the Beery Test). Rosenbloom's data, while not pertaining directly to a "poor reader" population, suggest that the use of procedures geared toward the manner in which children with defective articulation process language and speech may bring more productive results as opposed to assessment procedures which utilize hand preference tasks to make inferences about language lateralization.

Although the dichotic procedure leaves unanswered the question of whether poor readers are weakly lateralized for processing language, I. Liberman (1970) and I. Liberman et al. (1974) have raised the

important issue of what is meant by a language disability in disorders of written language when the "spoken language" of the child is "generally good." As I. Liberman (1970, p. 63) notes, "Why people who are lateralized well enough to speak and listen might not be lateralized well enough to read is not presently known."

Studies on comprehension and production of spatial terms

Despite the substantial body of evidence that poor readers encounter more difficulty in structuring non-linguistic aspects of three-dimensional and two-dimensional space (Lovell, Shapton, and Warren, 1964; Kinsbourne and Warrington, 1966; De Hirsch, Jansky, and Langford, 1966; Vernon, 1969; Schafer, Hellig, and Rubin, 1974) and in understanding words which refer to laterality on self and self in relation to the lateral position of a series of objects (Benton, 1959; Belmont and Birch, 1965; Alexander and Money, 1967), there has been almost no systematic investigation of how poor readers either comprehend or use three-dimensional spatial terms.

Available comprehension and production evidence are largely anecdotal and/or based upon the use of pictorial representation as stimulus material. Scattered throughout the literature are reports that "learning disabled" children often encounter difficulty in understanding what appears to be spatial perspective, or projective, terms.

Kaliski (1962), in an impressionistic report on the classroom functioning of clinically diagnosed minimally brain-injured children, ages seven to seventeen years, noted serious problems understanding terms such as "up," "down," "top," "bottom," "front," "back," "near," and "far" and confusion with left-right orientation. Frostig and Horne (1964) state, without offering supportive data, that language problems are common to children who have perceptual disturbances of position of space because they fail to understand words which designate spatial position such as "in," "out," "up," "down," "before," "behind," "left," and "right." In their longitudinal study of high risk premature subjects, DeHirsch, Jansky, and Langford (1966) concluded that the communicative difficulties of many of their five and six year olds, as defined by their oral language measures (see p. 38 for elaboration), were frequently accompanied by "conceptual" deficits since these children:

do not comprehend the small abstract words and phrases such as "on top of," "before," or "because" which represent spatial, temporal, and causal relationships (DeHirsch, Jansky, and Langford, 1966, p. 89).

J. Orton (1966) reports without substantiating data that:

some dyslexic children have little concept of time and space relationships; they confuse the terms before and after, or above and below... They may be slow in learning right and left (J. Orton, 1966, p. 130).

In a more formal study, Wiig and Semel (1973) explored a Piagetian-type hypothesis that a learning disability may consist of

both conceptual "deficits" and "deficits" in "logico-grammatical sentence comprehension," a description not defined further. Their learning disabled sample consisted of thirteen females and nineteen males with a mean age of nine years one month all of whom had been previously diagnosed as learning disabled by a school system "psycho-educational" team. Controls, or "achieving," subjects were matched for age and IQ. The testing procedure consisted of the administration of fifty sentences, all read in random sequence, taken from an adult test for aphasia. Ten sentences each represented: (1) Comparative Relationships ("Are parents older than their children?"); (2) Passive Constructions ("Mary was pushed by Jane. Who was pushed?"); (3) Relationships between Sequential Events ("Does April come before March?"); (4) Spatial Relationships ("Joe was to the right of Mary, and Jane was to the left of Mary. Who was in the middle?"); and (5) Familial Relationships ("Give another name for your mother's father").

Results were interpreted as confirming predictions. The learning disabled made a significantly greater number of errors on all sentence sets with the greatest number of errors occurring on the Spatial Relationships set. Nearly five times as many errors were found for the learning disabled on the latter set as for the controls. No sex differences were found.

The final conclusion of this study that "The qualitatively lower performance of the learning-disabled children is therefore considered to reflect preoperatory cognitive and logical processes (Wiig and Semel, 1973, p. 633)" appears unwarranted for several reasons. First, Wiig and Semel fail to provide a complete listing of their test sentences and are not specific as to whether their test material consisted of objects or pictures or just the stimulus question. Secondly, question content is not as clear-cut as the authors state. Structurally, the spatial relationship questions were longer than the comparative questions; thus, length may have been a confounding factor across question sets. Third, no intra-question set analysis was given. Apparently the erroneous assumption was made that, within a given set of sentences, all questions were of equivalent difficulty. Fourth, because Wiig and Semel scored protocols only on the basis of correct/incorrect responses, the data provide minimal insight into whether the learning disabled subjects were actually using qualitatively different strategies in their processing of both semantic and syntactic relationships. Finally, errors were ranked in order of increasing frequency with comparatives the easiest (mean errors 1.50) for the learning disabled and the spatial and familial sets the most difficult (mean error 4.70 and 5.00, respectively). The same rank order was not evident for the controls who found sequential events ("Does April come before March") strangely the most difficult (mean

error 1,75). However, when the Wiig and Semel data were re-ordered according to shared rank order, it was found that relative rank difficulty of the Spatial Relationships set remained identical for both groups (see Table 1).

TABLE 1
RELATIVE RANK DIFFICULTY OF SPATIAL
RELATIONSHIP SENTENCE SET*

Rank**	Learning Disabled	Rank	Achievers
1	Familial	1	Sequential
2	Spatial	2	Spatial
3	Sequential	3	Passive
4	Passive	4	Familial
5	Comparative	5	Comparative

* Adapted from Wiig and Semel (1973, Table 1, p. 630).

** Rank 5 denotes easiest and Rank 1 most difficult.

On the basis of this analysis, the difference between groups can only be interpreted as a quantitative difference because the basic difference appears to pertain only to differences in rate of acquisition. Since Wiig and Semel failed to establish a logical, or developmentally ordered, sequence for any of their sentence sets, the interpretation

of a qualitative difference between learning disabled and achieving children in cognitive stage and sentence comprehension is suspect.

In a further investigation of sentence comprehension by learning disabled children in middle childhood and preadolescence (mean age, nine years), Semel and Wiig (1975) found significant quantitative reductions in the comprehension of "critical verbal elements" on the Assessment of Children's Language Comprehension Test (Foster, Giddan, and Stark, 1972). Analysis of error patterns indicated that 80 percent of the vocabulary subtest errors were for the prepositions "on," "behind," and "over" and that the highest relative percentages of errors for the four-critical element subtest occurred on items containing "over" and "behind." Additionally, they found a ceiling effect for performance by the older learning disabled children, that is, the older subjects performed similar to the younger learning disabled subjects. Although they conclude that learning disabled children "exhibit quantitative reductions in the ability to process and synthesize critical verbal elements (Semel and Wiig, 1975, p. 57)," they note that the pictorial medium may differentially influence the nature of the response pattern because, "the scant representation of a package may be interpreted as the bottom of a staircase (Semel and Wiig, 1975, p. 57)."

Studies of this kind have led to the conclusion that limitations in the processing of language underlay reading failure (Stark, 1975; Wepman, 1975). However, the few studies which have examined this hypothesis have primarily focused on the learning disabled child's comprehension and production of verbal and written syntactic structures (Myklebust, 1973; Wiig and Semel, 1973; Vogel, 1975; Semel and Wiig, 1975). In most instances, there has been relatively little attention paid to the child's semantic strategies for comprehending particular sets of meaning relations. As Morehead (1975) points out, few studies have attempted to explore the relationship between knowledge of spatial terms and general structures of cognitive development in language-disordered populations. Indeed, the primary issue seems to be in what ways the learning disabled child can be also considered as a language-disordered child if his spoken syntax is theoretically intact.

Summary

The review of traditional approaches to the study of the relationship of visual perception, language lateralization, and language processing in the construction of a three-dimensional system of reference in disorders of written language has shown that:

- (1) Poor readers tend to produce heterogeneous performance patterns on achievement tests which have high spatial loading and which

vary in the level of representational complexity specific to a particular task (Kinsbourne and Warrington, 1966; Vernon, 1969; Klasen, 1972; Lovell, Shapton and Warren, 1964; Koppitz, 1964). By contrast, less performance heterogeneity is manifested on tasks which pertain to comprehension of the left-right dimension on self and others and self in relation to the relative position of a series of objects in which projection of viewpoint, or perspective, functions as a criterial feature (Benton, 1958, 1959; Coleman and Duetsch, 1964; Belmont and Birch, 1965).

(2) The establishment of stable preferential hand use, the result of neurophysiological processes of development, is not necessarily related to the comprehension of own person laterality in poor readers (Coleman and Deutsch, 1964; Belmont and Birch, 1965). Furthermore, the left-hemisphere effect for the perception of consonants is equivocal for poor readers (Bryden, 1970) although the age at which the left-hemisphere effect emerges appears independent of the age at which preferential hand use is attained or of the degree of manual dexterity in pre-school subjects with defective articulation patterns (Rosenbloom, 1975).

(3) Poor readers may have more difficulty in interpreting the content of "pencil and paper" tasks, which are two-dimensional representations, because of problems in transforming knowledge of three-

dimensional space onto a two-dimensional medium such as pictorial space (Lovell, Shapton & Warren, 1964; DeHirsch, Jansky, and Langford, 1966; Schafer, Hellig, and Rubin, 1974). Moreover, the use of the pictorial medium as stimulus may influence the manner in which the poor reader comprehends terms which syntactically function as prepositions (Semel and Wiig, 1975).

(4) When differences in performance are found between poor readers and achieving readers in the comprehension of sentences which refer to spatial relationships, these differences tend to be quantitative, and, thereby, imply that the poor reader differs from the achieving reader only on the basis of normal variability in the rate of acquisition (Wiig and Semel, 1973; Semel and Wiig, 1975).

(5) Disturbances of spoken syntax are not associated automatically with disorders of written language (I. Liberman, 1970; I. Liberman et al., 1974; Wiig and Semel, 1973; Semel and Wiig, 1975; Vogel, 1975) although the failure to comprehend particular syntactic structures may be correlated with a disorder of written language (Myklebust, 1973; Semel and Wiig, 1975; Vogel, 1975).

In view of the fact that reading and writing are currently acknowledged as the product of a complex interaction between cognitive and linguistic processes (see pp. 24-30), traditional approaches have proved to be unsatisfactory in explaining how the poor reader differs

qualitatively from the achieving reader in his organization of a three-dimensional spatial structure and in his organization of semantic space, the words which refer to aspects of cognitive space. In stressing perceptual organization only, traditional approaches have been restricted to searching for particular spatial and auditory abilities which are correlated with school achievement and which can be selectively disturbed. The theoretical weakness of the "modality deficit" explanation has been criticized as being unable to specify, beyond a minimal level, how much visual and, by implication, auditory perception is necessary to read and write competently (Malmquist, 1958) and for confounding auditory perception with speech perception (Rees, 1974; Stark, 1975; Studdert-Kennedy, 1975). Moreover, it would appear that the results of many of the studies reported upon can be attributed to either sampling biases, for example, failure to differentiate the "slow" reader from the truly dyslexic reader, or to the types of tasks administered in which achievements at one level are intrinsically unrelated to achievements at the subsequent level.

Most fundamentally, traditional approaches have been unable to state whether qualitative criteria do exist to differentiate within the "poor reader" category. It would seem unparsimonious to consider a disorder of written language as "language-based" in origin if the learning disabled child has no apparent difficulty with spoken language,

particularly when the latter is defined only in syntactic terms. An apparent incongruity exists between the inability to comprehend various sentence constructions when presented in verbal form and the ability to spontaneously produce acceptable spoken syntax.

What is necessary, then, to a more sufficient account of the synonymy of disorders of spoken and written language is a model which can account more parsimoniously for the manner in which the child represents spatial knowledge and the manner in which specific semantic forms of spatial knowledge are related to more general cognitive structures. The evidence for this alternate approach will be reviewed in the following section.

An Alternate Approach to Disorders of Written Language: The Construction of a Representational Spatial Structure

This section will survey the theoretical bases and supportive evidence for the general psychological reality of a representational space, including the semantic acquisition of projective spatial terms and abnormal acquisition of a conceived space. The final portion will survey studies on pictorial space in relation to the effect of medium on the comprehension and production of projective spatial relations.

In his description of the sensory-motor stage of development, the first stage of intellectual development, Piaget (1963) has proposed

that motor activity assumes meaning for the infant only in terms of its relationship to external mōvement through space and the subsequent sensory-motor coordination of these movement (action) patterns. In the Piagetian model, these external action patterns become progressively "interiorized"--assimilated--into a mobile and reversible set of cognitive structures, or operations (Piaget, 1970) which then makes possible, among other intellectual activities, the representation of the anticipation of movement by means of the visual image (Piaget and Inhelder, 1971).

In contrast to traditional views of the development of cognitive functions as a direct product of perceptual activities, Piaget (1955, 1969) does not consider the development of cognitive space as a linear extension of perceptual development. Rather, perceptual (visual) space and the perceptual activities which regulate its formation progressively become subordinated to the emerging cognitive structures and are subsequently reorganized by these cognitive structures. Moreover, there is some suggestive evidence (Piaget, 1969; Elkind, 1974) that perceptual development is not subject to stage-related laws as is cognitive development.

The space, then, of which Piaget and Inhelder (1967) speak is a representational space, not a perceptual space; however, both perceptual and representational spatial constructions have motor activity

as a shared features. "The fact of its continuous existence through all the stages renders motor activity of enormous importance for the understanding of spatial thinking (Piaget and Inhelder, 1967, p. 13)."

Theoretical Bases for a Projective Space

One of the first representational space formalizations is the theory proposed by Meyer (1940). Meyer stated that a progressive representation of space can be only understood in terms of the relations between objects and their movements. Based upon her series of experiments with sixty-three subjects from eighteen months to age five and a half years, Meyer described three stages of spatial construction: (1) a practical space in which objects exist only in relation to the child's own activity and not in relation to each other; (2) a subjective space in which activity becomes adaptive to the extent that objects are viewed no longer as obstacles to resist but as objects to be known which can be modified by the child's own action patterns (despite the child's increasing subjectivity, space is still defined in this stage in relation to the child as the obligatory reference point); (3) an objective space in which objects are constantly differentiated and reorganized according to object properties because the child now understands the independent movement of objects and can integrate his

movement with object movement. Within this framework, Meyer formalized the continuing organization and reorganization of spatial operations as they applied to new contents and, in addition, recognized the fragile nature of representational space in the preschool child who "can reconstruct the past but not predict future events (Meyer, 1949, p. 137)."

In a similar manner, Werner (1965) has aligned the ontogenic development of spatial thinking with the child's overcoming a subjective "space-of-action" in which the ego and the external world are initially undifferentiated and orientation and dimensionality are known only through action. The diffuseness and instability of orientation in this primitive space-of-action is characterized by features similar to those found in temporal succession, that is, movement in relation to orientation is irreversible since the child becomes lost if, for example, he has to reconstruct a return route in a reversed direction. While Werner implies that increasing objectification is a consequence of the construction of more complex spatial relations such as "before" and "behind," he cites Piaget's 1928 study of the development of absolute and relative left and right (Piaget, 1968) as empirical proof of the progressive disassociation of egocentricity from the external or physical world.

It is Piaget and Inhelder (1967) who have proposed the most comprehensive theory of the construction of a representational space.

Historically, metric--Euclidean--geometry was discovered first followed by the discovery of the more general and abstract projective and topological geometries (Piaget, 1970). Ontogenetically, Piaget and Inhelder hypothesize the reverse acquisition sequence with respect to the development of a more general system of spatial structures, a product of the emergence of the representational function at approximately eighteen months.

The first space constructed is a topological space⁴ (not dissimilar to Meyer's [1940] description of a practical space). These first spatial notions deal only with the inherent properties, the surface or external properties, of an isolated single object or configuration. For the child in the topological stage, the dimensions of objects change according to alterations in their perceptual configuration (Furth, 1969) or according to changes in projection of viewpoint. The construction of a topological space is followed by a long and simultaneous developmental elaboration of a system of spatial coordinates, Euclidean space, and spatial perspectives, projective space. The emergence of projective and Euclidean space herald a massive reorganization of topological space which becomes integrated into a three-dimensional spatial structure by which the child can progressively locate objects according to this system of perspectives and coordinate axes.

Projective Space

The psychological transition from a topological organization to a more advanced spatial organization occurs "when the object or pattern is no longer viewed in isolation, but begins to be considered in relation to a 'point of view' (Piaget and Inhelder, 1967, pp. 153-154). " By this process, the child begins to structure a projective space in which objects can be considered in relation to a point of view from either his viewpoint or of other objects onto which his viewpoint is projected .

This system of perspectives, the source of projective space, also implies the simultaneous construction of a system of axial coordinates whose source is Euclidean space. Piaget and Inhelder (1967) are clear that projective relations obtain meaning only in reference to a stable system of axial coordinates and, conversely, construction of spatial coordinates is dependent on a differentiation of various perspectives without which, according to Laurendeau and Pinard (1970), it would be impossible to conceive of a system of reference.

Projective concepts ignore objective distance and real object dimension since they are based on the transformation of apparent size and shape and also conserve the relative position of objects, or parts of a single object, in relation to the observer's point of view (Laurendeau and Pinard, 1970, p. 168). In summary, unlike the Euclidean system,

the perspective system does not conserve actual distances and dimensions but assumes in the child a progressive awareness of the possibility of multiple potential viewpoints.

As initially proposed by Piaget in 1928 (Piaget, 1968), extended by Piaget and Inhelder (1967), and elaborated by Laurendeau and Pinard (1970), the three hierarchally organized relations of projective space are:

Before-behind relation

The first dimension of projective space, and the basis of all perspective geometry is the before-behind relation empirically defined by the child's construction of a projective straight line giving a dimension of length to space. The notion of the straight line, or length in space, involves the understanding of spatial order (succession) and the ability to impose constant direction on movement along a straight path (Piaget and Inhelder, 1967). Its developmental importance concerns the fact that the straight line is the only aspect of shape which remains invariant despite changes in viewpoint since only the line's length is altered under a transformational change. The child comes to understand that the projective straight line, the diagonal, involves a "before-behind" relation, that is, the first element of the ordered succession masks the remainder with one element (or point) always before one and behind

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another (Piaget and Inhelder, 1967, p. 170).

Left-right relation

Additively combined with either the before-behind relation or the above-below relation, the creation of the left-right relation results in the surface plane which gives a dimension of width to space.

Empirically, left-right relations are defined by the long developmental elaboration of absolute and relativistic concepts. The more elementary absolute relation denotes awareness of spatial localization in regard to own person and of the transformation of the relation oppositionally according to the observer's viewpoint (Laurendeau and Pinard, 1970) while the more complex relativistic notion involves the coordination of two viewpoints in a systematic manner in relation to a series of objects.

Above-below relation

With the capacity to coordinate perspectives, the child has finally achieved a three-dimensional spatial structure in which conceptual space becomes multi-dimensional (Piaget and Inhelder, 1967; Laurendeau and Pinard, 1970). From his earlier egocentric or uni-dimensional space, the child has formed a reference framework which permits objects to be linked together in a coordinate system and viewpoints to be joined together by means of the three projective

relations: before-behind, left-right, and above-below which correspond to notions of length, width, and volume, respectively. The formation of this flexible system means that the child is not only aware of his own viewpoint but also is aware simultaneously of the theoretical possibilities for multiple viewpoints or perspectives. In relation to the graphic mode of representation:

Three-dimensional space, finally, offers complete freedom: shape extending in any perceivable direction, unlimited arrangements of objects and the total mobility of a swallow. Beyond these three spatial dimensions visual imagery cannot reach; the range can be extended only by intellectual construction (Arnheim, 1974, p. 218).

Studies on the Normal Acquisition of Projective Space

Construction of the projective straight line

The general hypothesis involves the prediction that perceptual recognition of a straight line--the topological straight line--as is the case in tasks where the child copies geometric forms, is not equivalent to reconstruction of a straight line between varying reference points, a task dependent on "picturing" the alteration of position using visual imagery (Piaget and Inhelder, 1967; Laurendeau and Pinard, 1970). A complimentary hypothesis relates to the nature of the verification strategy employed by the child in reconstructing the diagonal using a visual sighting procedure (a perspective procedure since diagonality is relative to the child's point of view) or manual measurement (a

Euclidean procedure).

In addition to the original 1948 study by Piaget and Inhelder (1967), Estes (1956),⁵ Lovell (1959), Dodwell (1963), and Laurendeau and Pinard (1970) carried out replication studies. Another major study (Olson, 1970), using different testing material and procedures, was concerned with the role played by verbal instruction in effectuating acquisition of diagonality.

The testing format for the four major studies (Piaget and Inhelder, 1967; Lovell, 1959; Dodwell, 1963, and Laurendeau and Pinard, 1970) was similar⁶ although there were serious differences across studies with respect to material dimensions, age of subjects, the standardization of instructions, performance criteria, and depth of data analysis (see Table 2 summary).

The general format consisted of two sections. In the first section, two endpoints (e.g., miniature houses [Laurendeau and Pinard, 1970]) were placed on a square or rectangular table or base under three different conditions: (1) with the endpoints each parallel to the table edge or parallel to the table edge on which the base was placed; (2) with each endpoint still parallel to the table edge but now located midway along opposite sides of the table or base; and (3) with each endpoint placed in two opposite corners (see Figure 4, Chapter III

TABLE 2
METHODOLOGY: CONSTRUCTION OF THE PROJECTIVE STRAIGHT LINE

Study	Subjects	Ages	Material	Instructions	Criteria	Data Analysis
Piaget & Inhelder (1948)	NS* (Swiss)	NS (Range: 2:6-7:9)	Square, round table; floor (no dimensions); matchsticks (number NS).	NS except at youngest ages when content changed to conform to comprehension.	Diagonal line via aiming strategy.	Qualitative; three stages & two sub-stages derived.
Lovell (1959)	133; sex NS. (English)	2:11-5:8	Rectangular table, round hoop (no dimensions); 10 matchsticks.	NS; stated only Ss must place matches in straight line between two endpoints.	Vague; percent straight, irregular, perceptual lines.	Quantitative; percent success criterion for placement in age category
Dodwell (1963)	194; sex NS; IQ over-represented at extremes (English)	5:1-11:3	Cardboard disk (14") & square (NS); 10 toothpicks.	Specified; included temporal terms as "beginning," "between," and "end."	Common types as noted by Piaget; if no sighting, line moved to other positions with child asked to predict which position would show "straight."	Quantitative; percent falling into Piaget's stages. Found large "mixed" category (overlap of stages in terms of ages).

(Continued)

TABLE 2--Continued

Study	Subjects	Ages	Material	Instructions	Criteria	Data Analysis
Laurendeau & Pinard (1970)	594; sex specified (French Canadian randomly selected)	2:0-12:0	Rectangular (26x35 cm.) & circular (34 cm. dia.) bases; two toy houses; eight miniature lamp-posts.	Standardized with follow-up questions. Pre-test to determine if child could discriminate between straight and other lines. Did not use temporal terms.	Two categories: (1) incorrect (four criteria), (2) success or partial success (two major criteria & seven sub-criteria for transitional cases).	Quantitative and qualitative (item analysis; scalogram for analysis by stages). Found four stages & six substages.

* Information not specified is marked notationally by NS.

for a schematic representation of the task).

For the second section, a circular table or base was substituted (Lovell [1959] used a hoop). Again, two endpoints were located under three identical conditions:

The houses are spaced first (problem 4) some 20 cm. apart on a small segment of the arc perpendicular to the child's plane of vision, then (problem 5) at about 30 cm. along a diameter still perpendicular to the plane of vision, and finally (problem 6) at some 25 cm. on a larger chord of the arc but this time on the oblique in terms of the plane of vision (Laurendeau and Pinard, 1970, p. 118).

For each of the six problems, the child was instructed to place his "lights" (toothpicks, matchsticks, etc.) in a straight line. The crucial conditions were problems 3 and 6, the diagonality conditions, since in these instances the child could not rely on perceptual cues to construct the line.

Of the four major studies, the one conducted by Laurendeau and Pinard (1970) was the most experimentally rigorous. Only Lovell (1959) found results disconfirming the stated hypotheses, findings which may be explainable by Lovell's failure to adhere to as rigorous procedures. The fact that his preschool subjects enjoyed earlier success rates with the diagonal may have been due to his sampling procedure in which subjects were selected on the basis of head teachers' subjective evaluation; therefore, his sample may have contained a greater

proportion of brighter children than found randomly (Lovell (1971) still maintains the accuracy of his earlier findings). It would appear, however, that conflicting findings reflect differences in the rate of acquisition, rather than the invariance of the sequence, particularly since the former may be affected by such variables as mental age differences among others. In the original study, Piaget and Inhelder (1967) found that the spontaneous emergence of the verification strategies (visual sighting or manual measurement), the hard criterion for mastery of the diagonal, did not occur before age seven years "on average." When age was used as the primary classifying criterion, Dodwell (1963) found an "overlap" falling into the Piaget and Inhelder (1967) stages for constructing the projective straight line (Stage I, inability to construct straight lines; Stage II, success with one linear configuration; Stage III, mastery of the diagonal). However, it is probable that Dodwell's age overlap reflects a testing artifact since he failed to analyze for transitional (Stage II) patterns of performance, thus, masking out intra-individual differences in rate of acquisition. In the Laurendeau and Pinard (1970) study, results indicated that mastery of the diagonal, independent of the particular linear configuration (rectangular or circular) began to emerge between the ages of six years nine months to eight years seven months. Unfortunately, the Laurendeau and Pinard findings had limited generalizability because of failure to record systematically whether

verification strategies co-occurred with mastery of the diagonal.

The relevance of these findings concern the meaning of the verification strategies for understanding the relativity of the straight line and the possible relationship between conceptual and semantic aspects of the spatial dimension of length.

First, because the aiming, or visual sighting, strategy is completely visual, it is vital to not only the notion of the projective straight line but also the psychological reality of the representational space construct. As defined, the aiming strategy cannot be a perceptual strategy but a conceptual strategy derived from the active representation of an operational intellectual system "a method by which the child links two points by putting the distant point in line with the near (Piaget and Inhelder, 1969, p. 165)." Piaget and Inhelder do comment, however, that in terms of experimental design, no reason exists as to why the child should prefer a projective method to the exclusion of an Euclidean method such as manual measurement because of the assumed psychological--and logical--interdependence of the projective and Euclidean reference systems and their simultaneous development. But, it would appear that a Euclidean or manual method (for example, drawing an imaginary straight line with a finger, bringing the hands together to estimate distance, etc.) would need to be reverified perspectively if the notion of a projective

straight line is to remain consistent.

Secondly, none of these studies were interested formally in evaluating the semantic content of either their verbal instructions to the child or the nature of the child's verbal descriptions in response to the task (Dodwell's [1963] findings may have been influenced by his instruction to put the toothpicks "between" the two posts). Unlike the left-right relation which has a more direct semantic referent, the semantic equivalents of "before-behind" are not as readily apparent in a task of this kind. Certainly, the relation of before to behind can be considered as being semantically equivalent to "in front of" and "in back of," if not the actual words "before" and "behind," and related to the manner in which the child comes to verbally encode the relativity of "the straight line." In terms of comprehension, both Piaget and Inhelder (1967) and Laurendeau and Pinard (1970) have noted that "straight" is not well understood by children under the ages of two to two and one-half years.

The study by Olson (1970) was specifically interested in the role of language in the child's acquisition of diagonality as well as the psychological reality of a representational space. Olson's experimental paradigm was dissimilar to those discussed above. Furthermore, it can be questioned whether his tasks were actually tapping construction of the diagonal in terms of reconstruction between varying reference

points since his two to six year old subjects were asked to copy a model according to a checkerboard pattern. While finding considerable support for the priority of cognitive space on mastery of the diagonal, Olson found also a number of children who were able to encode verbally the meaning of the diagonal but who were unable to construct it stably. Conversely, children at age five years who were able to construct the diagonal were not always able to provide a satisfactory verbal account of their action. Because of the apparent priority of the child's conceptual strategies in mastering the diagonal, Olson concluded that the general role of language on acquiring diagonality was better understood as "one means of directing the child to the critical aspects of the diagonal or to their interrelationships (Olson, 1970, p. 95)." His work, and that of Flavell (1968) and Hollos and Cowan (1975) on the communicative accuracy of subjects in the six to nine year range in effectively paraphrasing a story or instructions, suggests that at any given point a lag may exist between performance mastery on a particular task and the verbal capacity to encode that action according to the child's specification of his internal criteria.

Studies on the semantic acquisition of "in front of" and "in back of"

More substantial evidence for correspondences between cognitive and semantic space and for the psychological reality of a representa-

tional spatial structure comes from a number of recent investigations which have intentionally explored the relationship between early knowledge of the surface plane and comprehension of words which pertain to the surface plane (Brown, 1973; E. Clark, 1973a, 1973b, 1974; Hess and Cook, 1975a), and comprehension of the semantic relations which encode the projective space cognitive relation of before to behind (Parisi and Antinucci, 1970; Harris and Strommen, 1972; Yendovitskaya, Zinchenko, and Ruzskaya, 1974; Kuczaj and Maratos, 1974; Hess and Cook, 1975a). With the exception of Parisi and Antinucci (1970), only preschool subjects have been investigated.

The surface plane: in and on. --That the early language-learner soon begins to encode semantically aspects of spatial externality is found in the longitudinal data obtained from Adam, Eve, and Sarah (Brown, 1973). By Stage II, when MLU was 2.0 to 2.5 (equivalent to the chronological ages of nineteen months, twenty-seven months, and twenty-nine months for Eve, Adam, and Sarah, respectively [Cazden, 1968]), "in" and "on" had become semantically "principled" or distinguished. Moreover, Brown contended that the semantic encoding of these elementary locational terms derived from the child's non-linguistic knowledge since "in" referred to containment and "on" to surface or support. Two types of evidence are available from his data to buttress this hypothesis: first, order of acquisition in child speech

was related inversely to frequency of occurrence of the words in parental speech and, second, sequence of acquisition was simultaneously derived from the non-linguistic knowledge that location is first defined by "a moveable object and a locus (which) becomes differentiated into locational containment and locational support (Brown, 1973, p. 330)." The latter evidence comes from a series of "in" and "on" experiments presented in obligatory contexts with sentence pairs used as the stimuli, for example, "Put the dog in the cup," "Put the dog on the cup (in the latter case, the child needed to invert the container)." In the second instance, Brown found an "initial tendency" to use the cup in the non-inverted manner but, following a few trials, the "in"- "on" distinction was used appropriately. "Therefore, I conclude that they understood the semantic distinction but were briefly thrown off by requests to use an object of fixed function in an unaccustomed way (Brown, 1973, p. 330)." In other words, Brown takes this as confirmatory evidence that these two relations could not have been learned as individual vocabulary items or set phrases. What Brown fails to take note of is the fact that the meaning of "in" and "on" were not fully acquired given the cognitive context in which the alteration of both reference points and orientation functioned to define the stability of comprehension. Thus, for the young language learner, it is apparent that while containment and support are necessary to define object

location they remain insufficient since relative position cannot be eliminated as a criterial feature in the construction of either cognitive or semantic hypotheses about object location and orientation and the words which encode these relationships.

The importance of relative position to the child's construction of semantic hypotheses about the spatial relations between two objects when reference points are varied appears reverified in a series of novel experiments conducted by E. Clark (1973a) with subjects from eighteen months to three years of age.

Clark found that whether the task presented was one of copying the location of object x to object y (in which no locative words were used) or one in which the child had to reconstruct prior knowledge of location (on the basis of presentation of "in," "on," and "under"), object orientation played a crucial role in the comprehension of "on" and "under." Because the youngest subjects (eighteen months to twenty-three months) needed to reinvert a given object, for example, a glass, to its normal orientation, thereby, placing x "in" the glass rather than "on" (when "on" was the stimulus), Clark (1973a) stated "This suggests that young children may have certain expectations about the proper orientation of objects based on their experience of what the usual orientation is (E. Clark, 1973a, p. 172)," an explanation similar to that given by Brown (1973).

An alternate explanation would state that, while these young children comprehended that "on" referred to spatial location by virtue of the fact that their action was specific to a locative function, the orientation of the object was irrelevant in the formation of their cognitive hypotheses. Rather, what they seem to be relying on is what Meyer (1940) termed a "practical space" in which objects exist only in relation to the child's actions but not in relation to each other. That these children were not evaluating the relation of one object to another--in effect, they were using a topological analysis in evaluating each object in isolation--is suggested by the systematic error strategy employed in another Clark (1973a) modeling task. In this case, three "no contact" conditions were presented (x beside an upright glass, x beside a block, and x beside a bridge). These younger subjects reproduced the configuration so that contact was established. In other words, spatial interval was irrelevant but the topological properties of proximity and boundaries were important as criteria for reproduction.

Clark (1973a) notes further that when perceptual cues are increased, i. e. , when the child is given two identical reference points which differ only in orientation, the task is easier than when only one reference point is presented, for example, one inverted glass.

In a pilot study, children were asked to manipulate

an RP (reference point) so that it would conform to the instruction given. For example, if the RP was an upright glass but the instruction contained the word *ON* (author's italics), the child was to turn the glass up-side down so as to be able to place x on a surface. This task proved to be very difficult even for considerably older children (E. Clark, 1973a, p. 173).

The increase in task complexity is explained by the added variable of object manipulation. It is equally feasible that the more immediate obstacle to aligning cognitive hypotheses with semantic hypotheses derives from the fact that the one object task involves the capacity to anticipate a transformation of relative position whereas the two object task can be solved on the basis of perceptual identity. Therefore, it follows that the two object task is solved by more children at younger ages than the one object task.

Whether the child's conceptual organizing principles rather than his "perception of the normal or expected spatial relations that may hold between objects in the real world (E. Clark, 1974, p. 119)" function as the primary determinant for the manner in which relative spatial reference becomes encoded will be explored further in the review of "in front of-in back of"; however, available evidence seems to justify the conclusion that the comprehension of the surface plane terms "on" and "in" stabilize by age three, at least for structured experimental contexts (E. Clark, 1973a, 1974; Hess and Cook, 1975a) and are used correctly by age five years eleven months in production

tasks in which the child must verbalize the spatial relationship between two objects (Hess and Cook, 1975a).

The projective dimension of length: in front of-in back of. --

In a study with eighty kindergarten subjects ranging in age from four years nine months to seven years five months, Harris and Strommen (1972) asked the question of whether knowledge of body dimensionality, with respect to the distinct physical and functional differences between "front" and "back," was related to the semantic knowledge that objects had "fronts" and "backs." All subjects were presented with two sets of objects, "featureless" objects in which front and back were ambiguous (for example, glasses and blocks) and "featured" objects on which fronts and backs were more clearly defined (dolls, toy vehicles, a doll house, and chairs). Each object set was presented under two different conditions: (1) object-as-referent in which the child had to place object x "in front of," "behind," and "beside" object y, the featured or non-featured object and (2) self-as-referent in which the child was instructed to place x "in front of," "behind," etc., himself.

Although Harris and Strommen intended to identify patterns of performance regularity, their results are suspect because of serious problems in test construction and sample selection. First, given the wide variability in age of their kindergarten subjects (from less than five years of age to seven and one-half years), the authors appeared

not to have controlled formally for IQ differences. The only information provided was that their subjects were "somewhat above average IQ (Harris and Strommen, 1972, p. 260)." A more serious objection relates to the content of their instructions to the child. In neither the self-as-referent nor the object-as-referent conditions were subjects told to place x "on the y's front (back)." Instead, they were told to "put x in front of y" or place x in front of (yourself)." The authors state that, irrespective of featured object "face" orientation in the object-as-referent condition, seventy-nine of eighty subjects produced correct placement. However, what has not been satisfactorily ruled out is the possibility that some or all subjects were not analyzing "in front of" relatively but absolutely as "on the front(side)," using a correspondence procedure. This possibility receives further reinforcement in the notation by Harris and Strommen that on 50 percent of trials in this condition, the object was rotated by the experimenter necessitating reorientation by the child for correct placement. The fact that no child had difficulty across their rather broad age span may be more a testimony to the ability of this age group to match fronts and backs than to the knowledge that "in front of" and "in back of" are relative. If a correspondence procedure did not predominate then there is no reason why placement of x should have always corresponded to the front of the referent object since "in front of" could apply equally to

a left-right placement relative to the referent object. In fact, the latter placement pattern occurred in one instance with the featureless objects.

Moreover, the instructions also appeared to increase chances for correct placement since the examiner indirectly indicated possible locations:

You can put it anywhere on the board that you like. You can put it here (indicating the side closest to the child), or here, or here (etc., indicating with sweeping movements of his hand all areas of the board (Harris and Strommen, 1972, p. 261).

A third objection has been raised by Kuczaj and Maratos (1974) who pointed out that no distinction was made between (1) objects with "intrinsic" fronts and backs not subject to contextual change independent of the viewpoint, or perspective, of the observer (e. g., as opposed to the well-defined front and back of a human figure, the front of a car is that side in which direction consists of forward movement; however, when one stands by the side of a car and is requested to stand "in front of", an ambiguous situation is created) and (2) "non-fronted" objects which Kuczaj and Maratos (1974) term as totally situationally dependent since changing one's position in relation to a non-fronted object (e. g., a tree) results in equivalent changes in what is designated as the "front." In regard to non-fronted objects, Kuczaj and Maratos do not mention another possibility--that of maintaining one's own spatial position but imagining the possible position of another object, thereby, altering the designation of both "front" and "in front of." This possibility

will be reviewed more extensively in the section dealing with coordinating perspective.

In summary, the Harris and Strommen (1972) findings about the order of acquisition of "in front of" and "in back of" are inconclusive because of the objections outlined above.

A second study on the order of acquisition of "in front of" and "in back of" by Kuczaj and Maratos (1974) does tend to support the premise that the topological use of "in front of," that is, "on the front," is the product of an application of a particular semantic strategy derived from prior cognitive spatial strategies. Furthermore, their results demonstrate that such knowledge is independent of prior knowledge of the front-back axis of the body.

Five tasks were administered to forty-five subjects who ranged in age from thirty months and fifty-four months (and, thus, were younger than the Harris and Strommen (1972) sample): (1) the self-referent condition, two objects were placed successively "in front of," "in back of," "on the side of" self; (2) the touch condition in which the subject was asked to "touch" the front and back of eight small toys; (3) a placement of fronted objects task wherein the subject was given a standard object (a model of a small boy) and asked to place that standard "in front of," "in back of," and "on the side" of the objects from the second task; (4) a placement of non-fronted objects task which was instructionally identical to the third task but used non-fronted objects; and (5) a

generalization task in which two nonsense machines were used to assess the child's concept of front and back with novel objects.

Six predictions were made as a test of the H. Clark (1973) and E. Clark (1973b) Semantic Feature Hypothesis.⁷ It was predicted that knowledge of own person front, back, and side were the initial acquisitions. Similarly, knowledge of object fronts presaged knowledge of object backs in conditions where objects had clearly defined perceptual fronts (fronted objects) and then to less clearly defined perceptual fronts (non-fronted objects). The last prediction concerned the late acquisition of generalizing knowledge of front, back, and side to novel instances.

Data analyses found: (1) an age effect (older subjects' responses were more accurate than younger subjects); (2) a task effect; (3) an age-task interaction (older subjects differed from younger subjects on some tasks more than others); (4) no significant variability between front and back responses for any of the tasks; and (5) poorer performance with "side" than with "back" on self-referent and placement tasks with fronted objects only. This contradictory finding is not clearly interpreted, possibly because "side" is not necessarily equivalent to "front (side)" and "back (side)" with respect to the original instruction to the child. More likely, "side" refers to the left-right dimension; i. e., "put x on the side of y," adding a relational element. Furthermore, even though fronted objects were responded to more accurately than non-fronted, when placement

was demanded ("Put it in front of. . .") rather than touch ("Touch the front"), the activity of touching absolute fronts and backs proved easier than the activity of placing or linking relative position of self to objects, a finding replicated by Hess and Cook (1975a) for ten spatial terms in a preschool population. Despite the fact that the child independently knows the meaning of front and back, it would appear that definitions dependent on perspective relations are more difficult than meanings which refer only to the external or topological characteristics of the objects themselves.

In addition to finding only minimal support for the Semantic Feature Hypothesis, since front and back appear to be simultaneous acquisitions unrelated to particular object categories, the Kuczaj and Maratos results lend greater weight to the Barroso and Braine (1974) hypothesis that the child's organizing principals, or strategies, assume priority in the evaluation of both cognitive and semantic input rather than object features or structural equivalences among features.

"Children seem to learn various principals which allow them to define front and back for these objects in a way that does not favor any type over the other (Kuczaj and Maratos, 1974, p. 124)." Since only one-quarter of their sample could meet performance criteria for "in front of" and "in back of," it is apparent that the lexical acquisition of the projective "before-behind" relation remains an acquisition of middle

childhood, an emergence consistent also with results reported earlier by Parisi and Antinucci (1970) for forty Italian children, ages four to nine years.

A final comment pertains to the use of dimensional terms in children's verbal descriptions of spatial relationships. Few studies have addressed this issue. The study by Hess and Cook (1975a) included the child's production of such terms as "in front of" and "in back of" and "over," "above," and "below" in verbal production tasks. But, the specific eliciting contexts were not described in their procedure while order of acquisition for the ten prepositions was not delineated in regard to either comprehension or production.

Another source for data relating to children's verbal description of spatial relationships comes from Russian studies on the acquisition of "orientation in space" in the preschool child. Yendovitskaya, Zinchenko, and Ruzskaya (1974), in a review of such studies, cite an experiment by Kozyreva in which:

children from a younger kindergarten group were asked to arrange model furniture precisely in the same way as it was found in their living room ...correct reproduction of spatial relationships occurs only under conditions in which the child employs in his speech, accompanying his activity, such words as *AHEAD OF*, *NEXT TO*, *IN THE MIDDLE OF*, *BETWEEN* (authors' italics), etc. On the other hand, whenever the child limits himself to common, undifferentiated, verbal descriptions of space that do not reflect relationships (such as *HERE*,

THERE, RIGHT HERE (authors' italics), he is not able to complete the task successfully.

Inclusion in the child's verbal repertoire of such words as ON, UNDER, ABOVE, IN FRONT OF, BEHIND, TO THE RIGHT, TO THE LEFT (authors' italics), etc., indicating spatial relationships of objects, facilitates the isolating and the abstracting of spatial relationships and the forming of spatial representations (Yendovitskaya, Zinchenko, and Ruzskaya, 1974, p. 38).

Given the Russian theoretical orientation of the priority of speech in facilitating thought structures, the cited passage is interesting for several reasons. First, there is the implication that movement is related to the formation of a conceptual system of spatial representation and, hence, is related to the words which children use to encode relative spatial reference. Secondly, the use of descriptions as "here," "there," "right here" seem to refer only to a general recognition of object location in terms of an evaluation of external, or topological, qualities. In contrast, the use of such projective--dimensional--terms as "in front of," "behind," "above," "to the left of," etc., appear to be interpreted as specifying the relating of internal properties. Finally, the passage can be understood as supporting the view that spatial representation is integral to the comprehension and use of dimensional terms. Unfortunately, the authors do not discuss the relative difficulty of these semantic relations. Piaget (1968) and Piaget and Inhelder (1967) have stated that "to the left of" is not equivalent in meaning to "the left (side)" or "on the left" because "to the left (or right) of" can only specify

the internal relationship of objects to each other according to the observer's perspective. In other words, "on the left" or "on the right" are topologically-based descriptions which "can only refer to alternate directions of travel along a linear series (Piaget and Inhelder, 1967, p. 210)."

The basis for this statement will be examined next.

Concepts of left and right

The developmental character of the second spatial dimension, that of width, has been studied in the context of the acquisition of absolute and relative left and right relationships, own and other person laterality and self in reference to the relative position of a series of objects according to the point of view imposed upon them. Concepts of left and right were initially studied in 1928 by Piaget (Piaget, 1968) with findings replicated by Elkind (1961), Belmont and Birch (1963, 1965) and Laurendeau and Pinard (1970), the latter a large-scale study on the child's developing (representational) concept of space.

The original Piagetian inquiry procedure (Piaget, 1968) consisted of six question sets: (1) four questions of own person identification ("Show me your right [left] hand [eye, ear, etc.]); (2) four questions of oppositional left-right ("Show me my right [left] hand [eye, ear, etc.]); (3) two questions referring to endpoint position with two objects

("Is the pencil to the right or to the left of the penny?"); (4) same procedure as (3) but with the child opposite the examiner; (5) six questions relating to three objects in a row in which the location of the central object becomes crucial to defining relative position; and (6) the identical procedure to (5) but with two important changes--one object is substituted for the other from the previous set and all three are shown to the child for only thirty seconds after which they are hidden from view. Piaget (1968) considers the hidden object task the only criterion for verifying true mastery of relative left and right.

For test 12 (hidden objects), having the same logical structure as test 11 (three visible objects), calls in addition for retention of the data by means of a certain topological memory(knowing the position of three objects in a row which have been presented for half a minute). It is simply a matter of imagining the relations instead of merely seeing them (Piaget, 1968, p. 110).

In other words, the conceptual notion of the internal relation of left and right derives from the formation of a visual image whose function is to assist in maintaining the invariance of the relationship (Piaget and Inhelder, 1971).

The three replication studies found similar results for the child's mastery of own person left-right (see Table 3), the latter an apparent product of the end of the preschool years. Marked differences emerged among the studies with respect to the mastery of other person and relative left-right. The surprising finding pertains to the late

TABLE 3
METHODOLOGY: ABSOLUTE AND RELATIVE CONCEPTS OF LEFT AND RIGHT

Study	Subjects	Procedure	Criteria	Absolute (CA) ^a		Relative (CA)	
				Own Person	Other Person	3 Visible Reversed ^b	3 Hidden
Plaget (1928)	240; 4-12; 100 male 140 female (Swiss)	Six question categories	All questions correctly answered; 75 percent mastery by age level to analyze stage	5	8	11	12
Elkind (1961)	210; 30 at each CA level from 5-11 (American)	Same with modification	Same	5	7	10	not given
Belmont & Birch (1963, 1965)	50; 9:4-10:4 (English)	Same with modification	All questions answered correctly; 75 percent mastery for comparison to poor readers.	98%	82%	46%	36%

(Continued)

TABLE 3--Continued

Study	Subjects	Procedure	Criteria	Absolute (CA) ^a		3 Visible	Relative (CA)	
				Own Person	Other Person		3 Visible Reversed ^b	3 Hidden
Laurendeau & Pinard (1970)	400 (See Table 2) (French-Canadian)	Intra-question modification	All questions correctly answered; item analysis; scalogram for stage relation.	4:6-5:8 ^c	7:9 10:11	7:9 10:11+	not given	7:9 10:11+

^aCA denotes chronological age at which behavior attained.

^bTask refers to the same three visible objects as used in the previous task but the child now views the object from a position 180° different from his original position.

^cAge ranges for each stage refer to age of attainment, the age where 50 percent of subjects evidenced the particular behavior. Laurendeau and Pinard (1970) use this description as equivalent to onset of a stage.

acquisition of the relative aspects of left-right, an onset not emerging until preadolescence (see Table 3 for details). Laurendeau and Pinard (1970), in commenting on this late acquisition, suggest that mastery may not occur until the formal operations stage of intellectual development.

An inspection of Table 3 indicates that, despite methodological diversity, the hierarchial organization of the acquisitions appears to hold cross-culturally. What stands out is the marked discrepancy between onset and mastery, a lag most obviously emphasized by the Laurendeau and Pinard data. Their subjects were French-speaking Canadian children who, according to information provided by Laurendeau and Pinard (1970, p. 26), seemed to have entered formal schooling one year later than their American counterparts. In contrast, Elkind's (1961) subjects, although randomly selected from a larger sample of 800 children residing in Boston, were all of Jewish background. With the exception of Belmont and Birch (1965), none of the studies controlled for mental age differences. However, Laurendeau and Pinard (1970) did utilize the most stringent test construction, for example, increasing each question set from four to six to reduce the possibility of chance success and increasing the level of performance criteria for determining both emergence and consolidation (they rejected Piaget's [1968] 75 percent mastery criterion as being theoretically meaningless for an understanding of stage). This set of interacting variables, the selective

effects of mental age, effects of a given cultural environment, and the general stringency of test construction, could explain obtained differences in the rate of acquisition within the sequence although they do not necessarily explain why the sequence takes so long to be mastered (the Belmont and Birch [1965] data suggest that IQ differences in an intellectually "normal" sample appear to have only minimal effect on the invariance of the sequence).

Finally, it should be noted that only Laurendeau and Pinard have formally categorized left-right relations as projective spatial relations. Moreover, they are the only investigators who have attempted even indirectly to account for why children fail to comprehend and produce relative left-right terms. In their analysis:

The child who correctly chooses the right, for example in replying to . . . ("Is the pencil to the left or to the right of the plate?") may be quite satisfied with thinking in absolute terms, as if the question did not include a second term ("Is the pencil to the left or to the right?"). Whether or not the second object mentioned in the question is repeated in the subject's response, the problem remains entirely one of whether the subject distinguishes between the expressions "to the right" and "to the right of (Laurendeau and Pinard, 1970, p. 298)."

Although they do not elaborate further, their analysis would seem to imply that some children interpret a request for relative position as though it were a reference to alternate directions of movement along the linear surface only (Piaget and Inhelder, 1967). In other words,

"to the right of" is understood as "to the right side" or "on the right side."

The coordination of perspectives

In the past few years, the child's capacity to coordinate multiple perspectives has attracted attention from investigators interested in verifying both the psychological reality of a representational spatial structure and possible external variables which might account for performance restrictions attributable to age.

Most studies have explored the coordination of perspectives using a modification of the Piaget and Inhelder (1967) "three mountains" task (see Figures 1, 2, and 3).

The original task developed by Piaget and Inhelder (1967) consisted of three problems: (1) asking the child to reconstruct the "snapshot" of the mountains from positions A, C, B, and D (see Figure 1); (2) successively changing a model figure's position (a "man") to B, C, and D, requiring the child to select pictures the man could have taken from the particular position; and (3) reconstructing the pictures from the positions the man had occupied previously. For each problem, the child gave a verbal description of each of the man's views from the four positions.

Two studies were designed to replicate the original study.⁸

Dodwell (1963) used the Piaget and Inhelder (1967) design while Laurendeau and Pinard (1970) modified material and tasks. They included three problems (F, C, and B). For each problem, a model man, approximately one inch high, without facial features, was placed successively at positions F, C, and B (see Figure 2). The child's task was to find, from five alternate pictures depicting various arrangements of the three mountains (see Figure 3), the one picture which appeared to correspond to the model's perspective. The child had to justify also his pictorial selection and to explain why he rejected the four other pictures. Problem F necessitated use of the

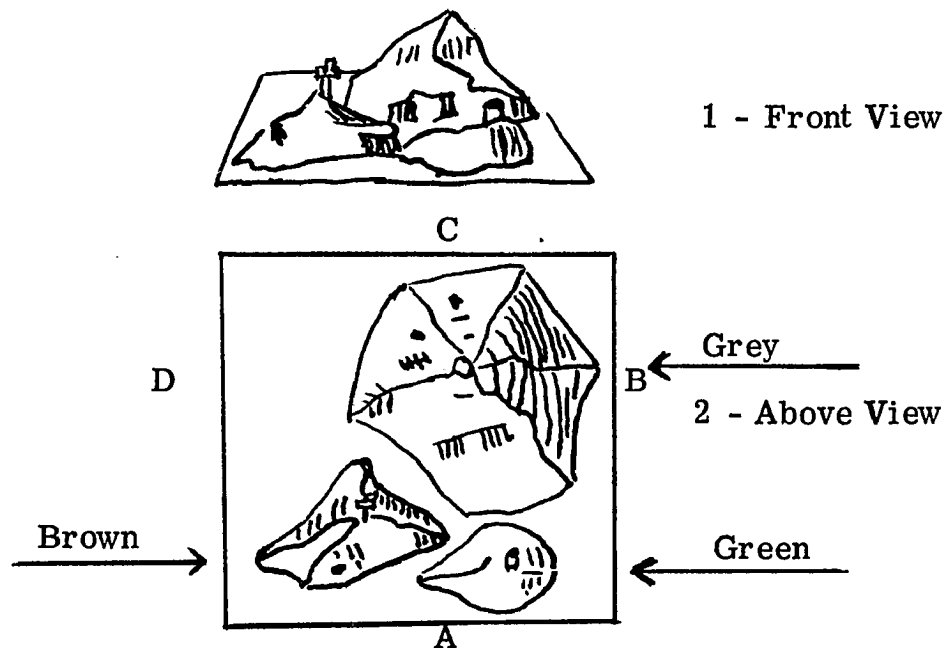


Figure 1. --Model of the three mountains task (Piaget and Inhelder, 1967, p. 211).

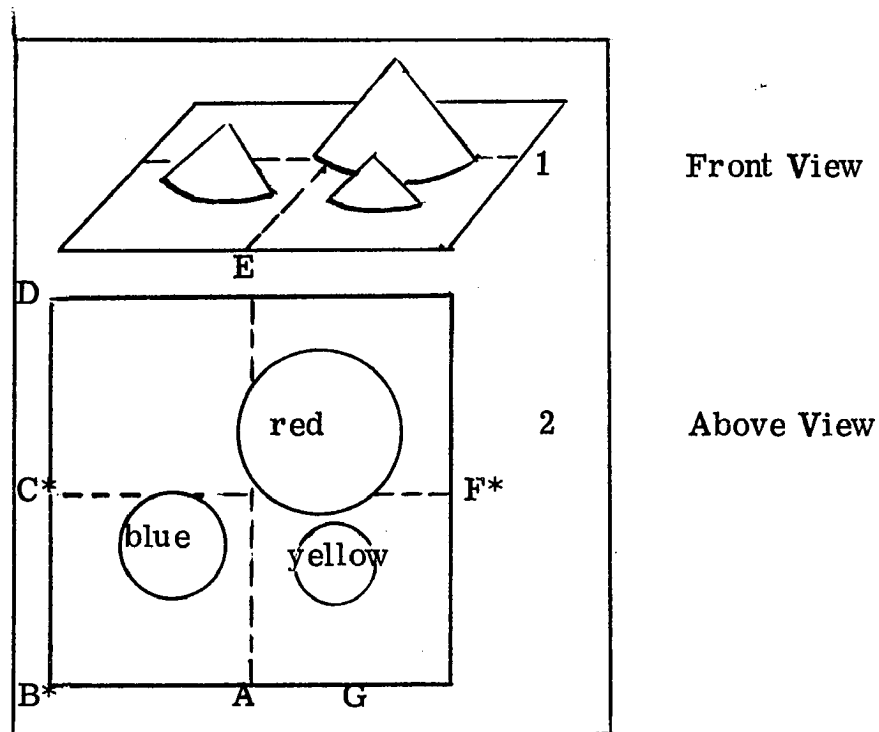


Figure 2. --Adaptation of three mountains task model (Laurendeau and Pinard, 1970, p. 314). F, C, and B denote successive positions of a one inch model man.

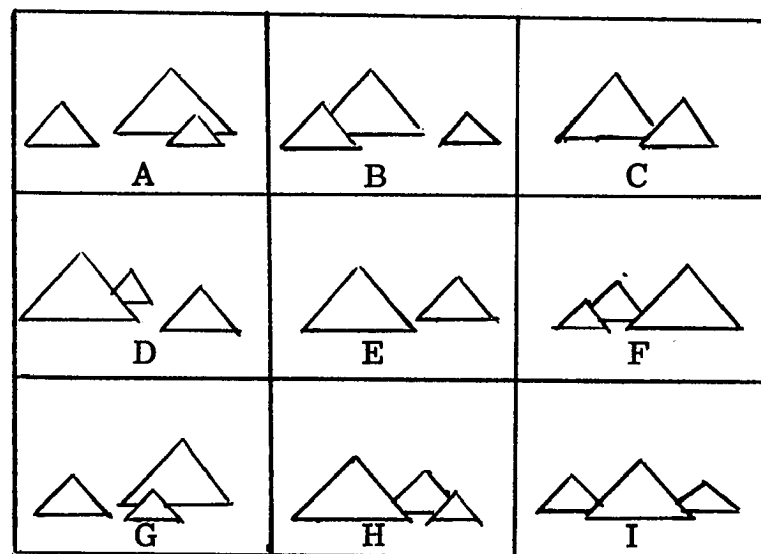


Figure 3. --Series of nine pictures representing different perspectives (picture I acts as a control since it is an impermissible perspective) (Laurendeau and Pinard, 1970, p. 315).

left-right relation for correct choice, problem C the before-behind relation, and problem B, a coordination of both dimensions for correct solution. Lastly, for problems F and C, the child was seated at position A while for problem B, he was stationed at position E. In none of the problems was the child allowed to move freely around the board. Thus, Laurendeau and Pinard (1970) altered Piaget and Inhelder's (1967) first task while maintaining similar conditions for the second and third problems.

Replication findings were generally consistent with those found by Piaget and Inhelder (1967) for invariance of the sequence. Coordination of either the before-behind or the left-right relation preceded the ability to coordinate both dimensions into a unitary system of spatial perspectives (see Table 4). Conflicting findings, for example, Dodwell (1963), appeared to have resulted from differences in the rate of acquisition. As in the task dealing with construction of the projective straight line, Dodwell (1963) found a "mixed" category of subjects (N=109) who "displayed different types of behaviour between the different items in the subgroup (despite their apparent similarity...) (Dodwell, 1963, p. 149)." These unclassifiable protocols may have been the result of Dodwell's method of analysis which excluded substages for coordinating perspectives and/or the nature of his criteria for performance. For example, his subject's were asked only to select the picture corresponding to the

TABLE 4
METHODOLOGY: COORDINATION OF PERSPECTIVES

Study	Subjects	Ages (CA)	Material	Verbal Justification	0	Stages**		
						I	II	III
Meyer ⁸ (1940)	NS * (German)	NS	NS	NS	NS	Practical space (below 7)	Subjective space (7-8)	Objective space (9-10)
Piaget & Inhelder (1948) (1967)	100 (Swiss)	21, 4-6 1/2 30, 6 1/2-7 33, 8-9 1/2 16, 9 1/2-12	Dimensions specified. Child remained stationary.	Verbal description of each of man's views from four positions.	NS	Fails to understand (below 7)	Egocentric view; attempts to differentiate viewpoints (transition-al) (7-8)	Incomplete relativity (transitional); Coordination or complete relativity (9-10 to 11-12)
Dodwell (1963)	194 (English)	NS	Similar to Piaget and Inhelder; dimensions NS	Child only asked to select correct picture.	NS	Egocentric view or random choice (5-9)	Transitional (5-10)	Complete coordination (8-10)

(Continued)

TABLE 4--Continued

Study	Subjects	Ages (CA)	Material	Justification	0	Stages**		
						I	II	III
Laurendeau & Pinard (1970)	448 (French-Canadian)	50 at each age from 4 1/2-12 (48 at CA 5)	Similar to Piaget & Inhelder but stimulus proper-ties & number of cards modified. Child moved own position.	Verbal description of man's position and justification of pictorial choice and rejections	Incomprehen-sion (below 6)	Complete egocen-trism (6-6 1/2)	Partial decentra-tion (8 1/2-11:8)	Operational coordination (11:8--)

* Information not specified.

** Ages refer to age of attainment.

man's point of view, a limited procedure most recently used by Hollos and Cowan (1975) in their study of Norwegian subjects from three different social class settings. Laurendeau and Pinard's (1970) results showed that children could select the correct view but not always for the right reason. Thus, in failing to include rejection criteria, many of Dodwell's "correct response" category may have been false positives. Laurendeau and Pinard noted that only forty of 448 subjects, including only 12 percent of their twelve-year-old sample, attained success on problem B according to their stricter performance criteria.

The effect of external variables on performance has been explored by several investigators. Brodzinsky, Jackson, and Overton (1972) studied the effects of minimizing distracting perceptual cues in an attempt to facilitate performance while Fishbein, Lewis, and Keiffner (1972) investigated the selective effects of task complexity (single versus multiple objects) on the mode of responding. Results of these studies were handicapped by alteration of performance criteria, thus, altering the basic task. Minnegerode and Carey (1974) intensified model complexity (increasing the number of perceptual cues, etc.) and found differences in performance by grade level in their third and fifth grade subjects according to single and multiple object arrays. In the single object array condition, only surface cues predominated mitigating a topological solution while, in the multiple object array, only coordination

of the internal (projective) relations could lead to a correct solution. Minnigerode and Carey found that, in the multiple object condition (which corresponded loosely to the three mountains task), the "attention" of their third grade subjects focused more often on the internal before-behind relation than on the left-right relation, a finding interpreted as supportive of the Piagetian hypothesis that before-behind relations stabilize prior to left-right relations.

Despite the fact that these three studies drastically altered both the basic task design and the criteria for determining how and when the child is able to coordinate perspectives, the internal consistency of the developmental sequence appears to remain intact.

None of the replication or external variable studies were formally interested in describing the possible hierarchial organization of spatial perspective terms. Minnergerode and Carey (1974) implied that such a hierarchial structure existed. For example, they noted that in the multiple object condition most of their third grade subjects used predominately surface terms, e. g. , "front" to describe the internal relation of "in front of. " Of the three projective space tasks, the coordination of perspectives task would seem to be the one where the nature of the child's verbal response is crucial to determining both acquisition and mastery. Secondly, the role of pictorial representation in influencing how the child describes a particular perspective has not

been pursued. Laurendeau and Pinard (1970) have argued that the child's difficulties with understanding pictorial or graphic symbolism is not the paramount factor in his inability to coordinate perspectives. Rather, they suggest it is his inability to consider any other viewpoint other than his own which functions as the primary obstacle.

Studies on the Abnormal Acquisition of Projective Space

Few studies are to be found in the literature which have addressed the issue of how children with either communication disorders or learning disabilities construct a representational spatial structure. The "dysphasic" or "dyspraxic" child's development has long been a matter of empirical interest for Piagetian theory because of the dual possibility that such children provide an alternate opportunity for studying mechanisms underlying the intellectual process and an unique opportunity to investigate the parallel development between symbolic imagery and language performance (Inhelder, 1966).

Ajuriaguerra (1966) has defined dysphasia as a general disturbance of linguistic function which cannot be ascribed to sensory or perceptual deficits. In a longitudinal study of forty dysphasic and dyspraxic subjects (ages unspecified), seventeen of whom were re-evaluated from two months to two years later after a "reeducation" program,

Aujuriaguerra noted that while improvement in communication ability occurred in terms of developmental changes in verbal comprehension and syntax the use of symbolism risked remaining "...highly idiosyncratic, quite removed from the common code which language represents (Aujuriaguerra, 1966, p. 123)." Assessment of the dysphasic sample indicated that performance on the WISC similarities sub-test of the verbal scale was an adequate indice of intellectual potential after age seven years despite poor performance on the other verbal sub-tests, an achievement that Aujuriaguerra explains by the non-analytic character of the task. In contrast to WISC performance patterns, when "Piaget-Inhelder" tests (also unspecified) were used diagnostically to allow greater performance flexibility, over 50 percent of the subjects were able to attain normal or superior performance patterns indicating only minimal delay in achieving concrete operational thinking. However, when given unspecified "tasks of spatial representation and figurative anticipation (Aujuriaguerra, 1966, p. 126)," 85 percent of the sample performed poorly. Aujuriaguerra does not elaborate further on this finding but does note that, despite the attainment of operational thought, two thirteen year old subjects had failed to make sufficient progress in achieving formal operations including a "proper grasp of language (Aujuriaguerra, 1966, p. 126)."

The extreme difficulty the Aujuriaguerra subjects had with spatial representation and the anticipation of spatial displacement (a finding similar to one found by Lovell, Shapton and Warren [1964] on the Kohs Block Designs with a group of poor readers) lends weight to the Inhelder (1971) hypothesis that one "abnormal constant" of both a language disorder and dyslexia involves problems in the systematic organization of logical relations rather than logical classes. Inhelder (1966) distinguishes further between a general deficiency of symbolic behavior, for example, childhood psychosis, and a specific restriction in the evocation and anticipation of symbolic imagery in the case of the child where normal potential exists to the extent that some degree of operational thought has been attained. In the latter instance, since the child is unable to evoke and to predict subsequent spatial displacement in a regular manner, he is considered as providing evidence for a "decalage" (lag) between operative and figurative forms of knowledge, the former a function of the mind's self-organizing activities and the latter knowledge obtained from the physical world which is itself transformed by operative knowledge.

Kershner (1970, 1971a, 1971b) and, most recently, Voyat (1975)⁹ have utilized the Inhelder framework in studying the spatial strategies of learning disabled and educationally disadvantaged children.

On the basis of test measures which included laterality preference tasks and tasks of reversed and rotated field configurations, Kershner (1971b) concluded that the persistent difficulty learning disabled children encounter in organizing a system of spatial reference may originate in a failure to form a representational spatial structure rather than mirror an inability to deal successively with immediately perceivable objects located within the visual field. However, Kershner's conclusion is questionable in view of his unclear methodology and apparent misunderstanding of the meaning of relative position. In defining the latter as the relationship of one figure to an adjacent point of critical interest or attention, Kershner confuses proximity relationships, which are topological (Piaget and Inhelder, 1967), with Euclidean relations involving knowledge of horizontal and vertical coordinates. Thus, exactly what he was measuring with his tasks remains ambiguous. In contrast, Voyat (1975) has incorporated specific tasks of spatial imagery into his studies of Indian children living on the Pine Ridge Reservation of South Dakota and low-income Black subjects in New York City.

Morehead and Morehead (1974) propose that the restricted creativity of the language-disordered child's linguistic performance reflects representational deficits. Lovell, Hoyle, and Siddal (1968), Brown et al. (1975), and Silver (1973, 1975) have suggested a parallel interpretation with language delayed preschoolers and language disordered

subjects in middle childhood and preadolescence whose less creative use of play and drawing were thought to mirror discontinuities in the symbolic function. These studies tend to support the thesis that disorders of spoken, and, indirectly written, language represent a qualitative difference in the methods by which language-disordered children organize cognitive and linguistic knowledge.

Studies on Two-Dimensional Space and the Comprehension and Production of Projective Spatial Relations

That the nature of the test, or instructional medium may selectively influence both the comprehension and production of spatial relations was not only recognized by Laurendeau and Pinard (1970) in their study of the child's development of a concept of space but also appears to be an important, although not well understood, variable in many studies on the characteristics which differentiate the achieving from the poor reader (Lovell, Shapton, and Warren, 1964; DeHirsch, Jansky, and Langford, 1966; Schafer, Hellig, and Rubin, 1974; Semel and Wiig, 1975). Two related issues arise from these studies in regard to the role of pictorial representation on the manner in which children understand and verbally encode locational and directional terms: (1) does mastery of these relational terms in three-dimensional space covary with comprehending a two-dimensional representation of the three-

relationship and (2) does mastery in the three-dimensional realm predict mastery of its pictorial representation? Twotypes of studies are available for review, those studies which have indirectly addressed the issue and cross cultural studies on strategies used by adults and children to interpret pictorial representations.

General studies

Swanson and Benton (1955), in collecting normative data on own person left and right, presented a front view picture of a boy to their elementary age subjects and found problems in interpreting oppositional left right despite the fact that some of the subjects could do so in three-dimensional space.

A study by Goodglass, Gleason and Hyde (1970) also included elementary age subjects in their investigation of such directional terms as "behind," "over," "under," and "next." Interested primarily in the "auditory language comprehension" of these directional prepositions, their three to ten year old subjects were tested by means of pictorial material described only as one or two girls placed in proximity to one or two cars. Results indicated that, even by age seven years, not all terms had been mastered in the context of pictorial representation. Since the relative difficulty of the various prepositions was not specified, the effect of pictorial representation on the verbal performance patterns

cannot be inferred. Also unknown is the degree to which their sample had either acquired or mastered these terms in three-dimensional space.

A final source comes from the Boehm Test of Basic Concepts (Boehm, 1971), a pictorial multiple choice test which attempts to assess children's understanding of "comparative terms." Standardized for use for children in kindergarten through Grade 2, test content consists primarily of spatial terms although there are other categories pertaining to time and quantity terms.¹⁰ Scoring of responses is dependent on a right/wrong criterion which provides only minimal insight into the nature of error patterns. However, the effect of medium on comprehension is indirectly commented on by Boehm (1971, p. 4): "It is possible that some children would be unable to answer items correctly in the test booklet but would respond correctly when comparing physical objects" (No data is offered to substantiate this statement). Although final test items were selected on the basis of their frequency of use in classroom instruction with respect to "concepts as presented on the printed page (Boehm, 1971, p. 4)," and their occurrence in verbal instruction, it appears that the frequency criterion functions to restrict generalizability of results. While over 50 percent of terms actually refer to space (which attests to the frequency of occurrence and importance of locational and directional concepts in the lower primary classroom),

Boehm fails to establish a logical sequence for any one group of spatial terms. Furthermore, test construction leaves unclear whether failure is a result of non-acquisition of the term or results from the child's applying a two-dimensional interpretation to a representation of a three-dimensional event.

Studies on cross-cultural pictorial space strategies

In contrast to procedures which ask only the limited question of "how many" pictures the child correctly or incorrectly responds to, pictorial space has been approached from the point of view of the strategies which the subject applies to interpreting the representation. The most extensive work on pictorial space has been done by Hudson (1960, 1967). Hudson designed a procedure in which the conventional depth cues of familiar size, overlap, and perspective were varied across six pictures while the conceptual content remained identical. In other words, the perceptual configuration varied as a function of the depth cues. In each picture, an African hunter with a raised spear, located on the left side, shared the same frontal plane with an antelope located on the right. In the background was an elephant reduced in size to represent relative distance and located equidistant between the man and antelope.

Hudson was primarily interested in defining the effects of culture on the transformation of three-dimensional space into its two-dimensional

representation. In the initial study (Hudson, 1960), both schooled and unschooled African children and adults were included in the sample but mental age was not effectively controlled with the result that the six to twelve year old white schooled sample developed earlier three-dimensional comprehension while the comparably aged black schooled sample still continued to interpret the pictorial representation in a two-dimensional or "flat" manner.

Hudson was not specifically geared towards exploration of the semantic aspects of pictorial space (although he was interested in the role of semantic evaluation as a determining strategy), but his verbal inquiry procedure is of some interest since the experimental criterion for "comprehension" cannot be dissociated from the content of verbal instruction and the content of the subject's response. For each of the six pictures pertaining to horizontal space (the man and antelope sharing the same frontal plane), three questions were asked: "What do you see?," "What is the man doing?," and "Which is nearer the man, elephant or antelope?." While even his unschooled adult subjects could name the objects contained within the picture, the relation of "nearer" was frequently interpreted as "near," that is, the response seemed to be based on a topological evaluation of the perceptual proximity of the spear to the elephant rather than based upon the internal projective relationship of the three objects to each other relative to the position of the

observer.

Despite the limitations of his verbal inquiry procedure, Hudson rejected the influence of semantic structure as a confounding variable because:

Candidates in all samples, choosing the elephant as the hunter's quarry, were those who perceived the elephant as nearer the hunter than the antelope. This means that the whole manifest content of the picture tended to be perceived two-dimensionally, and appropriately interpreted. The occurrence of this phenomenon is considered a function of perceptual organization and not merely a semantic evaluation (Hudson, 1960, p. 203)."

It is equally possible that the Hudson subjects two-dimensional interpretation was the product of their stage of construction of a representational spatial structure.

Mundy-Castle (1966) replicated the Hudson research in studying 122 schooled Ghanaian children from five to ten years of age. Both the number of pictures and the questioning procedure were modified. Mundy-Castle reduced the picture set from six to four (one familiar size, one overlap, and two perspectives). Stimulus material dimensions differed considerably from those used by Hudson (1960). The Mundy-Castle pictures measured approximately 24" x 48" compared to Hudson's 20" x 15". Additionally, Mundy-Castle included seven questions all of which were followed by a request for the child to verbally justify his decision. Question content varied also. While Hudson asked "Which is nearer?" Mundy-Castle asked "Which is closer?." Although it is probably valid to assume that these two terms are semantically

equivalent for the adult, depending on context, they may not be equivalent for the child. Performance criteria were similar to Hudson's. "Elephant" responses were assigned two-dimensional status and "antelope" responses three-dimensional status.

Hudson (1960), in analyzing for the relative difficulty of the three depth cues, found perspective a later acquisition than overlap. In contrast, Mundy-Castle (1966) did not report an analysis of item difficulty. He mentions only that even older subjects were still dependent on a two-dimensional strategy. Moreover, Mundy-Castle discounted the influence of object identification on performance because subjects encountered difficulty only with the labeling of the perspective depth cue (two converging lines representing "road" and a horizontal line denoting the "horizon"). It is unclear whether this particular difficulty reflected developmental limits on the mobility of spatial imagery or lagging acquisition of perspective cues and labels for the oldest subjects. The latter explanation is more likely since the Mundy-Castle subjects always tended to relate both the horizon line and the road to an existing schema. For example, the horizon line would be interpreted as "a ruler for measuring the tree so that its height might be known (Mundy-Castle, 1966, p. 193)."

More importantly, the nature of the error strategies employed by these children typically consisted of reference to the proximity either of the man to the elephant or of the elephant to the antelope. However,

the content of the instructions used by both Hudson (1960) and Mundy-Castle (1966) may have acted to produce this non-representational spatial strategy. In both studies, the only spatial relationship subjects were asked to evaluate was the above-below relation (corresponding to the third spatial dimension, volume), a relation which appears to be an emergence of a fully coordinated system of spatial perspectives during the preadolescent period (Piaget and Inhelder, 1967; Laurendeau and Pinard, 1970). None of the eleven samples used by Hudson or the Mundy-Castle child sample were asked to evaluate the before-behind or left-right relation.

It seems obvious that restricted experience with a diversity of pictorial material may explain why less acculturated groups do not perform as well on pictorial tasks as do comparable Western samples. Whether familiar object identification is equally dependent on cultural variables remains unknown. Gibson (1963), in analyzing Hudson's (1960) findings, goes so far as to suggest that object identification is independent of educational experience and "identifying objects in pictures, even when they are portrayed by simplified line drawings is culturally universal (Gibson, 1963, p. 172)." The veracity of Gibson's observation appears weakened by the recent research of Hess and Carlson (1975b) who asked thirty two to four year old subjects to identify four

prepositions (in, on, under and over) in three different contexts-- object identification, photographs of the objects, and line-drawings of the objects. Line-drawings, identical to the type of drawing used by Hudson (1960) and Mundy-Castle (1966), influenced comprehension of the prepositions while object identification and photographs did not. Thus, it would appear that the form of the pictorial representation contributes to how particular sets of semantic relations are understood and used as well as general experience with the pictorial medium.

Summary

The following conclusions can be drawn from the review of the literature on the psychological reality of a representational spatial structure:

1. Empirical evidence supports the invariance of the sequence underlying the construction of a three-dimensional system of spatial perspectives. Acquisition of the most complex above-below relation (corresponding to volume) appears to entail prior acquisition of both the before-behind relation (corresponding to length) and the left-right relation (corresponding to width) (Piaget and Inhelder, 1967; Dodwell, 1963; Laurendeau and Pinard, 1970). Similarly, the acquisition of relative concepts of left and right entails prior knowledge of at least before-behind and the location of absolute left-right in reference to self (Elkind, 1961; Belmont and Birch, 1965; Laurendeau and Pinard, 1970;

Minnegerode and Carey, 1974).

2. The emergence of a projective spatial structure appears not to occur prior to the onset of middle childhood (Piaget and Inhelder, 1967; Dodwell, 1963; Olson, 1970; Laurendeau and Pinard, 1970) while the attainment of a fully coordinated three-dimensional knowledge of space is reached only in late preadolescence or early adolescence (Piaget and Inhelder, 1967; Laurendeau and Pinard, 1970). Conflicting findings regarding age of onset and attainment may be accounted for on the bases of possible sampling biases (Lovell, 1959, 1971), failure to analyze for transitional patterns of performance between substages of a particular relation (Dodwell, 1963), and increasing or decreasing task complexity (Dodwell, 1963; Brodzinsky, Jackson, and Overton, 1972; Fishbein, Lewis, and Keiffner, 1974; Hollis and Cowan, 1975). In general, conflicting results have pertained to differences in the rate of acquisition rather than the invariance of the sequence. Because of the apparent hierarchial organization of the three projective relations, the data suggest that differences between stages are qualitative differences with respect to the nature of the child's strategy for organizing the relations of before to behind, left to right, and above to below.

3. Prior to the emergence of a representational spatial structure, the child appears to operate with a less cognitively complex strategy in which objects exist only in relation to modification by self

and not in a modifying relation to each other (Meyer, 1940). The pre-school years from age two to five seem characterized by a mode of operation in which only the external, or topological, features of objects are relevant while object orientation remains irrelevant to the formation of cognitive and semantic hypotheses about surface relations and their corresponding semantic relations (Laurendeau and Pinard, 1970; Parisi and Antinucci, 1970; Brown, 1973; E. Clark, 1973a; Barroso and Braine, 1974; Yendovitskaya, Zinchenko, and Ruzskaya, 1974). Whether relative spatial reference becomes encoded semantically on the basis of the child's cognitive expectations for the structural relationships which hold among physical objects (E. Clark, 1973a; Brown, 1973) or on the basis of conceptual organizing principals (Piaget and Inhelder, 1967; Laurendeau and Pinard, 1970; Barroso and Braine, 1974; Kuczaj and Maratos, 1974) appear to have important consequences for explaining spatial organization.

4. The lexical acquisition of dimensional terms seems to parallel the early topological spatial structure. Terms which refer to the general surface plane are acquired before terms which have as their referent the surface plane of the front-back axis of the body--at least with respect to comprehension (Parisi and Antinucci, 1970; E. Clark, 1973a, 1974; Kuczaj and Maratos, 1974). Little data are available on how children use topological terms which refer not

only to the front-back distinction but also to the linear distinction between left and right. The latter has been studied only in the context of the cognitive awareness that left and right exist as a lateral direction on self and others (Swanson and Benton, 1955; Belmont and Birch, 1963, 1965; Elkind, 1961; Piaget, 1968; Laurendeau and Pinard, 1970).

The acquisition of dimensional terms which refer to the internal relations between objects according to the observer's perspective also parallel the formation of a projective spatial structure. Relational terms which have as their referent the dimension of length (in front of-in back of) are acquired after front and back (Parisi and Antinucci, 1970 ; Kuczaj and Maratos, 1974) and indirectly correspond to attainment of the before-behind relation as realized by the construction of the projective straight line. Lexical mastery of relative left-right (to the left or right of) can only be inferred as a product of preadolescence on the basis of studies which have tested for conceptual understanding of the relativity of left and right in relation to the observer's projection of viewpoint (Belmont and Birch, 1965; Elkind, 1961; Piaget, 1968; Laurendeau and Pinard, 1970; Minnegerode and Carey, 1974). In a similar manner, lexical mastery of the above-below relation, the most cognitively complex relation, is inferred as an attainment of early adolescence at least for French Canadian subjects (Laurendeau and Pinard, 1970), and

schooled Ghanaian subjects (Mundy-Castle, 1966).

The data summarized above appear to justify the conclusion that the acquisition of topological and projective semantic relations is developmentally ordered and invariant.

5. An inverse relationship appears to hold for both three-dimensional and two-dimensional space between knowledge of projective relations and knowledge of particular object classes (Hudson, 1960; Mundy-Castle, 1966; Kuczaj and Maratos, 1974) but how the object is represented pictorially, for example, a more realistic photographic representation versus representation by line-drawing, may function selectively to influence object recognition in the preschool years (Hess and Carlson, 1975b).

6. Acquisition and mastery of the conventional artistic depth cues in pictorial space appear to follow the developmental order familiar size, overlap, perspective. These depth cues are necessary for evaluating relative distance and depth (Hudson, 1960; Kaufman, 1974). However, while depth cues are necessary for judging the relationship of objects to each other in a linear medium, they appear to be insufficient because of their primary function as surface cues. Moreover, given the fact that perceptual configurations vary either with change of position of the objects or the observer and, therefore, vary according to the observer's perspective, the invariance of the underlying conceptual

relations seems to be crucial in applying a three-dimensional interpretation to a two-dimensional representation of a three-dimensional relationship.

7. Pictorial representation may be a more complex medium than traditionally thought particularly when the child is still in the process of mastering projective spatial relations (Swanson and Benton, 1955; Goodglass, Gleason, and Hyde, 1970; Boehm, 1971).

8. Some evidence is available that children with known language disorders may have a specific restriction in the formation of symbolic imagery (Aujuriaguerra, 1966; Inhelder, 1966, 1971; Lovell, Hoyle, and Siddal, 1968; Morehead and Morehead, 1974; Brown, et al., 1975; Silver, 1973, 1975) which indirectly implies that the manner in which they organize conceptual and linguistic knowledge is qualitatively different. Little is known about how poor readers, whose spoken language appears superficially intact, construct a representational spatial structure. The data reviewed under traditional approaches to disorders of written language suggest that truly learning disabled children may evidence qualitative differences in their construction of a system of spatial perspectives and in their construction and reconstruction of projective spatial terms in both three-dimensional and two-dimensional mediums.

FOOTNOTES

CHAPTER II

¹Klasen's (1972) criteria for "specific language disability" are highly questionable. She appears to use the term to cover a broad range of symptoms including delayed speech development, past or current motor speech disturbances (articulation errors, stuttering, general rhythm disturbances, etc.) as well as "deficient" receptive and expressive language. She did find that peripheral speech disturbances, as opposed to language disorders, were common in nearly one-quarter of the sample. Furthermore, delayed speech development was found in 25 percent of the males ages six to thirteen years versus only an 8.2 percent incidence in the same female age span. Chi-square analysis indicated significant differences by sex for speech disorders and by primary grade for delayed speech. Chi-square values for speech disorders were among the largest obtained, a possible result of the tendency of chi-square to attain critical values when N is large. Secondly, considering the fact that one subject theoretically could have multiple speech problems, Klasen does not state whether, for the purpose of chi-square analysis, frequencies were assigned independently. According to Siegel (1956) several observations collected from the same subject cannot be treated as independent when chi-square is applied.

²The intent of the massive cross-sectional investigation by Laurendeau and Pinard (1970) was to explore the development of spatial operations. Results were not related by the authors to their subjects' educational achievement or lack thereof.

³Personal communication from Davida Rosenbloom, Speech and Hearing Center, Lehman College of The City University of New York.

⁴In addition to the original work on the ontogenetic priority of topological knowledge conducted by Piaget and Inhelder (1967), a number of studies have investigated the same hypothesis usually by means of a haptic, or stereognostic, perception procedure. In the Piagetian

framework, haptic perception deals with the transition between perception and the construction of the mental image, thus, its importance in studying the transition from a perceptual to a representational space.

With the exception of Lovell (1959), the four topological relations--proximity, order of elements, boundaries, and continuity--have not been studied independently. A majority of the replication studies (Page, 1959; Peel, 1959; Fisher, 1965; Laurendeau and Pinard, 1970), despite differences in test construction and performance criteria, have not disconfirmed either the ontogenetic priority of topological relations or the hypothesis that action rather than perception are the source of discovery of these elementary relations. Only Lovell (1959) has argued that Euclidean rather than topological distinctions were primary.

Finally, Laurendeau and Pinard (1970) note that haptic perception experiments have only minimal consequence for the study of projective space since perspective relations do not play a role in stereognostic recognition.

⁵The Estes (1956) study is not discussed further because of an almost total absence of procedural information. Estes reports only:

The investigator stuck two matchsticks in modeling clay and stood them up at each end of a long piece of cardboard. The Ss were asked to form a straight line between them with more matches and clay. (b) the matches were placed diagonally on the cardboard and the children were asked to form a straight line between them (Estes, 1956, p. 220).

⁶In addition to administration of the projective straight line, other projective and Euclidean tasks were given in each of the four studies. Lovell (1959) replicated five of Piaget and Inhelder's (1967) tests on topological and projective space. Not all subjects received the same tests nor did the same subjects in each category take all five tests. Dodwell (1963) administered seven tasks to all subjects pertaining to topological, projective, and Euclidean space while Laurendeau and Pinard (1970) included five topological and projective tasks in order to follow the developmental course and coordination of various spatial relations. All of their subjects received the identical tests. Furthermore, Laurendeau and Pinard eliminated the "zig-zag" condition used by Piaget and Inhelder, Lovell, and Dodwell in the construction of the projective straight line since, on preliminary

testing, they found that this condition did not increase the spontaneous emergence of verification strategies. Therefore, its inclusion unnecessarily increased the amount of testing time.

⁷According to E. Clark (1973b, p. 75), the Semantic Feature Hypothesis would predict that more general semantic features are acquired before acquisition of features specific to the particular meaning of the word. In addition to predicting sequence of acquisition, the hypothesis also predicts that antonymous terms are acquired before synonymous terms since the child must be capable of generalizing a feature, or combination of features, from one context (one word) to another context in which syntactic properties may differ.

H. Clark (1973) has applied the semantic feature theory to a possible explanation of how children construct spatial terms. Proposing that the possible rules of application should be universal because perceptual space, or structures, are universal (see Chapter I), Clark suggests that the rules of application imply a transitive relationship. In antonymous pairs the positive member, for example, "in front of", is acquired before the negative member, "in back of." However, knowledge of "in back of" implies knowledge of "in front of," and, therefore, is more complex requiring an extra rule of application since it must negate "in front of." In offering this cancelling operation, Clark has attempted to account for what he terms "the asymmetry of antonymous pairs (H. Clark, 1973, p. 55)," a shared feature of terms referring to spatial extent (e. g. taller - shorter), location, and direction.

⁸The earliest study on the child's progressive coordination of perspectives appears to have been conducted in 1934 by Meyer (1940). Citing a 1934 experiment on the child's capacity to reflect upon his own point of view as only one among many possible viewpoints, Meyer (1940) does not specify testing procedure. Rather, she confines her discussion to the various stages which define the coordination of perspectives.

⁹Personal communication from Prof. Gilbert Voyat, Psychological Center, The City College of The City University of New York.

¹⁰Boehm does note that many spatial terms fulfill a dual function in their reference to both space and time depending upon the nature of the non-linguistic context, for example, "Place the jar between the

doors" versus "Between trains, we can talk." H. Clark (1973) has called temporal terms a metaphorical extension of spatial terms in the sense that temporal terms have their source in spatial forms of knowledge.

CHAPTER III

PROCEDURE

In order to test Hypothesis 1, 2 and 3, a Modified Test of Pictorial Space (MTPS), modeled after Hudson (1960), was developed as a screening instrument for use in the six to ten year age span. On the basis of MTPS performance patterns and the results of other measures, subjects were selected for in-depth individual testing and assigned experimental or control group status. Individual testing was designed to test Hypothesis 4.

Description of procedure is divided into two sections. The first section will describe group testing with regard to sample selection and construction and administration of the MTPS and other screening measures. The second section will cover the procedure for the individual testing phase with respect to selection of experimental and control groups and a description of the diagnostic test battery.

Group Testing

Sample Selection

Because a suburban school district was thought to be more homogeneous and "advantaged", a search was undertaken for school

districts interested in participating in the study.

With the endorsement of the Northern Westchester-Putnam Board of Cooperative Educational Services, three schools from the largest central school district in Northern Westchester County (New York) with a K-5 population of approximately 4500 children agreed to participate.¹ Because one principal requested that his school be used only for the pilot study (designated the VC school), the two remaining schools (referred to as the LT and SO schools) were designated for full-scale investigation. According to a report issued by the Educational Goals Committee of the local school board in June 1972, 45 percent of district parents had completed high school while an additional 27 percent had received some post-high school education.

Aside from differences in the size of the LT and SO schools, it was determined that the most importance difference involved the diversity of reading programs used in both schools. However, math programs within and across schools tended to be more homogeneous.

In order to evaluate comparability of reading and math achievement levels for the LT and SO schools, the results of the 1973 Grade 3 New York State Reading and Math Tests were analyzed (these tests, given statewide at Grades 3 and 6, are prepared by the New York State Department of Education). Inspection of results indicated similar percentile rankings for the two schools in both schools for both academic areas.

Secondly, the individual school percentiles fell close to or at the total district percentile rank for Grade 3 which, itself, was well above the state median for reading and math achievement. It appeared reasonable to assume, therefore, that pupil achievement in reading and math, as measured by standardized tests for Grade 3, was comparable for LT and SO.

Pilot study subjects

One hundred forty-one subjects in the VC school, ranging in age from six years two months to nine years eight months, two classes on each grade level from Grades 1 to 3, 78 males and 66 females (CA range, 6-0 to 9-5; IQ range 88 to 145 [IQ data were unavailable for Grade 1]), were administered the provisional version of the MTPS by the examiner. One hundred thirty-six of 141 subjects also received two additional teacher-administered screening tests (see the following section for a detailed description of the MTPS and other screening tests). No attempt was made to match or eliminate subjects by IQ, chronological age, or academic achievement because the purpose of the pilot study was to validate the MPTS.

Full-scale study subjects

To gather developmental data on the MTPS and to determine its differential selectivity as a screening instrument in defining a group

of poor readers, two classes on each grade level from Grades 1 to 4 in the LT and SO schools received a revised form of the MTPS and the two teacher-administered tests (see following sections for description). There was one exception to the two-class-within-a-grade-level criterion: the Grade 1 sample was limited to a total of three classes because only one LT first grade teacher agreed to participate in the study.

The full-scale study sample totaled 368 subjects, 203 males and 165 females, who ranged in age from six years five months to eleven years four months. Again, no attempt was made to match or exclude subjects.

Construction and Administration of the MTPS

Initial form

Two forms of the MTPS were developed, an initial form utilized in a pilot study and a revised version administered in the full-scale study. In addition to assessing the general content validity as well as the predictive validity of the MTPS in identifying poor readers, the pilot study also explored alternate methods of administration.

The original form of the MTPS consisted of twelve black and white line drawings of a girl, dog, and horse, each picture presented separately on standard 8 1/2" x 11" white paper. The first two pictures, A and B (see Appendix A), were used only for the purpose of object identification and for practice in the recording procedure. Included in

the remaining ten pictures were the three conventional pictorial depth cues, familiar size, overlap, and perspective, either singly or in combination, changes in (conceptual) perspective, and changes in the left-right alignment of the girl and the dog. A total of forty questions were asked, covering both topological and projective semantic relations (see pp.140-141 for more detailed description). Four questions were asked with each of the ten pictures.

It had been planned originally to compare two different methods of administration: one involving transparencies of the stimulus material and, the other, the use of individual picture sets. It was found that the transparencies created uncontrollable problems in administration including such factors as the amount of available light in each classroom and constant screen size from room to room. This method was discarded in favor of each child receiving his/her own set of test pictures. The latter procedure was formally adopted for both the pilot and full-scale studies.

Revised form

In the revised set of the MTPS used for the full-scale study, the number of pictures were reduced from twelve to eight since it was discovered that four pictures failed to provide significant information. Pictures included in the above category were those in which familiar

size was the only depth cue and those in which the left-right alignment of the girl and dog was changed.

Pictures A and B remained essentially unchanged from the pilot study with one minor modification to be discussed below (see Appendix A).

Picture A showed three figures sharing the same frontal plane: (1) a semi-profile drawing of a girl located on the left side pointing with her left arm and hand to (2) a profile of a horse positioned in the middle between the girl and (3) a profile of a medium-sized dog located on the right side. Both the dog and the horse were oriented towards the girl and the fronts of all three figures were clearly demarcated. Proportionality among the figures was maintained by the technique of drawing the three figures the same size and then reducing them proportionally by a reduction machine to maintain realistic size relationships.

Picture B contained the three conventional depth cues: (1) familiar size (a large hill in the foreground); (2) overlap (the hill superimposed on the horizon line); and (3) perspective (two parallel converging lines representing a road and a separate horizon line). Eliminated from Picture B was an additional familiar size cue, a tree located on top of the hill, since its presence did not serve a necessary identification function.

The remaining six pictures, which are reproduced in Appendix A, each showed the same three figures as in Pictures A and B: (1) the girl pointing with her left hand to (2) the dog placed on the same plane and (3) the horse, positioned between the girl and the dog. Incorporated into each picture were four conditions: viewpoint (conceptual perspective), depth cue, projective spatial relation, and projective space semantic relation.

Viewpoint

Three pictures contained the subject's "head-on" view with the girl to the left and the dog to the right while three pictures reversed viewpoint but not actual position (see pictures 2, 4, and 6 in Appendix A). In the latter condition, relative position was transformed since the view represented was from the location of the horse. In these three pictures, the girl and the dog were reduced proportionately in size to represent relative distance cues.

Depth cues

Since familiar size is obligatory, it is present in all six pictures. The viewpoint-depth cue combination is summarized in Table 5. Inclusion of the S+O+P pairings was based on the Hypothesis 2 prediction that such a pairing would provide maximal perceptual redundancy of cues, thus, facilitating pictorial interpretation.

TABLE 5
VIEWPOINT-DEPTH CUE COMBINATION
IN PICTURES 1-6

Picture	Subject View	Reversed View
1	Size + Overlap + Perspective (S+O+P)	
2		S+O+P
3	Size + Perspective (S+P)	
4		S+P
5	Size + Overlap (S+O)	
6		S+O

Spatial relations

The three projective spatial relations, before-behind (length), left-right (width), and above-below (volume) were expressed under two different conditions: (a) a "constant" condition in which the three relations corresponded conceptually and perceptually to the subject "head-on" view (pictures 1, 3 and 5) and (b) a "variable" condition in which the spatial relationship remained conceptually invariant despite changes in the perceptual alignment of the three figures (pictures 2, 4, and 6).

Semantic relations

A total of forty-eight questions were presented, eight questions per picture. For each picture, the same eight questions were asked but in random order across pictures. Each set of eight corresponded to four categories of spatial relations--one category pertaining to topological relations and three projective space categories. The categories were:

1. Category I - proximity relation - (the topological relation of proximity was realized by the external, or surface, relationship of self-as-referent to the location of a single object, or of the relationship of the girl to a single action).

Who is closer to you, the (girl) (dog) or (horse)?²

Who is the girl looking at, the horse or the dog?

Who is the girl pointing at, the horse or the dog?

2. Category II - before-behind relation.

Who is the dog in front of, the girl or the horse?

(subject view presentation)

Who is in back of the dog, the girl or the horse?

(reverse view presentation)

3. Category III - left-right relation

Is the girl pointing with her left or right hand?

(absolute left-right)

Who is to the right of the dog, the horse or the girl?

(relative left-right)

4. Category IV - above-below relation

Who is closer to the girl, the horse or the dog?

The logical subject was varied across questions. Finally, sentence length did not exceed eleven to twelve morphemes in any question.

The complete set of forty-eight questions is found in Appendix B.

Administration of revised MTPS

The MTPS was administered by the examiner as a group test. Each subject was provided with a pencil and a pictorial answer sheet for recording of responses (the answer sheet appears in Appendix A). For each question, subjects were instructed to "color in" the appropriate box on the answer sheet following the stimulus question. The answer sheet was organized in a top-to-bottom orientation so that subjects needed only to move "down" to the next set of pictures.

Length of administration varied from thirty minutes for Grades 1 and 2 to fifteen minutes for Grades 3 and 4.

Instructions for administration appear in Appendix B.

Other Screening Measures

In order to evaluate the ability of the MTPS to screen out from a random sample those children encountering academic difficulty, several

independent measures were included in the general screening procedure. These included two standardized measures of academic readiness which correlate with early school achievement, standardized achievement and IQ measures, and teacher evaluation of individual subjects.

Teacher-administered tests

Research on the Developmental Test of Visual Perception

(Frostig, 1966) "indicates that scores on the test correlate with reading achievement in the normal first (author's italics) grade classroom between .40 and .50 (Frostig, 1966, p. 6)." The Position in Space subtest was selected for two reasons. First, the content of the test involves the recognition of differences in object orientation which, hypothetically, may be related to the content of the MTPS and, secondly, Olson (1966) found that only this particular subtest correlated with measures of word reversal in written text.

Similarly, Koppitz (1968) contends that the human figure drawing correlates with early academic achievement and that particular sets of errors, such as poor integration of parts and omissions of mouth, arms and body, correlates significantly with failure to achieve in kindergarten through second grade. Since the reproduction of the human figure can also be used as a measure of mental ability (Harris, 1963; Piaget and Inhelder, 1967; Koppitz, 1968) and can be easily administered as a group

test, it was included as a second screening measure.

Both of the above measures were administered by participating teachers at least one day prior to the examiner-administered MTPS. Order of presentation of the additional group screening tests were randomized across teachers and manner of administration was standardized by the examiner through the use of written instructions from the respective test manuals. Scoring of results was done by the examiner.

Instructions to the teachers for administration of the above tests appear in Appendix C.

Standardized achievement and IQ measures

Each teacher also provided the examiner with the previous year's reading and math achievement scores for word recognition, paragraph meaning, and math computational skill based on the Stanford Achievement Tests for subjects in Grade 2 and 3 and the Iowa Tests of Basic Skills for Grade 4 subjects. First grade teachers provided only the scores from the Metropolitan Readiness Test because Stanford scores were not yet available. In addition, IQ scores were provided from the following group tests: Otis-Lennon Mental Ability Test for Grades 2 and 3 and the Lorge Thorndike Intelligence Test for Grade 4 subjects.

Teacher evaluation

A data sheet, prepared by the examiner, was also given to each teacher for recording of the above information and for providing a brief subjective evaluation for children experiencing some degree of academic difficulty and/or receiving supplementary services, for example, remedial reading, speech therapy, or resource room assistance.

Guidelines for teacher comments and a copy of the data sheet are reproduced in Appendix D.

Individual Testing

Selection of Experimental and Control Groups

The individual testing phase of the study was designed to test the fourth hypothesis, that is, subjects previously identified as poor readers on the basis of their MTPS performance and performance on independent criteria would present qualitative differences with respect to their performance on tasks related to the construction of a three-dimensional projective spatial structure and the use of projective spatial terms in the encoding of relative spatial reference.

Experimental group selection

To facilitate selection of individual subjects for experimental and control group assignment--those subjects who would receive the diagnostic test battery--200 subjects, fifty on each grade level combined

across the two schools were selected by means of a random number table, from the original 368 sample for analysis of MTPS performance, performance on the teacher-administered tests, and previous reading and math achievement scores. With all other sampling factors held equal, a sample size of 200 is nearly as reliable as a sample size of 400 for field study purposes (McNemar, 1969).

Random selection for data analysis was effected by first numerically ordering each of the 368 subjects and then consulting a random number table for inclusion in the 200 sample. This procedure resulted in the selection of 116 males and 84 females, a division reflecting the sex ratio of the total 368 sample.

Since performance on the MTPS was the primary dependent variable for experimental group inclusion, the arbitrary decision was made that all subjects from the 200 sample whose total MTPS score placed them below -1.5 SD of the mean for either their grade or chronological age grouping would be candidates for the experimental group. This selection procedure produced sixteen subjects, 8 percent of the 200 sample. Table 6 summarizes these subjects by grade, school, and sex.

An inspection of Table 6 reveals an equal distribution by school and grade level but a 2:1 sex ratio of females over males. Mean IQ for the twelve Grade 2 to 4 subjects was 101.5 (range 89-129). Three

TABLE 6
EXPERIMENTAL SAMPLE SELECTION BY
GRADE, SCHOOL, AND SEX

Grade	School SO LT		Sex M F		MTPS Score	N	Total for Grade
1	4	0	1	3	21	4	4
2	1	3	2	2	20	1	4
					26	1	
					27	2	
3	2	2	0	4	24	1	4
					25	1	
					27	1	
					28	1	
4	1	3	2	2	22	1	4
					25	2	
					29	1	
Totals	8	8	5	11		16	16

of the twelve who were females had IQ's below 90 (range 83-89).

Since written parental permission had to be secured prior to administering the diagnostic test battery, the decision was made to extend the experimental sample size in order to ensure an adequate sample. The method of expansion involved the inclusion of all subjects who fell within the lower quartile of the MTPS, exclusive of the sixteen subjects previously selected all of whom fell within the tenth percentile. This procedure resulted in the selection of an additional thirty-six subjects (13 percent) of the 200 analyzed sample, eight each from Grades 1 and 2 and ten each from Grades 3 and 4. The sex distribution, nineteen males and seventeen females, more nearly approximated an equal distribution than did the sex distribution for the sixteen subjects in the tenth percentile.

Thus, the total experimental pool consisted of fifty-two subjects, sixteen subjects from the tenth percentile and thirty-six subjects from the eleventh to twenty-fifth percentile.

Control group selection

Potential control subjects were defined as those subjects whose cumulative MTPS score fell within $+1$ SD to $+2.6$ SD of the mean according to respective grade level and age groupings. To maximize random selection, every fifth subject who met performance criterion was

selected as a control for a final total of thirty-two, fifteen males and seventeen females, eight on each grade level from Grades 1 to 4.

Individual testing took place over a one month period from mid-May to mid-June, 1974.

Test Battery Description

Visual-perceptual tests

Four tests were selected on the basis of their known predictive value in either (1) defining a class of subjects characterized by early school failure or (2) defining individual children with deficient visual perception, and, by implication, spatial disorientation, as the basis of reading failure.

The following four tests were administered by the examiner to experimental and control groups.

1. The Harris Tests of Lateral Dominance (Harris, 1958).

An abbreviated form of the Harris was used. Subtests administered included (a) Hand Preference (three subtests): hand preference for ten common activities, simultaneous writing, and writing one's name with both the dominant and non-dominant hand; (b) Eye Preference (two subtests): sighting through a kaleidoscope and with a ruler; and (c) Foot Preference (two subtests): kicking and stamping.

All tests were administered and scored according to manual instructions.

2. The Bender Gestalt Test for Young Children (Koppitz, 1964). Administration (including timing duration for design completion) and scoring followed manual instructions.

3. Kohs Block Design (Weschler, 1949). A subtest of the Performance Scale of the WISC, the Kohs was the only speed task included in the visual-perceptual test set. Administration and scoring proceeded according to manual instructions.

4. Modified Tests of Absolute Left-Right (Benton, 1959; Piaget, 1968; Laurendeau and Pinard, 1970). Three categories of developmentally dependent tasks were incorporated: (a) Own Body Part Designation (six questions): the child was asked to "Show me your (left) (right) _____"; (b) Uncrossed and Double Crossed Commands Own Body (eight questions) (Benton, 1959): the child was instructed to either "Put your left _____ on your left _____ (uncrossed)" or "Put your right _____ on your left _____ (crossed)"; and (c) Other Person Body Part Designation (six questions): subjects were asked to identify left and right on the examiner, for example, "Show me my (left) (right) _____."

Within each question category, left and right were alternated. Administration and scoring of the Own and Other Person subtests followed the Laurendeau and Pinard (1970) instructions. The Uncrossed and Double Crossed subtest was presented and scored according to Benton

(1959).

Order of presentation of the visual-perceptual tasks was randomized across subjects.

Instructions and the complete set of visual-perceptual tasks appear in Appendix E.

Cognitive tasks

Three of the four sets of cognitive tasks in the diagnostic test battery were selected for their ability to evaluate the sequence of emergence of a representational structure of spatial perspectives. These three, adapted from the work of Piaget and Inhelder (1967) and Laurendeau and Pinard (1970), included: (1) Construction of the Projective Straight Line; (2) Relative Concepts of Left and Right; and (3) Coordination of Perspectives.

The fourth task, conservation of number, global substance (discontinuous quantity), and liquid quantity (continuous quantity), were included because of the theoretical relationship between spatial representation and the development of the conservation sequence (Inhelder, Sinclair, and Bovet, 1974) and the relevance of conservation to the age span under study (Piaget, 1965).³

Construction of the projective straight line (six subtests)

Pretest. --Prior to the administration of the task, a pretest was given in which the subject was asked to point out "a straight line"

from a set of three lines, a straight line, a curved line, and a zig-zagged line, drawn on standard 8 1/2" x 11" white paper. The purpose of the pretest was to ascertain that the subject, as a minimum requirement, understood the meaning of the noun phrase "a straight line."

Subtests 1-3. --Immediately following the pretest, the subject was presented with a 13 3/4" x 10 1/4" rectangular board, constructed from posterboard, which was labeled as "a field." Placed on the board were two endpoints, two miniature red houses as are commonly found in a Monopoly game, and nine miniature "lights," 1" x 1" pieces of styrofoam into which upright matchsticks had been inserted. The board was placed so that its lower edge extended approximately 1" over the edge of the testing table to reduce the effects of the perceptual cues offered by the table edge.

The subject was then instructed to "make a straight line between the two houses" under three different conditions: (1) with the end points located 3/4" from the edge of the board, 11" apart; (2) with the end points located midway along opposite sides, 3/4" from each side and 12 1/2" apart; and (3) with the endpoints placed along adjacent sides, 1" from each side and 13 1/2" apart to create a diagonal line (see Figure 4). It should be noted that the subject was not told that all nine lights need be used.

Subtests 4-6. --A circular posterboard with a diameter of 13 1/2"

was introduced. The subject was again asked to "make a straight line between the two houses" under the same three conditions: (4) with the endpoints spaced 6" apart on a small segment of the arc perpendicular to the child's line of vision (the seven o'clock and five o'clock positions); (5) with the endpoints spaced 12 1/2" apart along the diameter (the nine o'clock and three o'clock positions) still perpendicular to the child's line of vision and (6) with the endpoints spaced 12 1/2" apart on a larger chord of the arc but creating a diagonal in terms of the child's line of vision (the seven o'clock and one o'clock positions) (See Figure 4).

Thus, a total of six variable reference points were included, three involving rectangular boundaries and three involving circular boundaries.

In addition to actual task administration, a record was kept for conditions 3 and 6, construction of the diagonal, for subjects who spontaneously demonstrated either an "aiming strategy" (visual sighting) or a "manual measurement" procedure (use of the fingers or hands to align the elements).

Relative concepts of left and right (three subtests)

Subtest 1 - Relative Position of Three Objects. --With the examiner sitting next to the subject, a block, miniature plate, and pencil, following that left-to-right order, were placed on standard

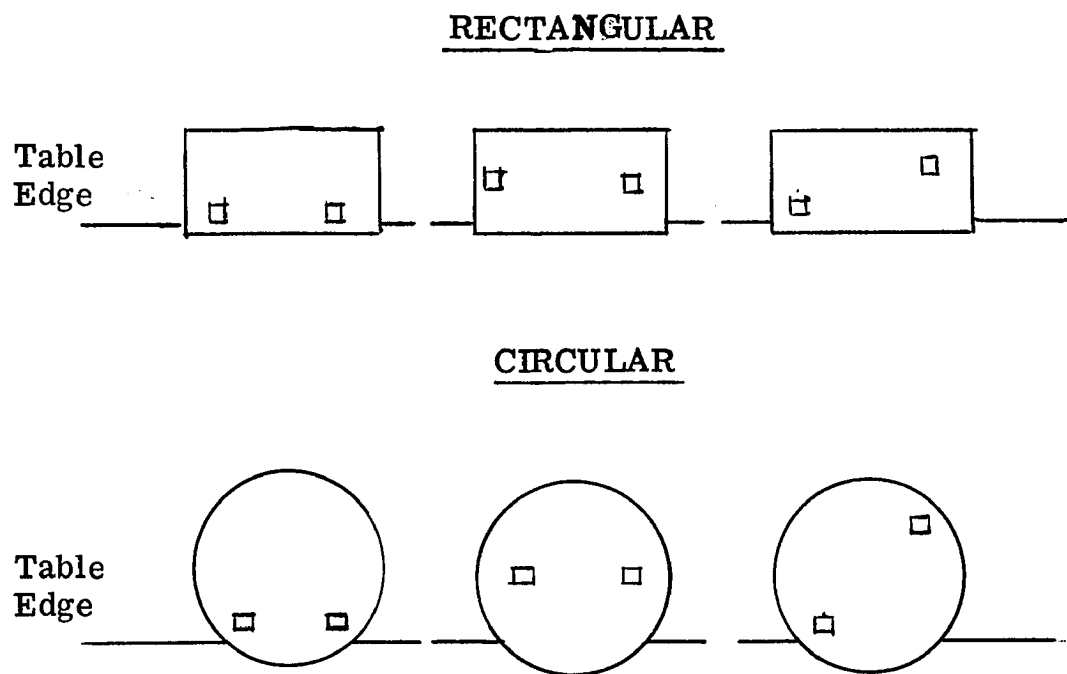


Figure 4. --Rectangular and circular boards used for construction of the projective straight line. Board dimensions and distances between endpoints were extrapolated from the data provided in centimeters by Laurendeau and Pinard (1970).

8 1/2" x 11" white paper in front of the subject. Six questions were then asked: two pertaining to the position of the end objects (total of four), e.g., "Is the pencil to the left or to the right of the plate?" and two pertaining to the location of the central object (total of two), e.g., "Is the plate to the right or the left of the block?". Left-right was alternated across questions.

Subtest 2 - Relative Position from Reversed Viewpoint. --The subject moved to the opposite side of the table from the examiner. Using the same three objects as in subtest 1, the subject was asked the same set of six questions but in the order 3, 5, 1, 6, 2, 4.

Subtest 3 - Relative Position of Three Hidden Objects. --The child returned to his original position beside the examiner and was told that three new objects would be placed in front of him, a toy horse, ball, and toy boat in that left-to-right order. He was instructed to look at the new objects. After fifteen seconds, the objects were screened with a cardboard and the same six questions were presented.

All three subtests focus on the location of the central object in relation to the other two as the main problem.

Coordination of perspectives (three subtests)

The coordination of perspectives task, with modification in the number of tasks included and in the size of material, generally followed

the procedure developed by Laurendeau and Pinard (1970). Material consisted of a 20 1/2" x 20 1/2" green poster board, a 1" wooden replica of a "man" without any facial features, three mountains: a large red, 5 3/4" high x 8" wide; a medium-sized blue, 4" high x 5 1/2" wide; and a small yellow, 2 1/2" high x 3 3/4" wide, and a set of nine 6 1/2" x 5 1/2" cards, the latter pictorial representations of various positions of the three mountains. The cards were colored-coded to match their three-dimensional models and only five cards were used for any one problem (see Figures 2 and 3 in Chapter II for a schematic representation of the task).

Pretests 1 and 2. --Two pretests were given, one prior to the other before presentation of the final problem, in order to provide the child with experience in the testing format and to ascertain that he understood the basic instructions.

For pretest 1, the "man" was placed at position A (directly in front of the child) and the child was asked to tell "what the little man sees when he takes a picture of the three mountains." He was then asked to select from a choice of two cards what picture the man would see from A.

In pretest 2, given just prior to the final problem (problem B), the child reversed his position 180° by walking halfway around the board to position E, the examiner's position, and was told to "Make yourself

very small like the little man" and "Tell me what you see." With both pretests, irrespective of the child's responses, the correct description of the position of the three mountains was provided by the examiner.

Subtests 1-3. --For each of the three problems, F, C, and B, presented in that order, the child always remained stationary, that is, only the "little man" changed position. If a child attempted to change position or to move his head in the direction of the man, he was discouraged from doing so.

Instructions for each problem remained identical across problems. The child was first asked to "tell what the little man sees from there" and then was instructed to select the picture from a possible five which corresponded the best to what the man saw from the particular position. Following pictorial selection, the child had to specify not only why the picture was selected but also had to justify why the remaining four pictures were rejected.

Subtest 1 - Problem C. -- (man, position C; child position A) Hypothetically the easiest problem, the correct solution for C necessitated only that the child focus on the before-behind relation, holding the left-right relation constant.

Possible options for pictorial selection included:

1. C-correct picture.

2. A-both reflect the mountains' position as they would

3. B-appear from the child's own viewpoint; thus, their

selection would indicate an egocentric choice.

4. E-a reversal of C but a reversal which conserves the left-right relation while only reversing the before-behind relation.

5. F-all the relations are reversed and, additionally, the yellow mountain is visible.

Subtest 2 - Problem F (man, position F; child, position A). --

F is considered more difficult than C since the child must manipulate the left-right relation, conserving the before-behind dimension.

Possible pictorial selections included:

1. F-correct choice.

2. A-egocentric choices since both pictures correspond

3. G-to the child's own viewpoint.

4. H-does not correspond to any possible perspective but is the mirror-image of F in reversing the left-right relation.

5. D-contradicts both the left-right and before-behind dimensions; therefore, its selection would indicate either a failure to understand or a random strategy.

Subtest 3 - Problem B (man, position B; child, position E). --

The most difficult problem, correct solution of B involves the coordination of both the before-behind and left-right relations.

Possible pictorial selections included:

1. B-correct choice.
2. E-egocentric choices since they correspond to the
3. D-subject's new position from E.
4. A-reflects the subject's earlier perspective from A.
5. I-an impermissible perspective because it is a composite of E and A.

The performance task was tape-recorded for all three subtests.

Conservation tasks (three subtests)

Subtest 1 - Number. --The child was first asked to create an equal number set. The examiner spaced out five pennies horizontally and instructed the child to select the same number (five) from a separate pile of six pennies.

Once the equivalence of the correspondence was determined (by asking "Who's richer?"), two different transformations were performed: (1) the child's row of pennies was closed leaving no spatial intervals and (2) all ten pennies were joined in a circular pattern.

For each of the closure and circular conditions, the child was asked, "Is there still the same number of pennies?" followed by "How do you know?".

Subtest 2 - Global Substance. -- The child was first given a ball of clay, termed the standard, and then was given additional clay which he was asked to make "exactly the same" as the standard. Once the judgment of "sameness" was made, two transformations were performed successively: (1) the subject's ball was transformed by the examiner into a sausage and (2) the ball was segmented into three equal pieces.

For both the sausage and segmentation conditions, the child was asked "Is there still the same amount of clay?" and "How do you know?"

Subtest 3 - Continuous Quantity. -- Two identical transparent glasses, A and B, measuring 6" x 8 1/4", were presented to the subject who was asked to "pour the same amount of water" into both glasses.

Once the evaluation of same was made, the examiner then took B and poured the water from B into two other transparent glasses B_1 and B_2 both of which were different in height and width from each other and from glasses A and B. B_1 measured 3 1/2" x 9 3/4" while the dimensions of B_2 were 2 3/4" x 7 1/4".

Following the transformation, the child was asked "Is there still the same amount of water?" and "How do you know?".

All three conservation tasks were tape-recorded.

Scoring of the cognitive tasks is discussed in Chapter IV. Order of presentation of the cognitive tasks was randomized within and across tasks.

The individual test form and the complete set of cognitive tasks appear in Appendix E.

FOOTNOTES

CHAPTER III

¹In January 1974, the district Board of Education approved the study with the proviso that parents of participating children be informed in writing of the purposes of the study and that no child be tested individually without written parental consent. These procedures were followed.

For the screening portion of the study, confidentiality of subject identity was protected by asking teachers to code children through numbering or through use of first names only.

²Parentheses are used to denote the fact that within any one question, two options were always presented, for example, "the dog or the horse" or the "horse or the girl."

³The order of acquisition of these "quantitative invariants" follow the sequence, number, length, substance (discontinuous quality preceding the conservation of continuous quantity), weight, and volume (Piaget, 1965; Inhelder, Sinclair and Bovet, 1974). Conservation of substance functions as a precondition for the conservation of weight and volume. Conversely, volume cannot be conserved unless substance and weight conservation precede it.

CHAPTER IV

RESULTS

Pilot Study Analysis

Preliminary data analyses were based on 141 subjects in the VC School. Results are presented in order of the hypotheses tested.

Hypothesis 1. -- (1) Order of acquisition of the three projective semantic relations--in front of-in back of, left-right (hand) and to the left (right) of, and closer to--in pictorial space would follow the same order of acquisition as their emergence in three-dimensional space; (2) Topological terms--closer to you, pointing at, and looking at--would be easier than the projective terms; and (3) poor readers would encounter greater difficulty in their comprehension of both topological and projective terms in pictorial space.

With respect to the first prediction, increasing mean scores by grade level were obtained for MTPS performance (based on the total number of correct responses). No formal statistical test was made of the significance of the difference among means by grade level. Because

the range of difference between Grades 1 and 3 was small, the number of questions presented in the full-scale investigation was increased from forty to forty-eight and the number of questions asked for each picture extended from four to eight. There were indications, however, that the projective semantic relations were developmentally ordered. "In back of" was the easiest for all three grades, "left (right) hand" was of lesser difficulty for third graders but still difficult for first and second graders, and "closer to" proved the most difficult through third grade.

In terms of the second prediction, the proximity questions "looking at" and "closer to you" were easy for all three grades while "pointing at" proved excessively difficult. The latter may have been a function of test construction since not all forty questions were asked an equal number of times across pictures, a restriction corrected for the full-scale investigation.

For the purposes of the pilot study, the final prediction of Hypothesis 1 pertained primarily to the predictive validity of the MTPS in identifying subjects encountering academic difficulty. Patterns of performance on the MTPS, the Frostig, and the Human Figure Drawing (hereafter referred to as the HFD) were analyzed in order to determine (a) whether the MTPS alone selected children who had been previously identified by their teachers as performing below grade-level

expectations and (b) whether poor performance on either the Frostig or the HFD was associated with poor performance on the MTPS.

On the basis of the subjects' low scores on one indicator (Frostig, HFD, or MTPS), two indicators (Frostig + HFD, HFD + MTPS, MTPS + Frostig), or all three indicators (MTPS + Frostig + HFD), 37 percent (N = 51; CA range 6-0 to 9-5; IQ range 89-121) were selected for follow-up conferences with individual teachers in order to ascertain how many were actually considered as poor readers.

1. Three Indicators (N = 9): All nine cases were described by their respective teachers as having severe reading difficulties.

2. Two Indicators (N = 25): Twenty-three of twenty-five protocols in this category involved the combination of HFD + MTPS. Seven subjects with very low MTPS scores were described by their teachers as having reading problems.

3. One Indicator (N = 19): In all nineteen cases, the MTPS functioned as the sole indicator. Five of the nineteen had low MTPS scores and four of five were described by teachers as children with serious learning problems.

Table 7 reports the grade placement of the twenty subjects described by teachers as having some degree of learning problems.

TABLE 7
GRADE PLACEMENT OF SUBJECTS SELECTED BY PILOT
STUDY SCREENING TESTS ALSO DESCRIBED BY
TEACHERS AS HAVING LEARNING
PROBLEMS (N + 20)

Grade	Number
1	7
2	5
3	8

These findings were interpreted as providing tentative support for the predictive validity of the MTPS in identifying a group of educationally higher-risk children. The decision was made to retain both the Frostig and the HFD as additional screening measures for the full-scale study because it was unknown whether performance on the MTPS correlated statistically with performance on these two measures.

Hypothesis 2.—(1) Interpretation of pictorial overlap cues developmentally should precede interpretation of perspective cues; (2) Familiar size as the sole depth cue would be the most difficult to interpret; (3) Inclusion of all three relative distance depth cues--familiar size (S),

overlap (O), and perspective (P)--should provide maximal perceptual redundancy, thus, facilitating pictorial interpretation; and (4) the alteration of conceptual perspective (viewpoint) would increase the difficulty level for interpreting content independent of depth cue combination.

The first prediction, the developmental priority of overlap cues, was not specifically analyzed for because the construction of the various pictures did not allow a clear test of this prediction. The second prediction was confirmed. The most difficult cue across the three grades was that of familiar size presented as the sole depth cue. Because of its difficulty, pictures containing this cue as the sole cue were eliminated from the revised MTPS. The third prediction also received tentative confirmation. Pictures containing the S+O+P combination appeared easier across the three grade levels followed by S+O. The fourth prediction, the effect of alteration of viewpoint on interpretation could be neither confirmed nor disconfirmed because of the inclusion of too many pictures with varying complexity, for example, as cited above, pictures with familiar size as the only cue and pictures in which the left-right alignment of the girl and dog varied. The latter pictures were also eliminated from the revised set.

Hypothesis 3. --IQ should be unrelated to the invariance of the sequence for the three projective semantic relations.

Because IQ data were unavailable for first grade, IQ scores from the two third grades ($N = 53$) were compared to total MTPS score for those two grades. A low negative correlation (Pearson Product-Moment Formula, $r = -.04$, $p = .05$) was found for MTPS performance and IQ. This result was interpreted as tentatively supporting the hypothesis.

The preliminary data were not analyzed for the effect of sex differences on MTPS performance.

Finally, Hypothesis 4, which had predicted qualitative differences with respect to the performance of poor readers on tasks involving the conceptual and semantic structuring of projective space, was not tested in the pilot study.

Full-Scale Investigation: Developmental Data

MTPS Quantitative Analysis

Effects of grade, age, sex, and IQ

Two initial questions were asked in determining whether the MTPS had developmental, and, hence, diagnostic value: (1) did means based on total score increase with grade-level and age and (2) if yes, were the obtained differences among grade, or age, levels significant beyond a chance level? Results confirm expected directions for both a grade and age effect. Tables 8 and 9 summarize the data for effect of grade-level.

TABLE 8

MTPS MEANS AND STANDARD DEVIATIONS BY GRADE
LEVELS (MAXIMUM SCORE OF 48, N = 200)

Grade	Mean	SD	Range of Scores
1	30.7	6.1	24
2	36.1	5.8	26
3	37.3	6.1	24
4	39.9	6.2	26

TABLE 9

SIGNIFICANCE OF DIFFERENCE AMONG MTPS
MEANS BY GRADE LEVEL (N = 200; df = 99)

Grade Condition	(t)
1 vs. 2	4.51*
2 vs. 3	.30
3 vs. 1	5.41*
3 vs. 4	1.69
4 vs. 1	7.34*
4 vs. 2	3.02*

* $p > .01$.

For four of the six conditions, the observed differences are greater than would be expected by chance. In the two conditions where the null hypothesis is not rejected (2 vs. 3 and 3 vs. 4), the alternate hypotheses can be offered that either these groups were more homogeneous or reflected a transitional stage in development. The latter explanation would be in agreement with previous findings (Kofsky, 1966; Bayley, 1970) that the seven to eight year age span manifests changes in mode of functioning and, thus, could be described as transitional.

In order to ascertain the main effect of chronological age, the data were reorganized into five arbitrary age groupings: (1) 77 to 90 months (N = 56); (2) 91 to 102 months (N = 47); (3) 103 to 114 months (N = 49); (4) 115 to 126 months (N = 45); and (5) 127 to 136 months (N = 3). Since only three subjects fell into the fifth grouping, their raw data were excluded from any age (but not grade) analysis. Results from these chronological age groupings were nearly identical to the grade-level analyses for MTPS means, standard errors of the mean, standard deviations, and range of scores. As a consequence, only the grade analysis is presented. It should be noted also that, although subjects were tested from Grades 1 to 4, the upper age limit of the sample was eleven years four months. Approximately ten subjects had been retained either at some point in their educational experience

or had been placed in a pre-first class. These ten subjects were, in fact, at least one year older than their grade-level peers.

IQ data were analyzed first with respect to general distributional properties according to sex, inter-school, and intraschool differences. An arbitrary decision was made to retain those subjects whose IQ scores fell below 90 ($N = 6$, two males and four females) because of the opinion that learning disabled subjects may perform poorly on group IQ tests such as those routinely given in public school. The IQ range for 150 Grade 2 to 4 subjects, 88 males and 62 females (IQ data were unavailable for Grade 1 subjects), was 77 to 150. Five males and three females fell within the 130 to 150 range. Mean IQ was 110.8, SD 13.2.

An analysis of general distributional properties by sex found male superiority for Grades 2 and 3 with a reversal of the superiority for Grade 4. Means between the SO and LT schools (combining data for the three grades within each school) were essentially similar. In general, it was found that IQ score diminished with increasing grade level, a finding which may be the result of testing artifacts inherent to group IQ tests, e.g., test construction, measurement errors, etc., rather than be representative of intrinsic mental ability.

IQ data were analyzed also in terms of their relationship to MTPS performance. Obtained correlations appear in Table 10.

TABLE 10
RELATIONSHIP BETWEEN MTPS SCORE AND IQ BY SEX AND GRADE
(PEARSON CORRELATION COEFFICIENTS, N=150)

Sex	Grade	N	r	N-2 df	Significance Level
Males	2	34	.19	32	.14
	3	28	.04	26	.41
	4	26	.24	24	.12
Females	2	16	.53	14	.01*
	3	22	.28	20	.11
	4	24	.63	22	.001**

* p = .01
** p = .001

Inspection of the correlations indicates little relationship between MTPS and IQ for males independent of grade and for females in Grade 3 only. The contrary relationship holding for Grade 2 and 4 females is surprising in view of the finding (to be presented shortly) that no sex differences were found between MTPS performance and the Metropolitan Readiness Test for Grade 1.

In summarizing the main effects of grade (or age), sex and IQ on MTPS performance, the following tentative conclusions can be made: (1) the MTPS did differentiate among subjects according to grade level at least with respect to Grades 1, 2, and 4; (2) performance was independent of sex for males in Grades 1 to 4 and for females in Grades 1 and 3; and (3) IQ correlated with performance level for females only (Grades 2 and 4), a result of possible sampling biases.

Teacher-administered tests

For both the Frostig and HFD, frequency distributions were obtained to compare inter-test performance patterns. The pattern of frequency distribution for the Frostig ($N = 200$) indicated that, independent of grade level, the vast majority of subjects were able to identify a minimum of seven (out of a maximum of eight) pictures correctly. In other words, a ceiling effect occurred rapidly.

Frequency distributions for the HFD supported previous IQ analysis. The total sample mean ($N = 200$, Mean = 4.96, SD = .07)

fell within the average intellectual range with 4.5 percent falling within lower limits (scores below four) and 5 percent falling within superior limits (scores above six with a maximum possible score of eight).

When the HFD data were recombined and analyzed according to grade by sex, the frequency distributions reconfirmed earlier sex differences in IQ: males demonstrated a slight superiority in reproducing the human form, performing well within the average to high average range, while females functioned slightly below, at the upper end of the low average to average range. More females (7.2%) performed poorly than the percentage of males (3.5%) at the lower extremes (scores below four) while more males (6.0%) performed at superior levels than females (3.6%).

In addition to frequency distributions, the Frostig and HFD data were analyzed for the relationship of one or both to MTPS score since it had been predicted (see Chapter III, p. 142) that the Frostig Position in Space subtest emphasis on the recognition of differences in object orientation might be related to aspects of MTPS content. Similarly, it had been predicted that the manner in which graphic space is utilized to reproduce a HFD might be related to the MTPS.

Significant correlations were obtained between performance on the Frostig Position in Space Subtest and MTPS for Grade 1 ($p = .001$)

and Grade 3 ($p = .03$) and between the HFD and MTPS by age for age groupings 2 and 4 ($p = .01$). These correlations are reported in Tables 11 and 12.

TABLE 11
MTPS AND FROSTIG POSITION IN SPACE SUBTEST BY
GRADE (PEARSON CORRELATION COEFFICIENTS;
N = 200; df = 198)

Grade	N	r	p
1	50	.48	.001
2	50	.06	---
3	50	.28	.03
4	50	.06	---

The HFD correlations most likely reflect an association with IQ (see Table 10) rather than a "content" association since, for the developmental analysis, only total HFD score was used. No attempt was made in this portion of the study to formally analyze for the various types of "emotional" indicators (for example, poor integration of parts, slanting figure, body omissions, etc.) which Koppitz (1968) has found related to poor early school achievement.

TABLE 12
MTPS AND HFD BY CA GROUPING (PEARSON CORRELA-
TION COEFFICIENTS: N = 196*; df = 194)

CA Grouping	N	r	p
1. 6-5 to 7-6	56	.08	---
2. 7-7 to 8-6	47	.33	.01
3. 8-7 to 9-6	49	.15	---
4. 9-7 to 10-6	44	.34	.01

* Differences in total N between the Position in Space Subtest and the HFD are due to absences on the day the HFD was administered.

Standardized achievement measures

Total MTPS score was also correlated with two standardized measures of written language: the Metropolitan Readiness Test (MRT) for Grade 1 and the Word Meaning, Paragraph Meaning, and Math Computational subtests of the Stanford Achievement Tests (Grade 2 and 3 subjects) and the Iowa Tests of Basic Skills (Grade 4 subjects).

Data analysis indicated a strong relationship between MTPS performance and retrospective performance on a standardized reading readiness test (MRT) and performance on the MTPS and achievement

on the Iowa Test Word Meaning and Math Computational Subtests for Grades 2 and 4. Correlations are reported in Tables 13 and 14.

In addition to the finding of no sex differences for Grade 1, it appears tenable to conclude that the MTPS may function as a predictor for success in first grade. The tentative relationship between the MTPS and the MRT increases when the content of the MRT is examined. A task analysis would indicate a high spatial loading particularly in those subtests emphasizing more elementary "visual perception" skills, for example, matching of forms, alphabet recognition, and number recognition, subtests all involving changes in the orientation of the target forms.

The correlations found between Grade 4 achievement on the two reading comprehension subtests and MTPS performance would seem to support the finding by Krause (1973) that third grade reading achievement scores are most predictive of future success. In fact, the Grade 4 reading (and math) scores were obtained while these subjects were in third grade since the time of MTPS administration occurred just prior to administration of the fourth grade achievement tests. Finally, the correlations obtained between MTPS performance and math computational skills are also consistent with previous findings, e.g., Chalfant and Scheffelin (1969), of an association between spatial "abilities" and the capacity to perform mathematical operations.

TABLE 13
MTPS AND THE METROPOLITAN READINESS TEST BY SEX
(PEARSON CORRELATION COEFFICIENTS;
N=46; df, 22; df, 20)

Sex	Grade	N	r	p
Males	1	24	.55	.001
Females	1	22	.62	< .001

TABLE 14

MTPS AND THE WORD MEANING, PARAGRAPH MEANING, AND MATH
COMPUTATIONAL SUBTESTS OF THE STANFORD ACHIEVEMENT
TESTS AND THE IOWA TESTS OF BASIC SKILLS
(PEARSON CORRELATION COEFFICIENTS)

Grade	Word Meaning N=148*			Paragraph Meaning N=137			Math Computat. N=147		
	N	r	p	N	r	p	N	r	p
2	48	.14	---	45	.17	---	48	.25	.04
3	50	.08	---	47	.12	---	50	.17	---
4	50	.33	.009	45	.24	.05	49	.32	.01

* Differences in total N among the three subtests are due to unavailability of scores.

Summary

On the basis of these findings, the following conclusions can be reached regarding the relationship of age, sex, IQ, and independent criteria to the MTPS:

1. The MTPS did differentiate among subjects by age (or grade) in the expected direction. Where significant differences were not found (Grades 2 vs. 3 and 3 vs. 4), they appeared to focus on third grade subjects who might be in a transitional stage of development.
2. A relationship between sex and IQ and MTPS performance was specific only to Grade 2 and 4 females. Given the fact that teachers volunteered to participate in the study (and, thus, teachers with more "problem" children might have a greater tendency to volunteer), the finding may be a result of sampling biases.
3. A strong relationship existed among MTPS performance and performance on a non-verbal test of pictorial space related to reading readiness (MRT) and the Frostig Position in Space Subtest for Grade 1 subjects. Since both the MRT and the Frostig Subtest deal primarily with the simple recognition of differences in orientation (as opposed to its reproduction between varying reference points), it is not surprising that little relationship was found for the Frostig Subtest after Grade 1.

4. An equally strong relationship appears to hold at the opposite end of the age continuum between MTPS performance and measures of written language for Grade 4 subjects.

MTPS Qualitative Analysis

Category 1 level of difficulty

The above data analysis does not address the issue of whether the three projective semantic relations are hierarchially organized with regard to their sequence of emergence in the pictorial space (two-dimensional) medium. Because the data pertaining to this issue were inherently classificatory, nonparametric tests (Siegel, 1956) were employed in analyzing results. Findings are reported in the following order: (1) object identification; (2) item analysis for each question category within and among the four age groupings, and (3) item analysis for each of the six pictures among the four age groupings.

Object identification

Independent of age, all subjects were able to correctly identify the first set of four objects in Picture A: girl, dog, horse, and hand. Thus, it appears that line-drawing representation of these objects had no effect on identity in the six and one-half to ten and one-half year age range.

An age effect was found for the recognition of the three pictorial

depth cue representations in Picture B: a hill, horizon line, and a road (two parallel converging lines). Whereas all subjects could identify the hill (overlap cue), Grade 1 and 2 subjects tended to make intra-categorical errors, that is, substituting the horizon line for the road and vice versa. Substitution of the hill for one or the other of the perspective cues was rare.

Question categories

Data were analyzed for both the four age groupings and grade levels. Unless stated otherwise, results are reported in terms of age.

The "in front of-in back of" category presented special scoring problems for the "in front of" question in the non-reversed viewpoint condition (the subject view). Questions involved were "Who is the dog in front of, the girl or the horse?" and "Who is the girl in front of, the dog or the horse?" A shift in the nature of the response pattern became apparent between first and second grade. Younger subjects generally chose the horse as their response while older subjects almost always chose the girl or dog (depending on the question). Both responses appear equally acceptable although whether or not they are of equal psychological difficulty remains open to question. This transitional shift was not taken into account in the design of the MTPS primarily because no mention of such behavior has been described in the literature. In order to maintain a standardized scoring procedure, a consistency

criterion was applied to scoring the raw data, i. e. , whether a response in this category was credited as correct or incorrect depended upon the consistency with which the child responded to the six questions in the category independent of the pictorial context. Total credit was assigned only when the child responded correctly to at least five of six questions with either one or the other alternative (horse or girl-dog). Children who produced an erratic or inconsistent response pattern were scored as incorrect.

Table 15 shows the percentages of subjects responding correctly to each question.

Tests for the significance of difference between two proportions (Bruning and Kintz, 1968) for within age were performed. In terms of the proximity questions (Category I), no difference within age was found except for the CA 6-5 to 7-6 subjects on "pointing at" versus "closer to you" ($z = 2.21$, $p = > .05$). For the projective questions, significant differences within a question set (in front of-in back of and left-right (hand)-to the left (right) of) were found only for "in front of-in back of" for subjects CA 6-5 to 7-6 and CA 8-7 to 9-6 ($z = 2.28$ and 2.06 , $p = > .05$). No within-age differences were found for comparison of the two left-right questions to "closer to." However, significant differences were found for the first three age groups when either the "in front of" or "in back of" question was compared to Category II and

TABLE 15
AVERAGE PERCENT OF SUBJECTS PASSING EACH QUESTION
CATEGORY BY AGE (N = 197)

Age Grouping	I		II		III		IV
	Pointing At	Looking At	Pointing At	Looking At	Pointing At	Looking At	
1. 6-5 to 7-5 N = 56	69.9	72.9	83.3	83.3	50.3	58.6	45.6
2. 7-7 to 8-6 N = 47	83.3	84.0	89.4	89.4	59.2	65.6	60.0
3. 8-7 to 9-6 N = 49	86.0	87.1	91.8	91.8	67.3	71.7	63.6
4. 9-7 to 10-6 N = 45	87.0	89.2	94.0	94.0	81.4	80.0	74.8

III questions. Thus, it appears that within age groups 1, 2, and 3, the "in front of-in back of" questions were easier than the Category II and III questions, while age group 4 found all questions equally difficult (or easy). Similarly, with the exception of the youngest subjects, all ages found the topological questions (Category I) equally difficult.

Pictorial categories

Analysis of each question by the pictorial context in which it occurred (X^2 for k independent samples, Siegel, 1956), indicated an interaction effect between question category and level of pictorial complexity (the type of depth cue combination and whether perspective was presented in the subject view or reversed condition). In other words, the proportion of subjects within each age (or grade) grouping who passed a given question varied as a function of the non-linguistic (pictorial) context (Table 16 summarizes this data based upon the frequency distributions found for each of the forty-eight questions for the four age and grade groupings matched against the particular depth cue combination for each of the six pictures).

Depth cues appeared to contribute less to the interaction than did the transformation of relative position as represented by the reversed pictures, which differentiated among subjects nearly three times as often as non-reversed pictures (see Table 16). However,

TABLE 16
INTERACTION BETWEEN QUESTION CATEGORY AND PICTORIAL
COMPLEXITY BY AGE (N = 197) AND GRADE (N = 200)¹

Question Category	Non-Reversed Pictures						Reversed Pictures											
	S+O+P x ²	df	p	S+P x ²	df	p	S+O x ²	df	p	S+O+P x ²	df	p	S+P x ²	df	p	S+O x ²	df	p
I. Closer to you	-----			-----			G ₂₄ .63	9	.001	-----			-----			-----		
Looking at	-----			10.37 G 5.49	4 3	.02 .05	-----			-----			G ₂₁ .12	9	.01	13.30 G ₁₄ .68	4 3	.01 .001
Pointing at	-----			-----			-----			17.12 G ₂₄ .27	8 6	.02 .001	17.41 G ₂₁ .63	8 6	.02 .001	30.18 G ₁₂ .10	8 6	.001 .05
II. In Front Of	-----			-----			-----			-----			-----			-----		
In Back Of	-----			-----			-----			-----			-----			-----		

(Continued)

TABLE 16--Continued

Question Category	Non-Reversed Pictures				Reversed Pictures				
	S+O+P χ^2	df	p	S+P χ^2	df	p	S+O χ^2	df	p
III. L-R (Hand)	42.80	8	.001						
	G41.89	6	.001				G13.99	6	.02
To L-R Of									
IV. Closer To									

^GRefers to data analysis by grade. Cells with dashed lines indicate that the null hypothesis must be retained for both age and grade; i. e., the proportion of pass/fail is the same for each age grouping or grade level.

it should be noted that this interaction did not affect rank order difficulty of the four question categories (See Table 15). Inspection of the vertical cells of Table 16 supports the Hypothesis 2 prediction that the S+O+P pairing, at least for the non-reversed condition, functioned to facilitate pictorial interpretation to the extent that the three depth cue combination provided maximal redundancy. With the exception of the absolute left-right category (in which the largest X^2 was found), the S+O+P pairing failed to differentiate among question categories in the "subject" view presentation. Maximal perceptual redundancy apparently served to equalize performance in this condition.

The relative difficulty of the overlap and perspective cues is less clear. The proximity question "Looking at" in the non-reversed condition provides the only information that utilization of the artistic convention for perspective as an indication of distance is a later developmental acquisition. However, when results are plotted by grade level as well as age, then the overlap cue differentiated the self-referent question "Closer to you." The method of analysis may be a testing artifact, because the same results were not always obtained when age grouping and grade level were compared. Furthermore, the grade level S^2 always were larger in the non-reversed condition.

Horizontal inspection of Table 15 data suggest that for the non-reversed condition, if age is held constant as the independent variable, the "closer to" question was the most difficult followed by absolute (but not relative) left-right, thus, supporting the Hypothesis 1 predicted order of acquisition. Independent of viewpoint condition, these two questions were the most difficult of the projective categories (Categories II, III, and IV) while the "in front of-in back of" questions were the easiest. Possibly, the "in front of-in back of" questions are easier, because length is the only three-dimensional relation integrated at least for the three oldest groups.

The finding that an increased level of difficulty occurred for the theoretically easier topological question "pointing at," in the reversed condition, requires explanation. Perhaps a more difficult situation occurs for the child when the maximal redundancy principal can no longer operate effectively. When a transformation of relative position happens--in effect, a 180° rotation which alters the child's point of view--the child's ability to capitalize on the overlap and/or perspective cues to evaluate relative distance is reduced. Essentially, in the reversed context, the child applies a two-dimensional strategy, interpreting the picture as a "flat" representation.

Summary of Developmental Analysis

Hypothesis 1: (1) Order of acquisition of the three projective semantic relations--in front of-in back of, left-right (hand) and to the left (right) of, and closer to--in pictorial space would follow the same order of acquisition as their emergence in three-dimensional space; (2) Topological terms--closer to you, pointing at, and looking at--would be easier than the projective terms; and (3) poor readers would encounter greater difficulty in their comprehension of both topological and projective terms in pictorial space.

The data appear to confirm the first and second predictions. The testing procedure, the MTPS, differentiated between younger and older subjects. While the proportion of subjects who passed each question varied with the stimulus picture presented, in other words, non-reversed versus reversed point of view, the rank order difficulty of the four question categories remained constant within the four age groups. In front of-in back of (before-behind relation) appeared equivalent in difficulty to the three topological questions (closer to you, pointing at, looking at) while the later acquired left-right and above-below relations ("left-right (hand), "to the left (right) of," and "closer to") were of greater difficulty with "closer to" still difficult even for subjects in the nine and one-half to ten and one-half age span.

Performance differences could not be attributed to unfamiliarity with the objects depicted (girl, horse, dog, hand) since identification reached 100 percent for even the youngest subjects.

The third prediction will be discussed in the following section on the diagnostic analysis.

Hypothesis 2: (1) Interpretation of pictorial overlap cues should developmentally precede interpretation of perspective cues; (2) Familiar size as the sole depth cue would be the most difficult to interpret; (3) Inclusion of all three relative distance and depth cues--familiar size, overlap, and perspective--should provide maximal perceptual redundancy, thus, facilitating pictorial interpretation; and (4) the alteration of conceptual perspective (viewpoint) would increase the difficulty level for interpreting content independent of depth cue combination.

The first prediction appears to be confirmed at least in terms of the ease of recognition for overlap over perspective cues. In contrast to the capacity of subjects to identify the depicted objects, subjects below Grade 3 had difficulty in systematically identifying both perspective cues (a horizontal line denoting a "horizon" and two parallel converging lines representing a "road"). The ability to identify the overlap cue reached 99 percent independent of age.

The second prediction was confirmed in the pilot study. Familiar size as the only cue for relative distance was difficult for subjects through Grade 3.

The third and fourth predictions are also confirmed. However, confirmation of the third prediction is qualified since, in the age span under study, the ability to utilize the three conventional pictorial depth cues varied with (1) conceptual perspective (the maximal perceptual redundancy principal was only effective in the subject view or non-reversed pictures and (2) question category. The principal operated more effectively with the developmentally earlier topological and before-behind relations (the proximity questions and in front of-in back of) and operated less effectively for the topological, left-right, and above-below relations (the proximity question "pointing at," the two sets of left-right questions, and "closer to"). Furthermore, the ability to use both the overlap and perspective cues remains difficult even for subjects in the nine to ten year age span when these cues were embedded in a condition of transformation of relative position. Thus, it appears that, while the perceptual pictorial depth cues are necessary for interpretation of pictorial content, they are insufficient. Rather, in order to meet the sufficiency criterion, the child must be capable of systematically representing the three projective relations.

Hypothesis 3: IQ should be unrelated to the invariance of the sequence for the three projective semantic relations.

This hypothesis could not be confirmed for females. IQ effects were found on the MTPS for Grade 2 and 4 females with respect to cumulative score. It is possible that this finding reflects a sex effect in that boys perform better on spatial tasks. However, the recent findings by Maccoby and Jacklin (1974) would dispute that explanation. More likely, the correlation is due to sampling biases or, alternately, to the nature of non-verbal group IQ tests which are heavily loaded with spatial content.

Hypothesis 4 will be discussed in the diagnostic analysis.

Full-Scale Investigation:
Diagnostic Data

Diagnostic data analyses were designed to test the final prediction of Hypothesis 1--that the MTPS would select a group of poor readers on the basis of their reduced performance in comprehending the topological and projective semantic relations--and Hypothesis 4. This hypothesis predicted that such a group of poor readers would produce performance patterns indicative of significant qualitative differences on tasks designed to evaluate the manner in which children construct a representational projective spatial structure and encode terms which refer to aspects of relative position.

Experimental and Control Groups in Final Sample

Because the end of the school year coincided with the individual testing phase of the study, fewer subjects were included in the final sample than originally intended. The sample tested consisted of twenty-eight subjects, eighteen experimentals and ten controls. Every attempt was made to include a majority of subjects falling within the tenth percentile of the MTPS ($N = 16$) whose parents provided written consent. Included, then, in the final sample were nine experimentals whose cumulative MTPS score placed them in the tenth percentile and nine experimentals whose cumulative score placed them within the twenty-fifth percentile. (Individual subject identification is found in Appendix F). Table 17 summarizes the final sample.

Teacher Evaluation

Approximately 75 percent of participating teachers provided written comments on children about whom they had concern. These comments were recorded on data sheets provided each teacher by the examiner and were written prior to the time that either the developmental or diagnostic data were analyzed. Following the experimental selection, individual conferences were held with each teacher to follow up on the children selected for further testing. In terms of the sixteen

TABLE 17
EXPERIMENTAL (N = 18) AND CONTROL (N = 10) SUBJECTS
IN FINAL SAMPLE

Grade	School* SO LT	CA Range	Sex M F	MTPS %tile 10th 25th	+1 SD
<u>Experimentals</u> N=18					
1	4 1	6-8 to 7-5	2 3	1 4	---
2	1 2	7-9 to 8-1	3 0	3 0	---
3	4 2	8-5 to 9-4	2 4	3 3	---
4	2 2	10-0 to 10-7	3 1	2 2	---
<u>Controls</u> N=10					
1	2 1	6-9 to 7-5	0 3	-- --	3
2	1 2	7-9 to 8-1	2 1	-- --	3
3	2 1	8-11 to 9-5	1 2	-- --	3
4	0 1	9-11	1 0	-- --	1

* The Grade 1 sample was drawn from only one LT class and two SO classes. The remaining samples were drawn on the basis of two classes on each grade level in each school.

subjects who fell into the tenth percentile of the MTPS, with the exception of one case, a second grade male, there was complete agreement between the selection procedure and teacher evaluation. Regarding the thirty-six subjects who qualified for the twenty-fifth percentile, the majority were described by their respective teachers as manifesting below-grade functioning (none of the subjects in the control pool were described as encountering any academic learning difficulties). Performance descriptions included inadequate verbal and oral comprehension, uncoordinated, poor word attack skills, seeks attention, and psychological problems (Teacher comments appear in Appendix G).

Hypothesis 1. The final prediction of Hypothesis 1 stated that poor readers would encounter greater difficulty in their comprehension of both topological and projective terms in pictorial space.

The teacher evaluations, therefore, independently confirm the third prediction of Hypothesis 1 and also, independently verify the predictive validity of the MTPS in identifying a higher risk educational group in Grades 1 to 4. Most importantly for the MTPS rationale and construction, the test did not select subjects who teachers described as functioning at or above grade level.

Moreover, it appears that children functioning poorly at the beginning of the school year continue to function poorly at the end of the

school year independently of grade and the amount of supplementary help being provided. The most common descriptions applied to subjects in the expanded experimental pool were "immature," attentional problems, and problems in both the comprehension and expression of spoken and written language; yet, no child was specifically labeled by any teacher as having problems with the grammatical structure of spoken language. With the exception of three cases in which the presence of mild to moderate articulatory problems required speech therapy, all subjects had "generally good (Lieberman, 1970)" spoken language.

Test Battery Results

Visual-perceptual test findings

The Harris Tests of Lateral Dominance

Results were analyzed on the basis of three task categories: (1) total hand dominance rating; (2) total eye dominance rating; and (3) total foot dominance rating. Since foot dominance does not appear to be as selective in differentiating between samples of good and poor readers (Harris, 1958), presentation of results will be restricted to findings for eye and hand dominance. With respect to hand preference, nearly one-third of the experimental group displayed mixed (or incomplete) preference versus none for the controls. Similarly, results

. . .

indicated that three experimentals showed a mixed eye preference (inconsistent preference) versus none for the controls. Tables 18, 19, and 20 summarize these findings.

When the data are classified into type and pattern of hand-eye performance in experimentals and controls, (χ^2 test of Independence, Siegal, 1956) the obtained differences were significant beyond the .05 level (χ^2 [Yeat's correction] = 9.65; df = 4). In other words, hand and eye preferences were associated in these groups.

Even within the Mixed category, a mixed hand-mixed eye pattern seems to be rare. Only 2.9 percent of the Harris (1957) clinical sample evidenced this pattern at ages nine to ten years although Harris (1958) notes that it can be found in a normal adult sample. Thus, Subject 15's mixed eye and hand preference pattern at age ten years can be said to be unusual even in contrast to other patterns of mixed preference.

The Bender Gestalt Test for Young Children

Cumulative score differences. --Protocols were first scored for total number of errors because Koppitz (1964, 1975)² maintains that cumulative score, rather than individual errors, is of diagnostic consequence. A positive Bender was defined as one on which the cumulative score exceeded more than -1 SD from the normative Bender score for a given age group (Koppitz, 1964). In order to refine scoring

TABLE 18
TOTAL HAND DOMINANCE RATINGS FOR EXPERIMENTALS
(N = 18) AND CONTROLS (N = 10)

	Strong Right	CA	Moderate Right	CA	Mixed	CA	Moderate Left	CA	Strong Left	CA
<u>Exper.</u> <u>N=18</u>	1 5 6 7 8 10 12 14 18	6:8 7:5 7:9 7:10 8:1 8:7 9:3 9:4 10:7	3 13 16	6:11 9:3 10:5	2* 4 9 11 15 17*	6:10 7:0 8:5 8:10 10:0 10:6	None		None	
<u>Controls</u> <u>N=10</u>	20 21 23 24 25 26 28	7:0 7:5 8:2 8:2 8:11 9:4 9:11	22	7:9	None		19 27	6:9 9:5	None	

(Continued)

TABLE 18--Continued

* Subject 2 considered himself a left-hander since he wrote and drew with his left hand. However, on the ten item hand preference subtest, he used his right hand for 80 percent of common hand activities (e. g., combing hair, brushing teeth, turning a door knob, etc.). Using this subtest as a sole classificatory criterion, Subject 2 would be categorized as Moderate Right, but his performance on the simultaneous writing subtest, in which he had a reversal with his dominant writing hand, placed him in the Mixed category. Subject 17, nearly four years older, demonstrated the same pattern. It should be noted that the six subjects in the Mixed category all evidenced a right hand preference.

TABLE 19
TOTAL EYE DOMINANCE RATING FOR EXPERIMENTALS
(N = 18) AND CONTROLS (N = 10)

	Strong Right	Moderate Right	Mixed	Moderate Left	Strong Left
<u>Exper.</u> <u>N=18</u>	1 2 4 6 7 9 10 11 12 14 18 16 17	None	3 8 15	None	5* 13*

(Continued)

TABLE 19--Continued

	Strong Right	Moderate Right	Mixed	Moderate Left	Strong Left
Controls <u>N=10</u>	20 21 22 23 25 26	None	None	None	19 24* 27 28*

* Two experimental and two control subjects evidenced contralateral eye-hand preferences (left eye-right hand); however, according to Harris (1958), this pattern is not unusual and, therefore, is not considered as diagnostically significant. In contrast, a mixed eye or hand preference is clinically significant.

TABLE 20
SUMMARY OF HAND-EYE PATTERNS

Type	Pattern	Experimentals N = 18	Controls N = 10
Consistent	Right hand-right eye	8	6
	Left hand-left eye	0	2
Crossed	Right hand-left eye	2	2
	Left hand-right eye	0	0
Mixed	Right hand-mixed eye	2	0
	Mixed hand-right eye	5	0
	Mixed hand-left eye	0	0
	Mixed hand-mixed eye	1	0

procedures further, a second category, borderline Benders, was defined as those protocols in which the composite score fell close to but did not exceed -1 SD for the respective age range.

Four experimental subjects produced positive benders: Subject 4 (CA 7-0, Gr. 1); Subject 12 (CA 9-3, Gr. 3); Subject 14 (CA 9-4, Gr. 3); and Subject 15 (CA 10-0, Gr. 4). Of the control subjects, only one, Subject 27 (CA 9-5, Gr. 3), executed a positive score.

Three additional experimental subjects produced borderline Benders: Subject 3 (CA 6-11, Gr. 1), Subject 18 (CA 10-7, Gr. 4) and Subject 17 (CA 10-6, Gr. 4). No control subject produced a borderline Bender.

In summary, 39 percent of the experimental group produced either positive or borderline Benders, while only 10 percent of controls did so. This finding takes on added strength when the fact is noted that, of the seven experimentals with positive or borderline scores, five were older than age nine, the point at which the Bender is said to lose its developmental significance because "visual-motor function has matured... (Koppitz, 1975, p. 13)."

Analysis of error patterns. --In addition to the composite score, the Developmental Bender Scoring System provides for an analysis of errors with respect to four categories: distortion, integration, rotation, and perseveration. The analysis of error patterns

is constrained by a methodological restriction, that is, chances for error are not equally distributed within or across each design since not all categories apply to each design. Distortion, integration, and rotation are found in seven of nine designs, although each category is not equally distributed within each figure, while perseveration is applicable to only three of nine figures.

A second scoring problem relates to the significance of various errors. Koppitz (1962) defines (but does not specify at what level significance is reached) two types of significance: (a) "Highly significant," a scoring item occurring almost exclusively among neurologically impaired children and (b) "Significant," an item which differentiated between neurologically and non-neurologically impaired but an item which did not occur exclusively among children with known neurological impairment. Inspection of Table 18 (Koppitz, 1964, p. 78) leads to the conclusion that "highly significant" pertains to the .01 level and "significant" to the .05 chance levels.

In classifying individual error patterns, the decision was made to apply a strict criterion, namely, including only those errors which met the "highly significant" standard. Only ten of thirty possible scoring items met this criterion. Those items are reproduced in Table 21. In analyzing these ten errors, it becomes apparent that rotations by 45° , substitution of straight lines for curves (a Figure 6

distortion error), and substitution of lines for dots (an integration error for Figures 3 and 5) are error patterns less subject to chronological age variation in the age five to ten year span. Koppitz (1975) also cites recent evidence that Bender rotations, in particular, are associated with age and that frequency of reduction in rotational errors is common to the six to nine year age range. In contrast to the rotational errors, some perseverative errors, such as repetition of design parts, fail to attain significance until age eight years.

Tables 21 and 22 reproduce both the highly significant and significant errors of experimental subjects with positive and borderline Benders.

Table 21 indicates that rotational errors were the most frequent of highly significant errors. In the case of the Figure 4 error, the nature of the error was identical across subjects, that is, the arc of the sinusoidal curve had been rotated by more than 45° around its axis of separation. In no case were these rotations equivalent to a reversal, that is, a 180° rotation as is more common with design A.³

Table 22 lists the seventeen significant scoring items. With one exception, control Subject 27, the significant error patterns of the positive Bender subjects appear equally distributed across categories although frequency of occurrence differs within the seventeen items. In contrast to the experimental pattern, Subject 27 exhibited what appeared

TABLE 21
HIGHLY SIGNIFICANT ERRORS OF EXPERIMENTAL
SUBJECTS WITH POSITIVE AND
BORDERLINE BENDERS

Error Pattern	Positive	Borderline
<u>Rotations by 45°</u>		
(Fig. 1, 4, 8 all age levels)	4 (4)* 14 (1&4)	3 (4) 18 (4)
<u>Perseveration</u>		
Repetition of design parts (Fig. 1, 2, 6 after CA 7)	12 (6)	None
<u>Integration</u>		
Omissions (Fig. 2 at CA 7)	4	None
Line for series of dots (Fig. 3, 5 all age levels)	None	None
<u>Distortions</u>		
Straight lines for curves (Fig. 6 all ages)	None	None

* Parenthesis denotes the design in which the error occurred.

TABLE 22
SIGNIFICANT ERRORS OF EXPERIMENTAL
SUBJECTS WITH POSITIVE AND BORDER-
LINE BENDERS

Error Pattern	Positive	Borderline
<u>Rotations by 45°</u> (Fig. A. 5 all age levels)	14 (A)	None
(Fig. 7 after CA 6)	14	None
(Fig. 3 after CA 7)	None	None
(Fig. 2 after CA 8)	12 15	17
<u>Integration</u>		
Failure to integrate parts (Fig. A. 4 all age levels)	4 (4) 14 (4)	None
(Fig. 6 all age levels)	None	3
Shape of design lost (Fig. 3 after CA 5)	4 15	17
<u>Distortions</u>		
Misshapen angles (Fig. A all age levels)	14	None

(Continued)

TABLE 22--Continued

Error Pattern	Positive	Borderline
(Fig. 8 after CA 6)	4	18
Angles for curves (Fig. 6 after CA 7)	12	None
Disproportions (Fig. A after CA 6)	None	None
(Fig. 7 after CA 7)	None	None
Circles for dots (Fig. 1 all age levels)	4 27*	None
(Fig. 3 after CA 6)	27* 15	18
(Fig. 5 after CA 8)	14 27* 15	None

* Subject 27 is the sole control subject with a positive Bender.

to be an intra-categorical pattern, that is, her errors were specific to the substitution of circles for dots in three of three figures in which that distortion can appear.

A cumulative index of errors by subject is reproduced in Table 23.

While it is obvious that Bender errors have an empirical significance in terms of differentiating among children, it is questionable whether current interpretations of the Bender designs have psychological relevance for the child. Koppitz (1964) makes a clear statement that time and space are two aspects of the Bender unrelated to visual-motor perception. More recently, Koppitz (1975) has stated that "Form perception in general seems to be based to a much greater extent on cognitive processes than most current theories maintain (Koppitz, 1975, p. 23)." The issue remains as to whether the various significant errors of the Bender do actually reflect different aspects of visual perception or, as Koppitz (1975) now characterizes this function, visual-motor integration. Another possibility is one in which the Bender errors are behavioral manifestations of qualitative differences in the child's construction of a system of reference. If the latter explanation holds, then the deficit cannot be one of visual form but, more likely, a lag in the construction and reconstruction of the rules which define the manner in which a representational space is graphically reproduced.

TABLE 23
CUMULATIVE INDEX OF ERRORS FOR EXPERIMENTAL (N=7)
AND CONTROL (N=1) SUBJECTS WITH POSITIVE AND
BORDERLINE BENDERS

Positive	Borderline	Highly Significant	Significant	Total
14		2	5	7
4		2	4	6
15		0	4	4
12		1	1	2
27*		0	2	2
	18	1	2	3
	3	1	1	2
	17	0	2	2

* Control subject.

A conceptual explanation for the logical nature of Bender errors will be discussed in Chapter V.

Analysis of dimensionality preference in design organization

That preschool and kindergarten age children utilize a directional strategy in the ordering of an array has been found by Huttenlocher (1967) for the orienting of objects and by Elkind and Weiss (1967) for the scanning of pictorial material. These putative plane effects have been observed indirectly for the execution of Bender figures. Koppitz (1964) considered "confused order" of figure location as associated with poor planning and the ability to organize material. There is also further evidence (Koppitz, 1975) that while confused order is not uncommon to the protocols of five to seven year olds, it is frequently found on the protocols of eight to eleven year old learning disabled children. Logical order is defined by Koppitz (1964) as an order which follows a logical sequence, that is, top-bottom or left-right.

Examination of the Bender protocols of all experimental and control subjects produced suggestive evidence that plane effects underlie the manner in which "graphic" space is used and that such graphic plane effects show a definable developmental sequence.

Two separate dimensional patterns were clearly distinguishable: top-bottom and left-right. Also apparent in a number of protocols

was a third, possibly transitional, category marked by a combination of top-bottom and left-right. A single instance of a fourth category was found, that in which circular order predominated over linear order (see Figure 5). Table 24 summarizes the dimensional preferences by grade level of experimental and control subjects.

Four tentative conclusions are drawn from the dimensional preference data:

1. Up-down, or top-bottom, arrays tended to be used by Grade 1 subjects. A shift to left-right seems to occur between Grades 2 to 3, a finding similar to that reported by Elkind and Weiss (1967) and Koppitz (1975) for adolescent Israeli subjects' maintenance of directionality on Bender drawings. The Koppitz data argue further for viewing knowledge and utilization of the left-right dimension in graphic activities as universal and independent of culturally-determined reading and writing directionality.
2. With one exception, all subjects began their drawings either at midpoint or along the upper left side of the paper. This pattern is consistent with the observations of Rand (1973) and Goodnow and Levine (1973) who found that their preschool subjects tended to follow the same route in the copying of isolated Euclidean shapes. The one exception, Subject 13, an experimental subject, used a consistent right to left orientation, beginning in the lower right quadrant and proceeding

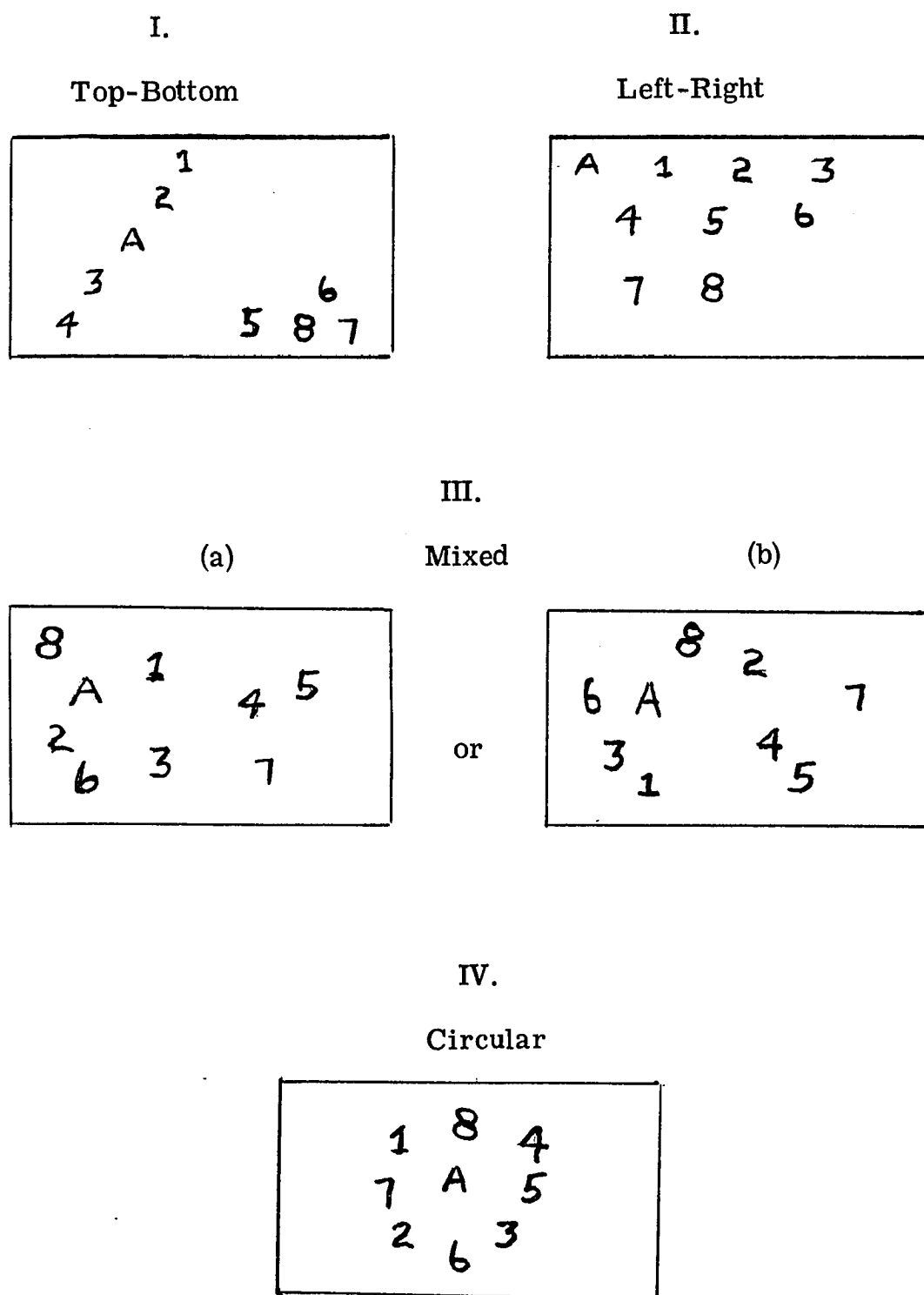


Figure 5. --Dimensional patterns of experimental and control subjects on the Bender.

TABLE 24

DIMENSIONAL PREFERENCES BY GRADE OF EXPERIMENTAL
(N = 18) AND CONTROL (N = 10) SUBJECTS ON THE BENDER

	Top- Bottom Only	Gr.	Primarily ^a Top- Bottom	Gr.	Circular	Gr.	Left- Right Only	Gr.	Primarily ^b Left- Right	Gr.	Mixed	Gr.
Exp. N=18	None		1 4* 5 12* 15*	1 1 1 3 4	14*	3	17+ 18+	4 4	13	3	2 3+ 6 7 8 9 10 11 16	1 1 2 2 2 2 3 3 4
Control N=10	19	1	21 24	1 2	None		22 28	2 4	23 27*	2 3	20 25 26	1 3 3

(* and + denote positive and borderline Bender, respectively)

^aCriterion: No more than three designs oriented towards the left-right plane.

^bCriterion: No more than three designs oriented towards the top-bottom plane.

left and upwards to the right.

3. The mixed category, rather than representing "confused order," may reflect a transitional stage from the first (up-down) to the second (left-right) dimension. Proportionally more experimental than control subjects (one-half versus one-third) fell into this category; however, the finding is circumscribed by the fact that control and experimental subjects were unequal in number particularly at Grade 4.

4. Subject 14's use of circular order, by definition an order without clear reference points, may be a general product of her lag in ordering separate elements which involve connecting intervals or reference points. Her performance on a Euclidean copy task like the Bender combined with her lag in reconstructing a diagonal with objects, to be discussed subsequently under the novel tasks, lends support to this thesis.

Modified tests of absolute left-right knowledge

Subtest 1. --Own Body Part Designation. All control subjects and fifteen of eighteen experimental subjects responded correctly to the six own person questions. The three experimental subjects who failed this subtest (3, 4 and 6) provided hard evidence for the use of a systematic reversal in designating one's own body parts.

According to the strict age criterion for determining the existence of a true systematic reversal (discussed in Chapter II), only 4 percent of subjects older than age five to eight continue to demonstrate this behavior. The last half of the seventh year seems to be a cut-off point between those who reverse because of age effects and those who continue to reverse because of other factors not well understood. When this strict age criterion is applied to the three subjects who failed this subtest, Subject 6 (CA 7-9) becomes the only subject for whom the systematic reversal is developmentally relevant. Furthermore, in using a narrow definition of this behavior, Subject 6 now represents 3 percent of the total (combined) sample, a figure comparable with that found by Laurendeau and Pinard (1970) for a theoretically randomized sample.

Subtest 2. --Own Body Uncrossed and Double Crossed Commands. Contrary to the regularity of designation in the majority of experimental subjects for the above task, only one of six below CA 8-1 was able to respond accurately to all eight questions. In contrast, nine of ten control subjects responded correctly.

Three different types of experimental performance patterns were found for the eight questions: (1) minimal lag (criterion, seven of eight possible responses correct); (2) complete or near total reversal of side (criterion, seven to eight uncrossed commands crossed or

crossed commands uncrossed); and (3) random (criterion, lack of consistency; apparent confusion over the nature of the task). With the exception of the three subjects who systematically reversed own person, the lack of experimental consistency between own person and crossed-same side left-right performance may be suggestive of a developmental lag in stabilizing a more elaborate schematization of one's own body as the constant spatial reference point.

The normal performance patterns of the eleven subjects above CA 8-1 were frequently accompanied by either marked hesitation prior to designation and/or subvocalization of the instruction prior to actual execution ("Touch your right knee with your left hand"). One experimental subject (10) needed to totally verbalize the action before she could begin to execute it. One possible explanation for this behavior may be due to memory constraints for this particular task. In contrast to the other two left-right subtests in which sentence length was held constant (five morphemes), instructions for the uncrossed and double-crossed actions consisted of eight morphemes. The fact that these four children (who ranged in age from 8-1 to 10-6) needed to verbally rehearse suggests that the types of memory strategies applied to the processing of task instructions were less economical or, perhaps, still transitional, in terms of the developmental passage from less to more efficient memory strategies (Gibson and Levin, 1975).

Subtest 3. --Other Person Body Part Designation. Only three experimentals (16 percent), all above CA 8-1, and five controls (50 percent), ranging in age from 7-5 to 9-11, were able to successfully compare the relative position of a single object through transforming the relations of left and right onto an opposite person.

With some variation, the identical performance classification used for own person designation was applied to categorize error patterns for this subtest: (1) inconsistent identification (criterion, consistent same-side errors); (2) complete or near total reversal (criterion, five to all six designations reversed; and (3) random (criterion, lack of any consistency; apparent confusion over the nature of the task).

The three subjects who manifested a systematic reversal pattern on own person presented special scoring and interpretive difficulties. Both Subject 3 (CA 6-11) and Subject 6 (CA 7-9) reversed not only own person but also uncrossed and double-crossed localization. Because their systematization of left and right provides a manner of coherence for them, when transposing these relations onto a single object, for example, an opposite person, the results technically are a false-positive, that is, they appear to properly assign left and right. However, in designating what seems to be accurate location and direction, both children were actually preserving their own reversed systems by orienting left and right on their own bodies to match counterparts on an

opposite person. The use of this correspondence procedure results in a systematic maintenance of the reversal.

In contrast to Subjects 3 and 6, Subject 4 (CA 7-0) produced randomized patterns on both uncrossed-crossed and other person tasks. This pattern runs counter to her performance on own person in which she totally, and consistently, reversed sides. In view of her performance on the more elementary own person task, the difficulties she encountered with transforming left and right cannot be attributed to a failure to assign appropriate meaning to the verbal labels "left" and "right." Rather, the problem appears related to the invariance which the transformation preserves despite the alteration of view-point. Subjects 3 and 6 gave every indication of understanding the externality of the relationship while Subject 4's performance was characterized by non-systematic errors. Table 25 a and b presents the performance patterns of experimental and control subjects on the three absolute left-right tasks and a summary of individual experimental and control error patterns.

Results of these three subtests seem to reconfirm the developmental progression of own and oppositional left-right. With respect to levels of difficulty, oppositional left-right was the most difficult independent of group assignment; however, the relative difficulty of the task was easier for the controls. It should be noted

TABLE 25a
SUMMARY OF PERFORMANCE PATTERNS ON ABSOLUTE LEFT-RIGHT

Own Person		Uncrossed-Double Crossed				Other Person			
All Correct	System Rever.	All Correct	Minimal Lag	Total/Near Total Rever.	Random	All Correct	Total/Near Total Rever.	Inconsist. Identif.	Random
Exp. N=18	3	7	2	3	1	3	6	8	1
Contr. N=10	-	9	1	-	-	5	3	2	-

TABLE 25b
SUMMARY OF ERRORS BY SUBJECT ON ABSOLUTE LEFT-RIGHT

Own Person		Uncrossed-Double Crossed				Other Person			
All Correct	System Rever.	All Correct	Minimal Lag	Total/Near Total Rever.	Random	All Correct	Total/Near Total Rever.	Inconst. Identif.	Random
Exp. N=18	3 4 6		5 7	1 3 6	4		1 3 5 6 7 14	2 10 12 11 15 16 17 18	4
Contr. N=10	None		24	None	None		19 25 26	20 23	None

that the four oldest experimental subjects (15, 16, 17, and 18) all of whom were over age ten, still could not consistently transform oppositional left-right. In a strict sense, they were the only subjects for whom the oppositional task could be considered as diagnostically selective.

Kohs block design

In order to assign performance levels, the WISC test-age equivalents for individual subtests was used initially. This procedure failed to prove useful in analyzing total performance patterns for each group. For example, a raw score of seven to eight is equivalent to a Test Age of 7-10 while a score of sixteen to twenty covers the Test Ages 10-2, 10-6, and 10-10. To overcome this scoring conversion limitation, the following values were assigned to the Test Age, or equivalent mental age, values:

- 1 = 1 1/2+ years below CA
- 2 = 1 to 1 1/2 years below CA
- 3 = Within CA $\pm$ 6 months
- 4 = 1 to 1 1/2 years above CA
- 5 = 1 1/2+ years above CA

As a first order determination, the means, SD's, and significance of the difference between the means were calculated for both

groups. Differences between the two groups were not statistically significant.

The primary conclusion drawn from this finding concerns the equivalence of mental age between the experimental and control groups. Although the control group scored, on average, one to one and one-half years above CA as compared to the within-age performance of the experimentals, the variability between groups was no greater than could be accounted for by chance. Sample size may have affected results obtained. Secondly, if the scale had been extended to seven to include performance which fell in ± 6 months to one year below CA, results may have been different. It is also possible that if the number of rotations per subject had been analyzed, similar to the procedure employed by Lovell, Shapton, and Warren (1964), rather than using total score as criterion, significant findings might have occurred. However, since the rationale for including the Kohs was not to assess mental age but to evaluate manner of performance, the finding of comparable inter-group mental age adds weight to the supposition that IQ differences are not intrinsically responsible for performance pattern differences.

The manner in which subjects executed the designs under a condition of speed revealed more meaningful information in terms of their general problem set and the nature of their errors. Furthermore, the Kohs was the only task administered which pro-

duced overt anxiety in a number of subjects irrespective of whether their performance met CA expectations.

Of the eleven subjects below CA 8, whether experimental or control, Subject 4 (CA 7-0) was the only one who, on the first trial for designs A and B, had difficulty producing a correspondence between the physical model and her copy. In other words, she was unable to use the horizontal and vertical coordinates to place the two red squares on the bottom and the two white squares on the top. Her end-product was a reversal of the relationship. In comparison, Subject 5 (CA 7-5), an experimental, had no difficulty with the physical model but was less able to deal with a pictorial representation which involved asymmetrical axes of separation (Design C) resulting in a reversal of the diagonal. Contrary to Koppitz's (1964) argument that the easier Kohs designs demand only simple matching of color squares, it would appear that the ability to reproduce even the simplest of designs demands the ability to utilize a system of coordinates. The color of the squares alone is insufficient to assist the child in effecting an accurate replica.

With the more complex designs (1 to 7), the types of general strategies applied to design completion were categorized as effectual and non-effectual. An effectual strategy was one marked by a systematic approach with an awareness of rotational errors regardless of whether

or not the given correspondence is resolved correctly. An ineffectual strategy was one characterized by a lack of planning with minimal awareness of the nature of the error. Subjects using ineffectual strategies frequently finished before the allotted time and did not always use the required number of blocks (four or nine depending upon the design). Nearly twice as many experimental as controls relied upon non-effectual strategies ($N = 7$ versus $N = 2$). As a matter of interest, Subject 15 whose Bender performance was positive, produced a level of performance on the Kohs outside the highest Test Age listed (CA 15-10).

Summary of visual-perceptual test findings

Test profiles for the tasks are found in Table 26. For the purposes of the individual test profiles, performance on the two screening tests, the Frostig and the HFD, were included. Criteria for inclusion on the HFD consisted of number and type of qualitative indicator produced, e. g., poor integration of parts, omissions, etc. that were related to poor school achievement (Koppitz, 1968).

Of the experimental subjects, 55 percent had positive, or poor, performance patterns on at least three of the six perceptual tests. In comparison, no control subject met this criterion. Subject 13 was the only experimental who did not present at least one positive

TABLE 26

**TEST PROFILES OF SUBJECTS WITH POSITIVE PERFORMANCE
PATTERNS ON THE SIX VISUAL PERCEPTUAL TASKS**

Frostig Position In Space *	HFD *	Harris Lateral Dominance	Bender	Absolute L-R Uncross- Cross	Other	Kohs
<u>Experimentals</u> N=18	2 3 4 7 8 14 15 16 18	2 4 9 11 15 17	3 4 12 14 15 17 18	1 3 4 5 6 7	1 2 3 4 5 6 7 10 11 12 14 15 16 17 18	4 5 9 14 16

(Continued)

TABLE 26--Continued

Frostig Position In Space*	HFD*	Harris Lateral Dominance	Bender	Absolute L-R Uncross - Own Cross Other		Kohs
Controls <u>N=10</u> 19	None	None	27	None	24 19 20 23 25 26	24

* Both the Frostig and HFD were included as screening tests and were not individually administered. The HFD was scored according to the number of indicators present on a drawing which Koppitz (1968) found related to poor early school achievement.

performance pattern. Frequency of positive performance is tabulated in Table 27.

TABLE 27
FREQUENCY OF POSITIVE PERFORMANCE PATTERNS
OF EXPERIMENTALS AND CONTROLS ON THE
SIX VISUAL-PERCEPTUAL TESTS

	6 Tests	5 Tests	4 Tests	3 Tests	2 Tests	1 Test	None
<u>Experimentals</u> N = 18	None	4	3 14 15	2 5 12 16 17 18	7 9 11	1 6 8 10	13
<u>Controls</u> N = 10	None	None	None	None	19 24	20 23 25 26 27	21 22 28

Cognitive task results

Complete results for the four sets of cognitive tasks are available for the ten control subjects and sixteen of eighteen experimentals. Incomplete protocols occurred because of subject illness or unavailability.

Conservation of number, global
substance and liquid quantity

Scoring criteria. -- Piaget and Inhelder, Sinclair, and Bovet (1974) identify two major classes of verbal arguments children use in conservation tasks.

1. Identity Argument. The child responds "Yes, it is the same (number or quantity) because it's the same amount." This type of argument is not considered a conservation response because the child is essentially saying "It's the same because the object's attributes are still the same." In other words, the subject is attending to the original and end states and not fully to the transformation.

2. Reversibility Arguments. These three theoretically equivalent sets of arguments all share the common property of a "multiple mapping" between dimensions, that is, the subject has focused on the displacement and resulting transformational change.

-- Addition-subtraction (additive identity): "It's still the same amount because you didn't add anything or take it away."⁴

-- Inversion: "If you pour the water back into the other glass, it's still the same amount."

-- Reciprocity: "The water is higher but the glass is thinner. It still doesn't change the amount."

In order to assign stage status systematically, all tape-recorded responses to the three conservation tasks were transcribed onto 3 x 5 cards. Examination of the twenty-eight protocols indicated four major types of verbal descriptions:⁵

1. Uni-dimensional (U): the transformation or change of state was irrelevant; rather the child attended only to one dimension of the end state, usually length, e. g., "Cause mine is longer and yours is shorter."

2. Identity (I): reference was made to the qualitative difference of the end state with either explicit or implicit denotation of a change in quantity, e. g., "Cause when I measured it, it was the same thing and then you poured it into both of these glasses and it had the same as yours, the same amount."

3. Addition-Subtraction (A-S): the irrelevance of the change in shape was verbalized usually by reference to a cancellation action,

e.g., "Because I had the same amount of water we both started off with. All you did was put 'em in different glasses and you didn't take any away or anything."

4. Reciprocity (R) and Inversion (I): specific reference to the irrelevancy of alterations in shape using reversal of order or inversion of order as operative criteria, e.g., "Cause when you had five (pennies) and I had five, there was ten all together... It's always the same amount of money even when you change the order."

A few subjects did respond with "I don't know;" however, when encouraged to attempt an explanation, their descriptions usually fell into one of the cited classifications.

Explanation 1 (U) was assigned preoperational status, 2 (I) was considered typical of the transitional state, and 3 and 4 (A-S, R, and I) characteristic of the operational child. The following response criteria were established to determine stage assignment for each set of conservation tasks:

Preoperational: 2/2 U arguments.

Transitional: 1 U and 1 I; or 2/2 I; or 1 I and 1 A-S, R, or I explanation.

Conserver: 2/2 reversibility explanations (either A-S, R, or I).

As predicted, one set of each conservation task proved easier

for transitional subjects than the second condition. Typically, these transitional children might give a conserving-like description for one condition but when presented with, for example, a prediction condition for liquid quantity, they would revert to an explanation more characteristic of the transitional child. By using such strict assignment criteria, it was possible to reduce the number of "false positive" protocols in the operational category.

Level of difficulty. --For the purpose of computing probability values for the assumed ordinal sequence of number, global substance, and liquid quantity, the twenty-eight protocols were treated as a whole rather than as separate treatment groups. On the basis of individual performance for each conservation task, subjects were assigned to either the Preoperational, Transitional, or Conserver category. Chi square values (Garrett, 1966) were then calculated for each task to determine whether each pattern was equally probable. Results are reported in Table 28.

Obtained differences in performance on each of the three conservation tasks do reflect differences in conservation status. Secondly, results substantiate the development priority of number conservation.

When the data were analyzed by stage and each task as a

TABLE 28
CHI SQUARE PROBABILITY VALUES FOR NUMBER,
GLOBAL SUBSTANCE, AND LIQUID QUANTITY
(N = 28)

Task	χ^2	df	Level of Significance
Number	19.11	2	$> .01$
Global Substance	6.48	2	$> .05$
Liquid Quantity	7.76	2	$> .05$

separate condition, findings indicated that 68 percent of the total sample were conserving number, 46 percent conserved global substance, while 36 percent conserved liquid quantity. These results are tabulated in Table 29.

TABLE 29
PREOPERATIONAL, TRANSITIONAL, AND CONSERVING
SUBJECTS BY TASK (N = 28)

	Pre-Op.	Transi.	Conserv.
Number	1	8	19
Global Substance	3	12	13
Liquid Quantity	3	15	10

It would appear, then, as predicted, that a true developmental sequence holds between at least number conservation and liquid quantity conservation (that is, between discontinuous and continuous quantities).

Patterns of performance. --Generally, younger subjects, specifically those below CA 8, tended to be transitionals; however, no clear age demarcations were evident over CA 8 (17/28 subjects). When group differences were compared, it was found that the experimentals, as a group, performed better on the conservation tasks than they had on the perceptual tests. However, the only preoperational behavior found was specific to four experimental subjects.

Eight patterns were identified for performance on number (N), global substance (GS) and liquid quantity (LQ):

1. Conserving N, GS, and LQ. (N = 8)
2. Conserving N and GS; transitional LQ. (N = 3)
3. Conserving N only; transitional GS and LQ. (N = 8)
4. Conserving N and GS; preoperational LQ. (N = 1)
5. Transitional N, GS, and LQ. (N = 3)
6. Conserving N; preoperational GS and LQ. (N = 1)
7. Transitional N and LQ; preoperational GS. (N = 1)
8. Preoperational N, GS, and LQ. (N = 1)
9. Unclassifiable (N = 2)

Performance patterns by experimental and control grouping is summarized in Table 30 (see page 235).

The pattern analysis found that approximately one-third of each group displayed hard evidence for the existence of true conservation on the three tasks.

Examination of pattern 2 was revealing in terms of Subject 14's status. Qualitatively, her performance on the conservation tasks was markedly superior to that which she produced on several of the visual-perceptual tests (e. g. , the Bender and Kohs Block Designs).

Variability was a distinguishing feature of pattern 3. As might be predicted on the basis of chronological age, Subjects 26 and 27, both controls, appeared to be on the verge of attaining conservation of both GS and LQ. Conflict of criteria producing uncertainty characterized their performance on these tasks. In contrast, Subject 10 provided evidence that she had only recently begun to move from a totally pre-operational to a more cognitive mode of functioning. The fragility of her status was demonstrated with the more difficult conditions where she reverted to a U explanation, the latter frequently verbose and unrelated to the presenting context. Finally, of the eight subjects in this category, Subject 18 was the only child who seemed to be operating with production constraints with respect to the organization of semantic content and syntactic structure.

TABLE 30
PERFORMANCE PATTERNS ON NUMBER, GLOBAL SUBSTANCE, AND LIQUID QUANTITY
FOR EXPERIMENTALS (N=18) AND CONTROLS (N=10)

	Pattern 1 CA	Pattern 2 CA	Pattern 3 CA	Pattern 4 CA	Pattern 5 CA	Pattern 6 CA	Pattern 7 CA	Pattern 8 CA	Pattern 9 CA
<u>Exper.</u>	7* 7-10 8 8-1 12 9-3 16 10-5 17 10-6	13 9-3 14 9-4	9 8-5 10 8-7 18 10-7	11 8-10	3 6-11 4 7-0	1 6-8	5 7-5	2 6-10	6 7-9 15 10-0
<u>Control</u>	22 7-9 25 8-11 28 9-11	23 8-2	19 6-9 21 7-5 24 8-2 26 9-4 27 9-5	None	20 7-0	None	None	None	None

* Subjects are identified by number. See Appendix , for more complete information on each subject.

Similar within-group differences were found for pattern 5. Subject 20's readiness level for operational thinking was high while the experimental Subjects 3 and 4 vacillated between preoperational and transitional behavior. Subject 4's performance, although acceptable in terms of her chronological age, was accompanied by difficulties in verbally reproducing what she comprehended.

The two unclassifiable protocols were assigned a separate category because of the incongruity of the logical sequences produced. Subject 15 conserved LQ although he was given transitional status for GS and N. Subject 6 conserved GS and LQ but manifested transitional behavior for N. Since both patterns are incompatible logically and developmentally, examiner variables (e. g. , questioning procedure) rather than subject variables may account for the interpretive inconsistencies. However, the patterns obtained may also have been the result of either the structurally bizarre or restricted nature of their respective verbal explanations.

In summary, with the exception of the two unclassifiable protocols described above, all subjects produced performance patterns consistent with the logical hierarchy posited for the acquisition of conservation (Piaget, 1965; Inhelder, Sinclair & Bovet, 1974). Intergroup differences in rate of acquisition were generally compatible with chronological age while intragroup differences indicated that more

experimental subjects were lagging behind their peers when chronological age was held constant. Four experimental subjects, (4, 6, 15, and 18), produced verbal explanations that were marked by a lack of semantic and/or syntactic well-formedness. It was believed that the latter was a contributory factor in the inability to classify the protocols of Subjects 6 and 15.

Construction of the projective straight line

Scoring criteria. -- Scoring procedures for coding of results followed the elaborated guidelines developed for this task by Laurendeau and Pinard (1970), who employed both theoretical criteria (specificity of line location and direction independent of the order of instructions) and empirical criteria (correctness or incorrectness of each construction according to the instructions given). Two criteria were used to evaluate over-all performance: (1) construction of both diagonals with or without the accompaniment of either a Euclidean (manual measurement) or projective (visual sighting) reverification strategy and (2) successful performance on the remaining four parallel straight line problems. The first criterion was considered the strict criterion for verifying mastery of the diagonal.

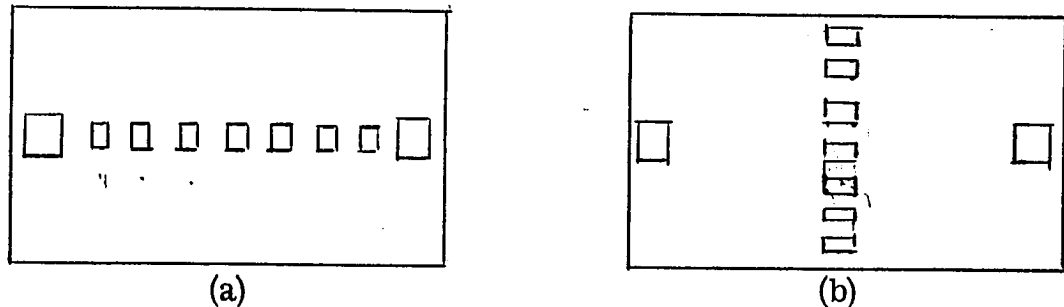
Secondly, it was found necessary to modify one aspect of the scoring procedure. Laurendeau and Pinard scored as successes those

protocols in which location is altered but directionality preserved, for example, when the child constructs a line perpendicular to the reference points (see Figure 6). They justified classifying these protocols in this manner by arguing that the child had not altered the basic problem difficulty despite the fact that he may have failed to understand the semantic relation underlying "between." Since this criterion not only deemphasizes the importance of semantic variables in the execution of the task but also because this pattern was found to be rare beyond Stage I, these protocols were scored as failures.

Level of difficulty. --Three distinct patterns of performance were found: (1) total success on both diagonals (+R+C); (2) partial success with one but not the other diagonal (+R-C or +C-R) and (3) total failure with both diagonals (-R-C) (Chi square test of independence from 50 percent [Siegel, 1956]; $\chi^2 = 8.86$; $df = 3$; $p > .05$).

Analysis of item difficulty indicated that both diagonals (problems 3 and 6) provided maximum variability in individual performance with variances of .24 and .25. Variances for the four parallel conditions (1, 2, 4, and 5) indicated greater homogeneity (variances of .13, .13, .12, and .22).

The greater difficulty of both diagonals for both the experimental and control groups was reverified by calculating phi coefficients for inter-item correlations (Ferguson, 1971). Of fifteen possible



-  = Reference points
 = Objects to be located

Figure 6: Problem 2 is represented, i. e., the rectangular condition in which the reference points are located midway along the opposite sides. Laurendeau and Pinard (1970) scored both (a) and (b), a construction in which the line is perpendicular to the reference points, as successes.

combinations, the only significant phi coefficient was found for problems 3 and 6 (ϕ , .49; X^2 [Yeat's correction] = 6.72; $p > .01$). These findings reconfirm Laurendeau and Pinard's (1970) previous results that problems 1, 2, 4, and 5 are of equivalent difficulty independent of whether the condition is rectangular or circular.

Patterns of performance. --Both diagonals were equally difficult for the experimentals and controls as separate treatment groups; however, proportionately, construction of the diagonal was more difficult for the experimentals (see Table 31).

TABLE 31
PERCENT OF EXPERIMENTAL (N=18) AND CONTROL (N=10)
SUBJECTS PASSING BOTH DIAGONALS

	Problem 3 (Rectangular)		Problem 6 (Circular)	
	Experimental	Control	Experimental	Control
PASS	50	80	45	70
FAIL	50	20	55	30

When the data were subjected to an analysis of the significance of the difference between percentages of experimentals and controls passing and failing each item, the obtained t ratios for each of the six problems failed to attain significance. Only the standard error of the difference for problems 3 and 6 approached the .05 level.

It was further determined that failure in maintaining the constant direction of parallel straight lines was not always associated with failure to construct a diagonal. However, failure in constructing one or both diagonals (-R-C, $N = 8$) was associated with a greater incidence of total problem failure. Proportionately more controls ($N = 7$) than experimentals ($N = 6$) met criteria for Stage III placement (mastery of both diagonals). Three controls and twelve experimentals manifested Stage II patterns (success with parallel lines but failure with the diagonals). Stage II patterns included both -R-C ($N = 8$) and +R-C or -R+C ($N = 7$).

These findings, then, are consistent with the developmental direction of the capacity to construct diagonal lines. Given the age span of the subjects (6-8 to 10-7), no subject met the Laurendeau and Pinard (1970) criteria for Stage 0 (inability to construct even a curved or twisting line) or Stage I (inability to form a straight line), that is, all subjects were able to build systematic linear constructions. Subjects under CA 8-5 tended to be able to construct only one or none of the

diagonals while subjects over CA 8-5 constructed both diagonals.

Table 32 summarizes results by experimental and control assignment.

Analysis of reverification strategies. --Five types of strategies were recorded during the construction of both diagonals:

1. Sighting - immediately following or during the course of construction, the child sighted on the endpoints using an "end-on" view.
2. Manual Measurement - following construction, the child used a finger or side of his hand to measure the accuracy of the product. Some subjects, prior to construction, used their finger or hand to draw an imaginary line.
3. Manual Adjustment - during the course of construction or immediately upon completion, the child adjusted unit intervals in order to align elements.
4. Visual Inspection - completion of the construction was followed by a visual scanning either by remaining stationary or by adjusting head position to scan the length of one or both sides of the imaginary straight line.
5. None - the child gave no indication (physical movement, verbal authentication, etc.) of an attempt to use a reverification procedure.

Chi square analysis of the frequency distribution of reverification strategies for all six problems (Garrett, 1966) supported the

TABLE 32

PERFORMANCE PATTERNS OF EXPERIMENTAL (N=18) AND CONTROL
(N+10) SUBJECTS IN CONSTRUCTING DIAGONALS FOR THE
RECTANGULAR (R) AND CIRCULAR (C) CONDITIONS

	Stage III		Stage II		-R-C		CA
	+R+C	CA	+R-C or -R+C	CA			
Experi- mental	2 ^M	6-10	5 ^M	7-5	1		6-8
	6 ^M	7-9	9	8-5	3*		6-11
	12	9-3	11	8-10	4*		7-0
	13	9-3	14	9-4	7		7-10
	15 ^M	10-0	16 ^S	10-5	8 ^{S&M}		8-1
	18 ^S	10-7	17	10-6	10		8-7
	21 ^S	7-5	24		19		6-9
	22 ^M	7-9			20		7-0
	23 ^S	8-2					
	25 ^{S&M}	8-11					
	26 ^M	9-4					
	27	9-5					
	28 ^S	9-11					

(Continued)

TABLE 32--Continued

M = Manual measurement strategy.

S = Sighting strategy.

* Of the twenty-eight subjects, only Subjects 3 and 4 demonstrated unusual difficulty in preserving directionality of parallel lines or in segmenting space into equal unit intervals. In addition, Subject 4 was the only child who, in the pre-test, failed to understand "straight line." In order to secure her agreement "straight road" had to be substituted. She also was the only child who stated "I don't know how to do that" when asked to make a straight "road" between the reference points and was also the only subject to produce a parallel line construction perpendicular to the reference points (see Figure 6b). Construction of both diagonals was marked by line curvature; construction of the rectangular was accompanied by total reverbalizing of instructions; and the end product was commented upon with "I put a straight line."

hypothesis that the five strategies were not distributed equally ($\chi^2 = 25.70$; $df = 4$; $p < .001$). The data are reported in Table 33.

Only manual measurement (Euclidean) or sighting (projective) were considered strict criterion for reverifying the relativity of diagonality.

Of the thirteen subjects who constructed both diagonals (+R+C), six experimentals and seven controls, ten utilized either a manual measurement or sighting strategy. In addition, three of these subjects used a combination of both projective and Euclidean procedures (see Table 32). The finding that a reverification strategy, either projective or Euclidean, was associated with the capacity to reconstruct the diagonal would seem to support the Piaget and Inhelder (1967) hypothesis that the "representational" straight line differs from the "perceptual" straight line (the parallel lines conditions or the drawing of continuous straight lines between constant reference points [Frostig, 1966]) "by virtue of the child's becoming aware of the part played by different points of view (Piaget and Inhelder, 1967, p. 169)."

Only one of eight subjects in the -R-C category invoked a verification procedure with the diagonals. In the rectangular condition, Subject B used sighting and then corrected his line which still remained curved. In the circular condition, he employed manual measurement

TABLE 33
FREQUENCY OF REVERIFICATION STRATEGIES ON THE SIX
PROBLEMS OF THE CONSTRUCTION OF THE
PROJECTIVE STRAIGHT LINE (N = 28)

	None	Visual Inspection	Manual Adjustment	Manual Measurement	Visual Sighting
Gr. 1 N=8	30	5	3	9	1
Gr. 2 N=6	9	9	9	11	3
Gr. 3 N=9	18	19	23	7	2
Gr. 4 N=5	3	8	11	6	11

but the end-product still was curved. The remainder of the six subjects used either no strategy on any of the six problems or relied on a combination of visual inspection and manual adjustment for the two diagonal conditions.

Relative left-right

Scoring criteria. -- Each of the three relative left-right problems involved the relative position of a series of three objects under three different conditions: visible (V), visible reversed (VR), and hidden (H). For scoring purposes, each condition was treated as a separate problem with an implied conceptual hierarchy underlying all three problems, that is, assigning correct left-right relations to V should precede or at least co-occur with the capacity to visualize or represent the relationships in H. The VR condition served as a control since, in this condition, the child's own position was changed causing a concomitant alteration in spatial boundaries and personal perspective. Common to all three conditions was the understanding that one object could not fill the same position as the two other objects. Therefore, each protocol was scored according to (a) success with all six questions within a given problem and (b) success with the eighteen questions across the three problems.

Level of difficulty. --The developmental difficulty of the three problems was apparent. All three problems were very difficult for

Grade 1 and 2 subjects ($N = 13$) independent of experimental or control group status. Difficulty indices were low, $V = .17$, VR and H both equaling zero (that is, no subject in Grade 1 or 2 succeeded with these tasks). Difficulty indices for Grade 3 and 4 subjects ($N = 14$) were somewhat better but still low, $V = .20$, $VR = .12$, and $H = .16$. When variances were combined for the V and H problems, the resulting .20 difficulty index for Grades 3 and 4 indicated homogeneity of performance.

When the three absolute and three relative tasks were analyzed, it was found that own person identification was the easiest location to which children could assign constant meaning. Oppositional left-right was found to be equivalent in difficulty to the relative V and H tasks. Thus, the data confirm the general difficulty level of the sequence of acquisition for absolute and relative left-right but with a lag in the rate of acquisition more explicit for the experimental group. Table 34 tabulates the frequency of success for the six left-right problems.

Patterns of performance. --On an individual basis, success with one or two of the relative tasks, usually V or H , did not necessarily follow chronological age but success or near success with all three tasks appeared to do so. Only three subjects, two experimentals and one control, performed significantly better on H than V , a pattern which

TABLE 34
PERCENTAGE OF SUCCESS ON THE SIX LEFT-RIGHT
PROBLEMS FOR EXPERIMENTALS AND CONTROLS

Problem	<u>ABSOLUTE</u>				<u>RELATIVE</u>						
	Own 1	%	Crossed- Uncrossed 2	%	Oppo- site 3	%	V 4	VR 5	H 6	%	
Exp. N=18	15	84	7	38	3	17	3	18	1	6	12
Cont. N=10	10	100	9	90	5	50	4	40	1	10	10

chance success cannot rule out on the basis of a single problem. No subject performed better with VR than either V or H.

Success Patterns - Subject 15 (CA 10-0), an experimental, was the only subject who reached 100 percent criterion on all three problems, a performance well beyond chance limits. His performance provides some evidence for doubting that, contrary to the Laurendeau and Pinard (1970) criterion, complete success with transforming left-right relations onto a single object is a necessary prerequisite for structuring the relativity of left and right with respect to a series of objects. An alternative explanation which is intuitively more convincing but not necessarily valid would explain this counter-instance by relating failure on the less complex task to such intangible variables as fluctuating attention or lack of interest. Laurendeau and Pinard (1970, p. 281) provide this latter argument for justifying the elimination of 4.3 percent of their protocols which failed to conform to the order of difficulty of the problems. There is some validity in construing Subject 15's performance as a "false positive" particularly since this is the second instance of his failure to conform to expected hierarchies of difficulty (see conservation tasks).

This argument would prove more attractive if Subject 15 were the only subject to perform better on the relative tasks in contrast to

less adequate opposite person identification. Unfortunately, Subject 15 was the only subject who reached criteria with the relative tasks. However, Subject 16 whose performance on the absolute other person task was similar to Subject 15's, managed near complete success with the relative tasks, correctly locating the relative position of all lateral objects and all but one of the central objects (in the VR condition).

Examination of the protocols of the eight subjects who reached criteria on the absolute opposition task indicated that only two, Subject 25 (CA 8-11) and Subject 28 (CA 9-11), both controls, achieved near success on the relative tasks. Subject 25 is another interesting case in point for questioning the total mastery of absolute left-right as a necessary precondition to constructing the concept of relative position. Unlike Subjects 15 and 16, Subject 25 reversed opposite left-right relations in five of six instances (he did not reverse own person). This type of performance can be used to argue that he has, in fact, acquired the necessary conceptual schemata. His performance, therefore, on the relative problems can be viewed in one of two ways: (1) reversal of oppositional relations does not preclude construction of the internal relations of left and right or (2) the internal relations are systematically reversed which means that his performance pattern is technically another "false positive."

Partial Success Patterns - partial success was defined by consistency of identification with the lateral objects across all three conditions above a 75 percent level and consistent errors with the central objects in no more than two of six presentations.

Only Subject 22 (CA 7-9), a control, and Subject 12 (CA 9-3), an experimental, met this criteria (in terms of strict application of criteria, Subjects 25, 28 and 16 also belong in this category). Subject 22, who reached criterion on oppositional left-right, manifested marked hesitations in the VR condition, another indication of the increased obstacles generated by a change of perspective on conceptions of relative position.

In summary, success with transforming oppositional relations did not correspond directly with the ability to define systematically the relative position of a series of objects. Conversely, less than full achievement with oppositional relations was not predictive of complete failure with a series of objects.

Failure Patterns - On initial inspection, the types of patterns, or strategies, specific to the failure category appeared to defy a common classification; however, an in depth analysis of protocols revealed five strategies used either singly or in combination depending upon the cognitive and semantic complexity of the problem for the individual child.

1. Perseveration of response--responses were identical, for example, Subject 4 (CA 7-0) termed all positions "right" in the H condi-

tion. She was the only child to respond in this manner on any of the three problems.

2. Chance responses--while chance success cannot be eliminated from any single problem, the usual pattern produced was one of either scatter across all problems or success with the easier V and failure with the other two conditions. A predominant chance or guessing pattern was defined as one in which the child encountered greater success with central than lateral objects or produced a more stable pattern on VR than either V or H.

Subject 3 (CA 6-11) was the sole subject whose total performance pattern could be classified in this manner.

3. Correct response to all six questions, including the central object questions, on one problem and failure with the two other problems. Only Subject 21 (CA 7-5) and Subject 8 (CA 8-1) produced a pattern in which they handled V correctly but were unable to deal with either H or VR (Subject 8 also reached criterion on oppositional left-right).

4. Reversal responses--the physical object, either lateral or central is assigned the opposite space, that is, when the physical object functioned grammatically as the logical subject, the child responds as if it functioned as the logical object. Reversal responses were not necessarily consistent across problems; rather, in most instances, they occurred in only one condition (See Table 35).

TABLE 35

DISTRIBUTION OF REVERSAL RESPONSES IN EXPERIMENTAL
(N=17) AND CONTROL SUBJECTS (N=10) ON THE
THREE RELATIVE LEFT-RIGHT TASKS

	N	V	CA	N	H	CA	N	VR	CA
<u>Exp.</u>	5	5 7 10 14 17	7-5 7-10 8-7 9-3 10-7	3	6* 9 14	7-9 8-5 9-4	1	10	8-7
<u>Control</u>	2	23 26	8-2 9-4	2	26 27	9-4 9-5	0	None	

* Reversed on all three problems.

5. Central object dislocation--the central object is not viewed as having contiguous space relative to the two end-objects. Its position is understood only in an absolute manner; it may belong to the same space occupied by its object of comparison; or "left" and "right" may not exist as a position. In the latter case, the child responded with "middle" or "in-between," behaviors common to Subjects 5 and 6 in all three conditions.

Eight subjects failed with all or five of six of the central objects: the experimental Subjects 5, 6, 9, 13, and 14 and the control Subjects 20, 26, and 27. Failure with all the central objects, however, cannot be readily distinguished from performances on which subjects attained some level of chance success. Since central object questions were not presented an equivalent number of times as the end-object questions, any success short of criterion must be held suspect.

Table 36 (see page 256) tabulates subjects according to the Laurendeau and Pinard (1970) stages. It should be noted that Laurendeau and Pinard did not include the VR condition in their testing procedure and, therefore, their delineation of stage is based upon two tests of absolute own and oppositional left-right and two tests of relative left-right (V and H).

TABLE 36

**STAGES OF FUNCTION ON RELATIVE CONCEPTS OF LEFT AND RIGHT
FOR EXPERIMENTALS (N = 17) AND CONTROLS (N=10)**

Stage III Complete Objectification				Stage II Relation of External Opposition (Subjective Only)				Stage I Relation of Internal Opposition Only				Stage 0 Total In- comprehension
IIIb	CA	IIIa	CA	IIb	CA	IIa	CA	Ib	CA	Ia	CA	
<u>Experimental</u> 15	10-0	12	9-3	8	8-1	9	8-5	1	6-8	4	7-0	None
		16	10-5	13	9-3	10	8-7	3	6-11			
						11	8-10	5	7-5			
						14	9-3	6	7-9			
						17	10-6	7	7-10			
						18	10-7					
<u>Control</u> None		22	7-9	21	7-5	20	7-0	19	6-9	None		None
		25	8-11	24	8-2	23	8-2	26	9-4			
		28	9-11			27	9-5					

Coordination of perspectives

Scoring criteria. --Each of the three problems (C, F, and B) was analyzed according to cognitive and semantic criteria. Cognitive relations, the differentiation of the subject's point of view from the man's point of view, were evaluated for each problem in three separate conditions:

(a) board position (or three-dimensional space, hereafter referred to as 3D space).

(b) pictorial choice (pictorial or two-dimensional space, hereafter referred to as 2D space).

(c) pictorial rejections (pictorial or 2D space).

Semantic relations, the semantic differentiation of perspectives, were analyzed under three similar conditions for each problem:

(a) verbal description of board position (3D space).

(b) verbal description of pictorial choice criteria (pictorial or 2D space).

(c) verbal description of pictorial rejections criteria (pictorial or 2D space).

All protocols were transcribed and classified by the examiner in accordance with the general cognitive and semantic criteria specified above. The classification procedure developed by Laurendeau and Pinard (1970), with certain modifications, was employed in evaluating cognitive aspects only.

Level of difficulty. --Eight possible patterns across the three problems were identified as denoting total failure, partial success (or failure), and total success. Results are reported in Table 37.

TABLE 37
FREQUENCY DISTRIBUTION OF SUCCESS, PARTIAL
SUCCESS, AND FAILURE (PROBLEMS C, F, &
B) FOR THE TOTAL SAMPLE (N = 26)

Number of Problems Correct of Three	Pattern	N
0	-C-F-B	8
1	+C-F-B -C+F-B	8
2	-C+F+B +C+F-B +C-F+B	6
3	+C+F+B	4

Application of the Kolmogorov-Smirnov one sample test (Siegel, 1956) yielded a value of D which approached the .05 level for the frequency distributions of Table 37.

When performance across problems was dichotomized according to experimental or control group assignment, significant probability values (Binomial Test for Small Samples, one-tailed [Siegel, 1956]) were found for the partial success pattern (two of three correct) and success with all three problems. Probability values are reported in Table 38.

Analysis of item difficulty, therefore, appears consistent with earlier findings (Laurendeau and Pinard, 1970; Minnigerode and Carey, 1974): varying both the Before-Behind and Left-Right dimensions (Problem B) proved more difficult than either the theoretically easiest task of varying Before-Behind with Left-Right held constant (Problem C) or the mediumly difficult varying of Left-Right with Before-Behind held constant (Problem F). No child, experimental or control, succeeded with or partially succeeded with Problem B alone while failing the two other problems.

Although the item analyses supported the invariance of the hypothetical sequence underlying the coordination of perspectives, quantitative measurement alone tended to be misleading. Four subjects selected the correct picture and maintained consistency of their selection criteria in rejecting other choices for the three problems (the +C+F+B pattern). However, qualitatively, no child strictly met the requirement for placement in Laurendeau and Pinard's Stage III,

TABLE 38
PROBABILITY VALUES ASSOCIATED WITH SUCCESS, PARTIAL SUCCESS,
AND FAILURE (PROBLEMS C, F, AND B) FOR
EXPERIMENTALS (N=16)* AND
CONTROLS (N=10)

Number of Problems Correct of Three	Experimental N	p	Control N	p
(0) -C-F-B	5	---	3	---
(1) +C-F-B -C+F-B	5 (Chance Success Region)	---	3	---
(2) -C+F+B +C+F-B +C-F+B	4	.04	2	.05
(3) +C+F+B	2	.01	2	.05

* Two experimentals did not receive this test.

that is, success could be achieved by focusing on one dominant relation, for example, the disappearance of the yellow mountain in Problem C, but such success failed to meet the requirement that, for Problem B, all three relations be coordinated.

Patterns of Performance - Cognitive patterns. -- Three different patterns, or strategies, were isolated across the three conditions (F, C, and B) on the basis of the consistency with which the particular strategy was employed within both the actual (3D) and pictorial (2D) condition for each problem (see Figures 2 and 3, Chapter II, page 104 for 3D and 2D stimuli). These strategies were labeled as strategies X, Y and Z.

Strategy X was defined as a total or partial representation of the man's viewpoint as a viewpoint distinct from that of the child's. Six controls, ranging in age from CA 7-9 to 9-11, and ten experimentals, ranging in age from CA 8-1 to 10-7, applied an X strategy in at least one problem. Two different applications were evident: (1) those who consistently used strategy X across all three conditions (five controls and four experimentals) and (2) those who used X for one problem and either strategy Y or Z for one or both of the remaining problems (one control and six experimentals). Consistent application of X may have represented a transitional phase between Stages II and III while a variable application reflected a transition between Stages I and II.

The dominant relation strategy used by X subjects varied with

the problem. For example, in problem C (left-right held constant, before-behind varied), the total disappearance, or spatial displacement, of the yellow mountain served as the predominant critical feature for some subjects while, for others, the red mountain-blue mountain overlap, the relative distance cue, fulfilled the identical function. Focus on either one or the other feature (but not both) was indicative of the fact that the child was still using a partial topological strategy, a surface or external strategy in which the evaluation of relative distance was dominant to represent the internalized projective relations. Use of a partial topological strategy frequently resulted in the child's selection of a perceptually similar but conceptually dissimilar pictorial representation, for example, picture E in problem C.

Strategy Y was characterized as an egocentric pattern. In this case, the child demonstrated that knowledge of viewpoint was relevant. However, he was unable to represent any possible view other than his own. Strategy Y was specific to four younger control subjects, ranging in age from CA 6-9 to 8-2, and one experimental, Subject 14, CA 9-4. Their patterns of function would place them strictly within Stage I (complete egocentrism). Control Subject 19's method for constructing relations was instructive. In the board conditions, for all three problems, Subject 19 always needed to rely on motor representation as a physical means of evaluating the relative distance between

mountains. In each problem, she drew imaginary lines with her fingers between target mountains. Her reliance on a total topological framework was a common property shared with the other subjects in this group.

The final strategy, Z, was found to be a variable pattern in that the child shifted from egocentric to random strategies or the reverse. Random patterns were often characterized by a failure to understand that viewpoint was relevant. For example, the child would not respond to the presenting context or would refer to unrelated content.

Strategy Z was specific to five experimental subjects only. They ranged in age from CA 6-8 to 8-7 (Subjects 1, 4, 5, 6, and 10). The decision was made to place these five children in the lower half of Stage I rather than Stage 0 (total incomprehension or refusal) since, on at least one problem, they provided evidence of being able to operate with Strategy Y. In a real sense, their pattern of function may be indicative of transitional progress from Stage 0 to Stage I (Laurendeau and Pinard [1970] seldom found Stage 0 after age six years).

In general, these five children tended to itemize what they actually saw, or when pressed, would specify criteria according to non-relevant context, for example, the little man would see "snakes and trees."

One final observation is of importance. Within each strategy

category (X, Y, or Z), an infrequent occurrence of dominant relation reversal was found. Reversal patterns occurred for each condition (C, F, and B) and were specific to three experimental subjects, 16, 4, and 6. Subject 16 reversed the dominant relations for problem F, while Subjects 4 and 6 reversed the relations in problems F and B, respectively. Other subjects occasionally reversed lateral endpoints within a given picture but only three selected a picture in which the dominant relations were completely reversed. Laurendeau and Pinard, noted that for problem F, only 7 percent of their large sample chose the reversed picture (H), a percentage comparable to this sample. While Laurendeau and Pinard did not elaborate upon why such a selection may have occurred or state whether such selection was confined to a particular age range, the infrequency of such choices attests to the unusual behavior in selecting a reversed picture.

It is apparent, therefore, that classification into a particular stage did not denote an equivalence of performance. Within a given stage, the variations in performance were considerable irrespective of experimental or control assignment. Secondly, chronological age was not necessarily an appropriate criterion by which predictions could be made about performance patterns, particularly for the experimental group. In fact, one of the youngest subjects, Subject 22, age CA 7-9, a control, functioned in a manner superior to not only his

peers but also to older control subjects. In sum, differences in the rate of acquisition were considerable in the context of the invariance of the sequence underlying the coordination of perspectives. Finally, the inter-problem variability in performance within the same child would appear to demonstrate the context-sensitive influence of both the transitional aspects of acquiring a representational spatial structure and less than full attainment of operational thinking.

Stages of classification based on the Laurendeau and Pinard (1970) stages, are reported in Table 39 (see page 266).

Semantic patterns - In contrast to other sub-tests, the coordination of perspectives task was semantically open-ended, that is, the child was not given a limited set of alternatives on which to base a decision. Both descriptive and pictorial conditions were in free variation to the degree that the child could attempt to differentiate viewpoints using an unrestricted combination of projective and non-projective dimensional terms.

Ten possible outcomes were predicted in regard to the underlying semantic relations within conditions (3D and 2D [pictorial]) conditions for each problem. The outcomes were derived from two general categories: (a) internal terms (the projective relations) and (b) external terms (topological or surface relations). The crucial question was whether or not the child utilized a similar set of semantic relations

TABLE 39

**STAGES OF FUNCTION ON THE COORDINATION OF PERSPECTIVES
FOR EXPERIMENTALS (N=16) AND CONTROLS (N=10)**

<u>Stage III</u> Operational Coordination		<u>Stage II</u> Partial Decentration				<u>Stage I</u> Complete Egocentrism				<u>Stage 0</u> Incompre- hension or Refusal
		IIb	CA	IIa	CA	IIb	CA	Ia	CA	
<u>Exp.</u>	None	8	8-1	7	7-10	14	9-4	1	6-8	None
		12	9-3	9	8-5			4	7-0	
		15	10-0	11	8-10			5	7-5	
		16	10-5	13	9-3			6	7-9	
				17	10-6			10	8-7	
				18	10-7					
<u>Control</u>	None	22	7-9	23	8-2	19	6-9		None	None
		25	8-11			20	7-0			
		26	9-4			21	7-5			
		27	9-5			24	8-2			
		28	9-11							

for "talking" about the relativity of position and point of view for both 3D and pictorial conditions. Predictions are reported in Table 40. A predominance of outcomes (1) through (5) would indicate use of semantic criteria corresponding to a cognitive strategy involving the coordination of internal, or projective, relations. Predominance of (6) through (9) would correspond to a cognitive strategy focusing on external, or topological, relationships. A predominance of (10), which is essentially topological, would be indicative of (a) a partially effective cognitive strategy and a restriction in using language to specify spatial operations, as realized by the dominant relations, or (b) an ineffectual cognitive strategy resulting in a lack of semantic specificity ("in the wrong place").

Outcome (2) was found in only one instance. Outcomes (3), (4), and (8) were not found in any of the twenty-six protocols. However, failure to find these outcomes cannot be construed as meaning that the children have failed to construct the underlying relations but only that the particular relation failed to function criterially for the child in a given context. An analysis of outcomes indicated a difference in the pattern of relational use according to stage and cognitive strategy. Furthermore, when within-stage use was analyzed, marked differences occurred between experimental and control subjects in the 3D and pictorial conditions. Excerpts from transcripts for Problem C appear in Appendix H.

TABLE 40
**VERBAL ENCODING PREDICTIONS FOR THREE-
 DIMENSIONAL AND PICTORIAL CONDITIONS**

No.	Outcome	Spatial Terms
1	1D Internal *	In front of, in back of, before, behind.
2	2D Internal *	To the left of, to the right of.
3	1D and 2D Internal	Combination of (1) and (2) either singly or coordinated (e. g. , in front of (x) to the left of (y)).
4	2D Internal and 1D External	Combination of (2) and (6) either singly or coordinated (e. g. , to the left of (x) in front).
5	1D Internal and 2D External	Combination of (1) and (7) either singly or coordinated (e. g. , in front of (x) on the left).
6	1D External	Front, back, in (the) front, in (the) back, beside, next to.
7	2D External	(On the) left, (on the) right, on the left (side), on the right (side), on the side .
8	1D and 2D External	Combination of (7) and (8) either singly or coordinated (e. g. , in back on the side).
9	Proximal-Distal (PD)	(In)there, (over) here, closer (to [x]), far.

(Continued)

TABLE 40--Continued

No.	Outcome	Spatial Terms
10	Other	Itemizing objects; perceptual identity ("in the wrong place"); spatial extent or spatial segmentation ("it's taller," "in the middle"); spatial displacement or feature salience (invoking the dominant relation alone, e.g., "yellow's missing"); failure to specify ("I don't know").

* 1D denotes terms referring to uni-dimensional space; 2D indicates terms referring to bi-dimensional reference.

Results of verbal descriptions are reported in the following order: Stage IIb and IIa (Strategy X); Stage Ib (Strategy Y); and Stage Ia (Strategy Z).

All Stage IIb and IIa control subjects evidenced consistency of use between description of relative position in the 3D situation and description in the pictorial condition. Subject 22, in his 3D verbal description, focused on the disappearance of the yellow mountain with respect to its relative position from the man's viewpoint and its internal relationship to the blue mountain ("the yellow one behind it"). He continued to maintain his original criterion (yellow's disappearance) in his choice of the correct picture (C), locating blue and red externally in terms of their lateral order.

In contrast to Subject 22, Control Subject 26 relied solely on topological relations. She was unable to represent another possible view other than her own and used perceptual cues (proximity of each mountain from each other and from her) to resolve the problem. Thus, in both conditions, her criterion converged on the "nearness" or "farness" of each mountain from the other. Despite differences in strategy, one partially effective (Subject 22), the other ineffectual (Subject 26), both children consistently dealt with the underlying conceptual relations for both a series of objects and with a two-dimensional representation of the three-dimensional relations.

In contrast, the experimental subjects in this category seemed to share a problem with either abstracting in a regular manner the co-occurrence of pictorial depth cues and underlying spatial relations (Subjects 11, 13, 15, and 17) and/or in using language to specify the manner in which spatial operations are reconstructed according to alterations in the mode and content of representation (Subjects 17 and 18).

An interesting case, Subject 18, repeatedly attempted to demonstrate position via motor representation, a behavior more typical of the younger subjects, or to use gesture as a symbolic substitute for verbal production of his cognitive criteria. When presented with problem B, Subject 18 became overly agitated (see Appendix H).

Although Subject 18 had available 1D and 2D terms, similar to Subject 15, he applied them in terms of their external situational context. In this regard, however, Subject 18 was not always able to systematically vary the left-right external dimension (resulting in reversals) and, occasionally, failed to vary in a regular manner the before-behind dimension (his initial selection of a totally reversed picture for problem F). Lastly, his lack of semantic specificity as realized by regressions to such general topological phrases as "Right there" indicated the fragility of his functioning relative to the cognitive context in which he operated.

Stable subjects were frequently concerned with the orientation of the man's face since the lack of facial features appeared crucial to their determination of position. Discussed first are two control subjects in this substage (Subjects 19 and 20) and then the only experimental subject (Subject 14).

Subject 19's criteria remained stable within conditions although it tended to vary across conditions. For both she and Subject 20, the dominant relations were irrelevant; rather, surface features functioned totally as the salient features. Semantically and syntactically, Subject 20 attempted to coordinate two dimensions but could not conceptually represent the left-right dimension preserving lateral order. In her pictorial choice justification, she appeared to have retained an image from the 3D condition (yellow in back), overgeneralizing it to its pictorial location.

For Experimental Subject 14, endpoint location (as seen from her point of view) functioned as the crucial feature, a conceptual and semantic strategy which remained consistent across the three problems and within each problem, 3D and pictorial.

On the basis of her performance on the coordination of perspectives, there was no indication that Subject 14 was systematically reversing left-right relations as she had with oppositional left-right or as she had tended to do with relative left-right (visible object condition). The evidence supports the thesis that Subject 14 encountered difficulty

holding left-right relations constant when another dimension had to be varied. This thesis is further supported by the finding that she tended to refer to the left-right dimension non-specifically, e. g., "on a side of him," when it co-occurred with the before-behind dimension. Again, her performance reinforces the context sensitivity of a given relation when its construction remains primarily absolute and external in application.

Five experimental subjects only were assigned to Stage Ia (see Table 39).

Subject 1 performed the best in the 3D condition of problem C, providing some indication that he could utilize the overlap depth cue as a method for locating object position. For the problem F and B 3D conditions, he merely itemized the content of his perceptions ("The mountains... These (F)" or "All of 'em (B)"). However, he appeared unable to extract identical information from pictorial representation when projection of his own viewpoint functioned as the pivot criterion, hence, his tendency to select unrelated, or impermissible, graphic replications, i. e., the choice of picture F in problem C. In his choice of F, he maintained the perceptual constancy of the most meaningful perceptual feature, that of size ("[red is] much closer... is taller so the man can see it"). Thus, his organization of space remains topological with objects viewed in isolation rather than in

relationship to each other.

For each of the three 3D conditions (in problems C, F, and B), Subject 4 focused on one mountain as the dominant feature denying completely for problem F that the man could see any other mountains. In problem C, she provided some evidence that she could perceptually compare the spatial order of two objects but her selection of the correct picture (C) was held to be suspect because of the content of her rejection criteria. In each rejection instance, she used yellow's disappearance as the focal criterion but in a stimulus-bound sense, a reaction which may have been perpetuated by the examiner initially asking her "What doesn't the little man see in that picture (C)?" In her selection of picture D for problem F (a random choice), she justified her choice by stating "Cause he's right in back of it," that is, the man is right in back of the red, an alignment which did not exist. Rather, Subject 4 again was centering on size as the most meaningful perceptual attribute relating the man to that attribute alone. In the 3D condition of problem B, she relied again upon a proximity relationship, that is, the man was closest to the blue mountain; therefore, that was what he saw. She then proceeded to select an impermissible picture (I) in which both dimensions were reversed.

What is evident from the strategy that Subject 4 applied in each case was her inability to compare a series of objects using relative

position as a criterial feature and herself as a meaningful reference point, a result of the rigidity of her operative criteria under changes in mode of representation. Although Subject 4 could apply proximity terms appropriately, she could not always consistently apply internal ID terms, an indication that she did not yet fully understand the semantic content of "in front of-in back of."

Subject 5's performance pattern indicated that she had only begun to organize a projective spatial structure using herself as the reference point in relation to a series of objects. The ambiguity created by the faceless features of the man operated to decrease the importance of orientation in evaluating "what is" her point of view from "what might be" the man's. Only with problem C was she able to use herself as a reference point, albeit an egocentric one. However, her pictorial justifications and rejections across all three pictorial conditions always consisted of telling why the man could see the picture, not why he could not. Perspective, as represented pictorially, was irrelevant.

Subject 6 appeared to produce "errors of commission" with locative terms. For example, in the 3D condition of problem C, he reported that blue and red were "on the front," the only subject to misapply these basic locative terms.

In addition to his commissional errors, surface, or external,

terms predominated almost exclusively in his descriptions within and across conditions. To the degree that he was encountering difficulties in stably structuring notions of length and width as obligatory spatial dimensions, his use of terms which referred to length (in, on, in front of, in back of) and width (left-right) reflected this instability. It will be remembered that Subject 6 was the only child providing hard evidence for the systematic reversal of both absolute and oppositional left-right relations. Rather than viewing such performance patterns as a reversal specific to left-right, the pattern can be alternatively understood as one involving reversal of both length and width relations depending on the cognitive complexity of the task (see also Subjects 14 and 18). Further evidence for this position is found in Subject 6's performance in the 3D condition of problem F. Finding it taxing to coordinate the external relations of left and right with the external relations of before-behind, he interpreted the examiner's question "Would the (red) mountain also be somewhere else like to his left or right?" as "on his left," a response easily achieved by matching his own left side at position A with the blue mountain. Subject 6 also chose a totally impermissible picture for problem F (H) in which both the before-behind and left-right dimensions were reversed.

Subject 10's patterns were similar to those of Subject 5; however, Subject 10 was over one year older than Subject 5 and in Grade 3.

Subject 5, in contrast, was a Grade 1 pupil. In the 3D conditions, Subject 10 operated with a strict topological strategy emphasizing spatial alignment relative to distance or proximity. Even in the 3D condition of problem C, she had difficulty representing the man's view since blue and red did not share the same frontal plane as viewed from position C. In a similar manner, her rejection of the correct picture C corresponded to her initial description, that is, the overlap cue (blue superimposed on red) failed to correspond to how she actually viewed the blue-red relationship. Note that this overlap is disregarded as a crucial feature for picture E where suddenly yellow's disappearance asserts itself as the dominant relation. In the 3D condition of problem F, she utilized familiar size (the man would only see the red mountain) and was unable to locate positions of the other mountains because of the ambiguity created by the man's faceless features (the man could see the other mountains "by turning"). When pressed to specify what the man would see, she could only provide coherence by calling upon already constructed knowledge, for example, "maybe a few snakes cause snakes live in mountains."

Summary of Diagnostic Analysis

Hypothesis 4. Elementary school-age poor readers in normal classroom placement would produce performance patterns indicative of

significant qualitative differences on tasks pertaining to the assessment of (a) the sequence of emergence of the three projective relations in three-dimensional and two-dimensional space; (b) the understanding of projective spatial relations in structuring a three-dimensional projective space; and (c) the use of projective space semantic relations in the verbal encoding of relative spatial reference in three-dimensional and two-dimensional mediums.

All three predictions appear to be confirmed. The experimental subjects, or at least a sub-group of the experimental subjects, consistent with their performance on the MTPS, produced qualitatively different performance patterns than the control group on the conservation tasks and on the three projective space tasks.

An analysis of item difficulty for each of the projective tasks indicated a similar sequence of emergence for the experimentals. The before-behind relation was easier than either the left-right or above-below relation for the experimental group as a whole. Proportionately less experimentals than controls met criteria for Stage III placement for the easier before-behind relation (construction of the projective straight line), for Stage II placement for the left-right relation (less had mastered the developmentally earlier absolute left-right) and Stage Ib and IIa for the above-below relation (the coordination of perspectives). There was also the suggestion, based on performance on the latter task,

that, depending on the stage of development, both the before-behind and left-right relations are reversed when task complexity increases, for example, when the child must simultaneously manipulate both relations in pictorial space.

In their verbal descriptions on the coordination of perspectives, relative to stage, more experimentals than controls tended to use topological, or external, terms to describe internal (projective) relationships ("on the front" for "in front of"), particularly in the pictorial condition or reverted to a lack of semantic specificity in specifying the man's perspective (the non-specific topological, or locative, designation "Right there" or reference to irrelevant criteria, "Maybe a few snakes cause snakes live in mountains").

Lastly, proportionately less experimentals than controls met criteria for transitional or conservation status on each of the three conservation tasks which may indicate that, cognitively, their mode of function (stage of development) is qualitatively different. In general, attainment of conservation, as measured by performance on the liquid quantity task, was associated with developmentally appropriate performance on the three projective tasks.

The four visual-perceptual tests, with the exception of the absolute left-right task, provided minimal information about underlying strategies, particularly the type of strategy leading to error, which the child used in attempting to solve the problem. Secondly, the

visual-perceptual tasks were not integrated in terms of content. As a result, these tasks tended to either underestimate actual performance or underestimate problem areas. For example, Subjects 4, 14, 15, 16, 17, and 18 all had positive performance patterns on three to four of the visual-perceptual tasks (see Table 25) while on the Piagetian tasks they tended to function in a more integrated manner. In contrast, Subjects 1, 6, 8, and 10 functioned well on the visual-perceptual tasks while their performance on the Piagetian tasks was indicative of lags in constructing a systematic network of spatial perspectives in both 3D and 2D space.

Since the Piagetian tasks empirically realize a theoretical set of converging cognitive operations applied to related contents, these tasks lend themselves to a more adequate specification of whether a difference exists in both the rate and manner of spatial organization in both cognitive and semantic domains. From an analysis of performance patterns within the experimental group, two major sub-groups were found who divided along this quantitative-qualitative boundary as follows:

1. Rate of acquisition of differences (quantitative): defined by greater variability in the speed with which the child has progressed from a topological to a projective spatial system but with a consistency in the manner of organization across domains and tasks.

<u>Group I</u>	<u>Group II</u>	<u>Group III</u>
Subjects:	Subjects:	Subjects:
8	1 9	10
13	2 11	12
16	3 14	
	5 15	
	7	

Group I children were subjects who functioned more like the controls than the experimentals while Group III presented borderline patterns between categories (1) and (2).

2. Rate and manner of acquisition of differences (qualitative): defined as presenting greater variability in the speed of construction as well as presenting discontinuities in applying consistent strategies to represent spatial operations in varying situational contexts and/or mapping these conceptual relations onto their corresponding semantic relations.

Subjects:

4 17
6 18

It is proposed that only this second category of four children meet a strict definition for "learning disability." The qualitative basis for this alternate definition and for considering disorders of spoken and written language as synonymous is discussed in Chapter V.

In general, all control subjects performed with equal com-

petence, relative to their cognitive stage of development, on both the visual perceptual and cognitive tasks.

FOOTNOTES

CHAPTER IV

¹In Table 15, degrees of freedom reflect either (1) how many responses for a given question were classified other than right or wrong (in certain cases, the child filled in more than one box or the examiner could not determine which response had been chosen) and (2) whether the data were run by age or grade. In the latter case, the presence of a fifth age grouping ($N = 3$), children over age ten years six months, added an additional column to the $k \times r$ tables in the grade analysis (making $k = 5$) while, in the age analysis, these three subjects were eliminated (making $k = 4$).

Unclassifiable responses never exceeded 3.5 percent of the total sample for any question; therefore, the absence of unclassifiable responses reduced r from four ($r = 4$ would include unclassifiable responses such as no response) to three ($r = 3$ would include right, wrong, and ambiguous responses) to two ($r = 2$ which included only right and wrong).

²Since the Bender data in this study were analyzed, Koppitz (1975) published a second volume covering Bender research from 1963-1973. Although some revisions were made in the manner of administration and in reducing interpretive ambiguities, the basic administration and scoring of Bender protocols remained unchanged from the 1964 instructions. Therefore, it is believed that the data obtained would not be altered significantly in using the 1975 procedures.

³Two experimental subjects, one a first grader and the other a second grader, produced a highly significant error (line for series of dots on Figure 5); however, their cumulative score placed them within the normal range relative to chronological age. Therefore, the presence of such an error cannot be considered meaningful although it may be indicative of a mild lag in coordinating certain aspects of spatial segmentation.

⁴Inhelder, Sinclair, and Bovet (1974) note that characteristically, discontinuous quantity, such as number, tends to be justified by means of the additive (addition-subtraction) argument "since the method of forming equivalent quantities by a process of one-to-one correspondence highlights the action of adding (Inhelder, Sinclair, and Bovet, 1974, p. 35)." Piaget (1970a), however, appears to apply a narrower criterion for what constitutes a reversibility argument. In his definition, the additive argument has features of reversibility but does not fulfill the same requirements as does the "compensation" argument (reversibility by inversion or reciprocity) which denotes the co-varying of two dimensions simultaneously. Thus, use of the compensation argument as it relates to conservation of at least continuous quantity, the developmentally more advanced conservation, may be a stricter application of the scope of mastery of conservation.

⁵Brainerd and Brainerd (1972) identified another category of verbal explanation which they termed "tautological." Tautological explanations, logically defined as statements in which the truth value resides within the logical form itself, were specific to number conservation. Examples of tautology were also found in the number task for this sample, for example, the statement "Because you just made a circle of 'em (pennies)." Because tautological explanations are not strictly invariance explanations and because their occurrence in this study was specific to the number task only, they can be as readily understood as a sub-set of the addition-subtraction argument. The few instances of such tautological explanations in this study were treated, therefore, as additive arguments.

CHAPTER V

DISCUSSION AND SUMMARY

Interpretation of Performance Differences Between and Within Groups

Interpretation and discussion of findings are divided into two sections. The first section will offer possible explanations which might account for the consistent performance differences found between the experimental and control groups on the visual perceptual and cognitive tasks. Discussion will focus first on the nature of task requirements with respect to the distinction among mode, level, and medium of representation. The nature of the performance characteristics which differentiated the experimental from the control groups and the patterns of performance among the experimentals will then be explored and discussed in terms of their relevance for the representational space model.

The second section will analyze the adequacy of the representational space model as a satisfactory account of learning disability. Three areas for future research will be presented and discussed in terms of their implications for considering disorders of spoken and written language as synonymous.

Discussion of Visual Perceptual Versus Cognitive Task Requirements

The diagnostic data from the visual perceptual and cognitive task sets revealed consistent differences in levels of performance between the experimental and control groups. Furthermore, on the basis of the performance patterns obtained on the Piagetian (cognitive) conservation and projective spatial tasks, differences within the experimental group appeared to be qualitative rather than quantitative. To validate this distinction, thereby supporting the fourth hypothesis relating to qualitative differences among the "poor reader" group in structuring cognitive and semantic aspects of projective space, it would have to be shown that differences in performance patterns were not simply the product of the confounding of different performance modes. In other words, the possibility that these differences are explainable in terms of individual preferences or styles for non-verbal versus verbal modes of performance would have to be ruled out.

All tasks, whether demanding a verbal or non-verbal response, involved language to the extent that the child had to be instructed verbally to perform in a specified manner. However, the mode, level, and medium of response differed within and across task sets.

Differences in mode

The Harris, Bender, Kohs, and the two absolute left-right subtests were classically non-verbal in that the child needed to respond only by relatively simple forms of movement or motor activity... gestural (pointing) for absolute left-right, gestural (imitative) and graphic for the Harris, graphic in the case of the Bender, and manipulative in the case of the Kohs. Similarly, the three projective tasks--relative left-right, the projective straight line, and the pictorial selection condition in the coordination of perspectives--demanded either a simple gestural response (pointing) or manipulative activity (adjusting a series of "lights" to symbolize a straight line). Despite the commonality of the non-verbal mode across the two task sets, it cannot be assumed that each subcategory is equivalent in complexity. For example, the gestural-imitative action in response to "Show me how you throw a ball" (Harris Test of Lateral Dominance) is not equivalent to the use of the hands to estimate relative distance between segments of an imaginary line (Construction of the Projective Straight Line).

In contrast, the three conservation tasks and the descriptive and justification sections of the Coordination of Perspectives required verbal response.

In spite of the differing response modes, all of which can be

considered as production modes, each of the tasks shared in common, to a greater or lesser degree, the representation of previously acquired knowledge via gestural, graphic, and verbal means.

Differences in level

Given a common base of the representational function as a product of a set of cognitive operations, not all tasks shared equivalent levels of cognitive complexity for the age span under study. Therefore, it can be inferred that performance differed within and between subjects to the extent that a particular task demanded a systematic representation of a system of reference utilizing various production--or, more accurately, reproduction--modes. At this point, two important distinctions are necessary. The first distinction concerns a general system property of cognitive function, the difference between (1) the child's construction of what is to be known as an object of knowledge, specifically, the manner in which the child progressively internalizes, or represents, the three dimensions of space and (2) the reconstruction of what is known, the manner in which he externalizes, or reproduces, spatial knowledge using gestural, graphic, and verbal modes of representation in particular formal task situations.

The second distinction pertains only to the nature of task requirements in the reconstruction of what is known. It can be argued that the Bender and Kohs, as visual perceptual tasks, require less complex

reconstructive activity because spatial imagery does not intervene in a strict sense in the execution of either task. Both tasks are copy tasks in which the (graphic) image is immediately present (perceived) and static in form and content. In other words, the content of both tasks refer to motionless configurations (Piaget and Inhelder, 1971, p. 100). In contrast, the projective spatial tasks, as cognitive tasks, deal with content in which the physical model is not present and, thus, require the use of spatial imagery whose function is either the anticipation of the result of movement or the anticipation of the successive path of motion. This differentiation between static images (which have a more direct connection to perception) and kinetic images which deal with movement and are assumed by Piaget and Inhelder (1971) to be symbolic in character makes no claim about the developmental status of mental imagery in either the experimental or control group. Rather, the only assumption made is that the cognitive tasks require more complex reconstructive activity. Despite the increased cognitive complexity of the projective tasks, visual perceptual copy tasks (e. g. , the Bender) are not devoid of symbolic content. Piaget and Inhelder (1971) argue that even an "exact" copy retains a symbolic function since "the mental image constitutes not so much an attempt to produce a totally adequate representation of the thing 'seen,' as an idea used by the subject to express the characteristics of what he 'sees' (Piaget and Inhelder, 1971, p. 49)." Essentially, the

image, as an internal model, functions as an analogy between the percept and the concept and assumes symbolic meaning because it has an indirect resemblance to the thing symbolized.

Differences in medium

In addition to mode and level of representation, tasks differed with respect to the medium in which spatial knowledge had to be reconstructed. In other words, tasks differed with respect to execution in 3D space or in graphic (pictorial) space, the latter characterized as a 2D representation of 3D relationships. In two cases, tasks required a certain level of coordination between mediums, from 2D to 3D for the Kohs and from 3D to 2D for the pictorial selection portion of coordinating perspectives.

Table 41 schematizes the relationships among the visual perceptual and cognitive tasks in terms of the mode, level, and medium of representation.

With the distinction among mode, level, and medium of representation clarified, it is possible to consider whether performance pattern differences between the experimentals and controls support the existence of qualitative differences in the level of organization of spatial perspective.

TABLE 41
MODE, LEVEL, AND MEDIUM OF REPRESENTATION FOR THE
VISUAL PERCEPTUAL AND COGNITIVE TASKS

	Mode							
	Motor				Verbal			
	Gestural		Manipulative		Graphic			
Level:	Imitative	Reconstructive	Imitative	Reconstructive	Imitative	Reconstructive	Imitative	Reconstructive
Medium: 3D	Harris	Absolute L-R (including Benton Test)	Kohs	Projective Straight Line				Conservation Tasks, Relative L-R, Coordination of Perspectives
2D					Bender Harris			
3D to 2D								Coordination of Perspectives
2D to 3D			Kohs					

Differences Among Patterns of Performance

Visual perceptual tasks

The Harris test

Findings revealed a greater incidence of mixed hand-eye preferences in the experimental group throughout the six to ten year age span. In contrast, mixed patterns were not characteristic of the control group. This finding may appear to support the theory of prolonged maintenance of bilateral speech representation in poor readers (e.g., Zangwill, 1975).

However, these results must be interpreted with caution for two reasons. First, in this limited sample, the vast majority of subjects could not be described as "dyslexic." Secondly, there was no clear evidence that mixed preference was necessarily related to restrictions, in all cases, in the formation of projective space cognitive categories when stage of development rather than age was used as the classifying criterion. Of the four experimentals classified as meeting strict criteria for "learning-disabled" and the two other experimentals considered as borderline, only two females (a seven year old and a ten and one-half year old) fell into the mixed preference category.

In view of current research methodologies directed towards the manner in which the two cerebral hemispheres process differential input, both speech and non-speech (Bever, 1975; Studdert-Kennedy, 1975),

hand and eye laterality preference testing is probably an outmoded form of clinical assessment. The fact that most differences in laterality preference between true dyslexics and non-dyslexics seem to ultimately disappear (Critchley, 1975) suggests that (1) laterality differences are unrelated to dyslexia in a random versus a clinical population, (2) such differences where found are merely relative rather than absolute since it is unknown the degree to which equipotentiality must be inhibited if the child is to acquire normal written language competence, and (3) laterality as a preference does not bear an isomorphic relationship to the graphic and verbal reconstruction of laterality as the projective and Euclidean dimension of width.

The findings of this study seem to point to two circumscribed conclusions. First, the early establishment of strong to moderate ipsilateral preferences does not seem to predict the stage of spatial construction which a given child has attained. Secondly, the failure to establish ipsilateral preferences during late middle childhood and early preadolescence is not necessarily related to failure to achieve developmentally appropriate knowledge of three-dimensional space.

The Bender

With one exception, positive and borderline Benders were specific to the experimental group.

Koppitz (1975) explains positive Benders as resulting from "problems with perceptual-motor integration... (a) difficulty with higher level integrative functions (Koppitz, 1975, p. 5)." In order to address the questions of: (1) whether the significant error patterns for the experimentals reflect qualitative differences in performance, (2) whether form perception in general is based on "cognitive processes (Koppitz, 1975, p. 23)," and (3) whether the Bender, as currently constructed, provides insight into the nature of learning disabilities, it would seem necessary to analyze the formal requirements for the satisfactory reproduction of Bender designs. Do error patterns reflect an "immaturity" in perceptual-motor integration or, alternately, do they reflect underlying differences in the child's construction of a system of reference and their reconstruction through the graphic mode? If the latter, then the problem cannot be one of the failure to adequately perceive and integrate visual form but, rather, may be symptomatic of a lag in the construction of the rules which define the manner in which space is organized graphically.

The Bender designs are geometrical (Euclidean) shapes involving the reproduction of static images only. None of the nine designs necessitate prediction, or anticipation, of a displacement of shape due to movement. Developmentally, the copying of individual geometrical

shapes appears earlier than the copying of a series of shapes on formal tests of mental ability (for example, on the Stanford-Binet, the copying of a circle is a Year III task while the copying of a diamond is a Year VII task). It would appear, then, that the capacity to copy isolated Euclidean shapes does not guarantee accurate copying of a series of shapes, a general requirement of the Bender.

A possible explanation for why successful copying of isolated shapes does not predict accurate copying of a series of shapes involves the nature of the spatial knowledge which must be reconstructed in graphic form for both kinds of tasks. In the case of the copying of single shapes, the child needs knowledge of topological reference points internal to the object (for example, boundaries of the object). However, once a second form is introduced to be reproduced in conjunction with another form, the child must now be capable of referring to a set of reference points external to forms. In the latter case, a quasi-form of Euclidean coordinates has been introduced. Piaget and Inhelder (1967) note that when two separate figures are compared, the ability to evaluate reference points exterior to the figures themselves requires knowledge of a system of horizontal and vertical coordinates, a form of spatial knowledge not acquired before the stage of operational thinking. This precondition of operational thinking might explain why several of the Bender designs

reach significance only after ages seven to eight (see Tables 21 and 22).

While this explanation may clarify the developmental lag evident between the copying of individual shapes and the copying of a series of shapes, it does not account for the greater incidence of positive scores in the experimental group. All seven subjects with positive and borderline scores were able to recognize visually what was required of them, inasmuch as no subject executed the set of designs, or any portion of a design, in an illogical manner. Evidence suggests that the manner in which the child constructs a finite set of drawing rules determines the manner in which he will systematically reproduce isolated and then related Euclidean shapes (Piaget and Inhelder, 1967; Rand, 1973; Goodnow and Levine, 1973). Piaget and Inhelder (1967) attribute the difficulty children encounter in drawing more complex rectilinear forms (for example, the developmentally ordered sequence square, rectangle, triangle, diamond) to the graphic reconstruction of the rule by which angles, or discontinuous lines, can be analyzed. Simply, the rule states:

Angle = Reference point (location) + orientation of two
continuous lines (direction) + intersection.

Only when the child structures this rule can he begin to approximate reproduction of rectilinear shapes. Therefore, coordination of the directionality of lines appears crucial to the formation of angles. If the child misapplies this rule, then the result will be a distortion of shape

or a failure to integrate lines. While the failure to integrate lines is common to the copy patterns of preschool children (see Rand, 1973), it becomes less frequent after age five, particularly with less complex rectilinear forms as the square.

Within this framework, then, three general developmental variables may account for Bender errors. First, many of the Bender errors can be reanalyzed as general rotational errors since misapplication of the angle rule results in a displacement of reference points and the misorientation of straight line intersection. Secondly, because accurate reproduction of the copy from the sample is also dependent upon locating reference points exterior to the figures, the whole becomes definable only by relating the parts in relation to displacement from a central axis. The relating of parts to wholes implies knowledge of horizontal and vertical coordinates. Third, research by Piaget and Inhelder (1967, 1971), Huttenlocher (1967), and Goodnow and Levine (1973) has demonstrated a strong relationship between the effects of relative position, in terms of symmetrical (horizontal) versus asymmetrical (vertical) axes of separation, and the orientation of the elements in the sample to be copied. In effect, left-to-right arrays are more difficult for preschool children to copy than top-to-bottom arrays because the former create an asymmetrical axis of separation. In contrast, top-to-bottom arrays create a symmetrical

axis of separation.

Applying this analysis to the errors made by the four experimental subjects with positive Benders and the three experimental subjects with borderline scores, particularly those error categories selective at all age levels, it becomes possible to analyze the types of strategies underlying the error.

Integration errors characterized by a failure to integrate parts (Designs A and 4) may derive from the child's analysis of each figure independently, an analysis totally topological since only the internal relations of each figure are reproduced without recourse to external reference points. Distortion errors involving misshapen angles (Design A) can probably be accounted for by a misapplication of the angle rule formulated for the reproduction of isolated shapes. However, in this instance the rule takes on more complexity since the scope of its application must cover both symmetrical and asymmetrical line orientation. The more common rotational errors (Design 4 in particular), all of which involve displacement from a central axis of separation, derive not from the child's "confusion" between left and right but from his need to levy the coherence of symmetry upon asymmetrical axes of separation. According to Huttenlocher (1967, p. 1175), this developmentally earlier symmetry strategy (which, again, denotes a topological

analysis) can be described as follows:

Relative to position, when one figure is symmetrical around one of its axes and the axes of separation are parallel (horizontal) to the axes of symmetry, then the other figure is also symmetrical around one of its axis of separation.

Application of a symmetry strategy for asymmetrical conditions may account for the common rotational errors specific to Bender figures A, 1, and 4. Furthermore, application of the erroneous symmetry strategy may be a result of the order of the array for these figures. Because the order of the array for each figure proceeds from left to right, an asymmetrical axis of separation occurs. The developmental difficulty inherent in operating on asymmetry in these particular designs receives support from the Koppitz (1975, p. 24) comment that Designs A, 3, and 4 retain "rotational pull" the longest. In other words, the incidence of rotational errors, even among normal children in the six to nine year age span, was the greatest for these designs.

It is doubtful that such visual perceptual factors as the failure to recognize what the design is can account satisfactorily for the experimental error patterns, because, as noted previously, no subject executed the task in an illogical manner. This line of reasoning is also consistent with the findings of Brainerd and Vanden Heuvel (1974) who found that production of geometric images was a more difficult task than recognition for middle childhood subjects. Furthermore, training studies on improving

the accuracy of shape reproduction through emphasizing such perceptual-motor activities as tracing (Rand, 1973) fail to support the position that visual-motor coordination failure is responsible for the quality of design reproduction. Finally, failure to analyze visually the distinctive feature equivalences between the sample and copy appears less important than the child's underlying organizing principles (Rand, 1973; Barroso and Braine, 1974); thus, current interpretations of the Bender which imply a failure in some unspecified manner to "integrate" visual perceptual and motor modalities are unsatisfactory because they fail to explain what is the integrative mechanism and whether performance differences are differences in kind as well as degree.

Recently, Koppitz (1975) has suggested that Bender performance may be unrelated to the acquisition of written language. The findings from this study can neither support nor reject this assertion. However, the findings do indicate that if copy tasks, such as the Bender, are to be interpreted as tapping cognitive functions underlying the acquisition of written language, then task definitions and interpretation of results must be placed in a broader perspective. A shift of emphasis from static image copy tasks to exploration of the nature of spatial imagery as it progresses from static to anticipatory states in the poor reader might prove to be a more heuristic avenue for future research. This possibility will be further discussed under research implications.

In conclusion, the tentative interpretation applied to the Bender data in this study is that qualitative differences existed not only between the experimentals and controls but also within the experimental group. This richer interpretation argues that error patterns result from the application of either more elementary topological strategies (those instances in which errors cross categories) or regression to specific forms of topological analysis depending on the complexity of a given design (errors which are category-specific). Recourse to a spatial "organizing principle" would account also for why the Bender loses its developmental sensitivity after ages eight to nine. By that point in the normal course of development of a three-dimensional representational structure, the topological system--which operates solely on perceptual data--has become integrated into the system of Euclidean coordinates and spatial perspectives.

Cognitive tasks

The experimentals, consistent with their performance on the MTPS and independently of age and grade, regularly performed more poorly on the cognitive tasks. Despite the differences between groups, the hierarchial organization of the three projective relations remained invariant. Construction of the projective straight line and own person left-right were easier than oppositional left-right, relative left-right, and the coordination of perspectives. Conversely, no child reached

criterion on the coordination of perspectives while failing the theoretically easier tasks. Since these findings substantiate the developmental hierarchy previously established for the three projection relations, the question arises whether the differences between groups reflect qualitative differences or merely a developmental lag.

Before-behind dimension

The child's capacity to perform the motor task of reconstructing systematic linear constructions between variable reference points must rest on an ability to evaluate his internal representation of "straight" with its external representation in the absence of perceptual cues. The very act of sighting or manual measurement as reverification procedures implies an awareness of the relativity of imaginary movement, or the kinetic use of visual imagery, for the purpose of anticipating the end-result of the external reproduction. It appears that more of the experimentals were unable to construct a diagonal because they continued to rely on perceptual cues such as the boundaries of the curvilinear and rectilinear boards. Even in the case where Stage IIb subjects constructed one of the diagonals, there was a lesser tendency to use a reverification procedure. These Stage IIb subjects, as well as Stage IIa subjects, were not as able to anticipate, or predict, the relative position of the units in their reconstruction. For them, neither perspective nor manual

measurement were strategies for verifying diagonality.

Left-right dimension

It appears that stabilization of children's capacity to coordinate two viewpoints, their own and another person's, is not complete until the end of the middle childhood years. Because of the differential rate of achievement in the acquisition and consolidation of this behavior, the question arises as to the diagnostic value of left-right testing beyond the level of identifying own body laterality in the six to nine year age span. The value of diagnostic tests for left-right knowledge depends on the purpose of that testing.

First, if the intent of testing is to determine whether the child can perform or not, then results offer minimal insight into cases where the child does achieve successfully. With three exceptions, Subjects 3, 4, and 6, all subjects in the age range covered by individual testing (CA 6-8 to 10-7) were consistently able to localize position based upon their own point of view. Semantically, stable localization of own body laterality implies knowledge of the meaning of "left" and "right" as a relation which exists between the lateral location of body parts. In the sample under study, minimal variation was found in the understanding of "left" and "right" in the self-referent condition ("Show me your right (left) hand"). Even in the three cases of systematic reversal, the form

of the response pattern remained regular, that is, "left" and "right" were understood as "words" denoting laterality. Thus, if stability is used as a criterion for performance, the argument that poor readers have an underdeveloped sense of body image (e. g. , Sapir and Wilson, 1968) is unsupported.

If, on the other hand, the purpose of testing own person knowledge is to assess the extent to which children can follow complicated actions of localization, then the Benton Test functioned more selectively ("Touch your right eye with your left hand"). In terms of reaching 100 percent performance criterion, no subject over CA 8-2 encountered any difficulties with this task. However, certainty of performance was confounded by the sentential length of the Benton verbal instructions. Because of this latter variable, failure on this test cannot necessarily be attributed to a lack of extension of own person left and right but, instead, may result from the child's difficulty in processing sentences which touch the boundaries of available processing space in short-term memory.

If the intent of testing is to evaluate both the rate of acquisition and the invariance of the sequence in the acquisition and consolidation of this developmentally earlier emergence, then other person transformation produced maximum variability in both cognitive and semantic domains across the age span investigated ("Show me my left hand"). Why should

children who encounter no problems with assigning "left" and "right" on themselves find it so difficult to consistently apply those meanings in a non-self oppositional condition?

Within the general systematic reversal category, a distinction existed between those subjects who reversed both own and other person (three experimentals) and those who reversed only in the oppositional condition (four experimentals and three controls). Children who reversed only in the latter condition did not appear to be operating with a reversed schema; rather, the source for the reversal derived from the decision to apply a perceptual correspondence strategy which can be described as:

When left and right change sides according to how
I see them, then left and right still correspond to my
own left and right.

The uncertainty generated by the more complex transformation of view caused them to revert to the same-side correspondence strategy used for orienting self. Therefore, a systematic reversal specific only to the oppositional condition functioned as a less advanced form of the more intermediate phase, inconsistency of identification. The inconsistency pattern can be conceptualized as a behavior indicating an emergence of more formal awareness of the regularity of the internalized relations despite changes in the perceptual context.

Within this framework, then, a task failure cannot be considered equivalent to a failure to understand the word. The very fact that the child attempted systematically to locate the physical position of left and right argues otherwise. On the contrary, it was the change in reference which caused the child to apply a restricted and more variable meaning to the semantic relations.

A related issue remaining unclarified concerns whether the systematic reversal of left-right relations on one's own body and its transformation oppositionally is maintained in constructing relative notions of left and right. That such a pattern was specific to the experimental group only is substantiated by the data. This particular finding, however, was found in experimentals below age eight years and, therefore, no generalizations can be made about the effect of absolute left-right reversals on relative left-right. Whether the systematic reversal of absolute relations becomes systematized into a truly reversed structure or whether such reversals merely reflect uncertainty over relative position, in view of the more complex transformation involved in the latter case, needs further exploration in preadolescent and adolescent subjects who have stabilized oppositional left-right. In general, reversal of oppositional left-right was correlated with the reversal of relative relations in the visible (V) and hidden (H) objects conditions.

The association, however, can be as readily explained by the regularities of developmental construction, i. e., the successive strategies used by the child in order to obtain closer approximations to the adult mode of functioning.

Coordination of perspectives

Three distinct patterns emerge from the data: (1) the irrelevance of perspective irrespective of the medium of representation (Stage Ia); (2) an egocentric point of view applied independently of the medium of representation indicating that the child is aware of at least one perspective, his own (Stage Ib); and (3) a more developmentally advanced awareness that other possible perspectives exist in addition to one's own. However, the scope of such awareness may be dependent upon both the complexity and the medium of representation (Stage IIa) or dependent only on the complexity of the transformation independent of the medium of representation (Stage IIb).

While the first pattern might be expected from preschool children who are still preoperational, it was found only in five experimental subjects whose grade placement varied from first to third grade. Four manifested either preoperational or low transitional status on the developmentally earlier conservation tasks while the fifth could not be classified.

The second pattern could be anticipated from normally developing subjects transitional in their attainment of operational thinking. Its

occurrence was specific to the younger control subjects all of whom were either in first or second grade and one third grade experimental subject.

The final pattern might be expected from subjects who had attained operational thinking. In fact, ten of fifteen Stage II subjects had either attained the latter or could be considered as close to attainment; thus, the data are consistent with previous findings, (e. g. , Laurendeau and Pinard, 1970) that the capacity to represent at least one other possible perspective other than one's own, independently of the medium of representation, is the product of the consolidation phase of operational thought. Furthermore, this period functions simultaneously as the precondition for the formation of the final stage of mental organization--that of formal operations. However, the degree to which Stage II subjects could imagine and compare another's perspective and verbally specify that possible perspective appeared dependent not only on the complexity of the coordination (problem C versus problem B) but also dependent on the fact that the same relations were represented further in an alternate medium of representation, pictorial space. In one case (Subject 13), rejection criteria indicated that the child was assigning a two-dimensional interpretation to a particular picture. But, in two other instances (Subjects 17 and 18 who, although fourth graders, were actually

one year older than their grade peers) verbal descriptions in the pictorial conditions were marked by either a regression to general topological designations of location (e. g., "here," "there") or the substitution of motor representation for verbal representation. Piaget and Inhelder (1971) comment that the passage from the use of static imagery to (erroneously) reproduce kinetic images "is frequently signaled by gestural behaviour. This shows that in the case of the more difficult movements imaginal representation is not immediately internalized (Piaget and Inhelder, 1971, p. 93)." As noted in Chapter IV, the use of gesture as a substitute for verbal explanation was more common with the Grade 1 (transitional) control subjects. Its appearance in the oldest subject, the experimental Subject 18, suggests a fruitful area for investigating the relationship between spatial imagery and gestural and verbal modes of reproduction in at least two kinds of clinical populations. Such studies could include learning disabled children with superficially acceptable spoken language and communicatively disordered children whose spoken language is marked by violations in the use of syntactic structure.

A conservative interpretation of the Piagetian cognitive tasks on the development of spatial perspective relations appears to support: (1) the finding that only four subjects (Subjects 4, 6, 17, and 18) clearly function in a manner qualitatively different from their peers and (2)

the interpretation that such differences are not attributable to individual preferences for non-verbal versus verbal modes of performance. Rather, their patterns of performance appear to derive from organizational problems in the construction and reconstruction of spatial knowledge through gestural, graphic, and verbal modes of representation.

Conclusion: The Adequacy of a Spatial
Explanation as the Primary Source
of a Learning Disability

From a practical viewpoint, the developmental and diagnostic data have both clinical and educational application. Pictures are almost an obligatory facet of classroom and therapeutic assessment and instruction. The so-called "non-verbal" assessment procedure frequently depends upon pictorial representation. Findings from this study indicate that a "positive" test result may actually be a "false positive." For example, the pictorial representations used in non-verbal reading readiness tests, non-verbal intelligence tests, and tests of "auditory language comprehension" often contain relationships in which both perceptual depth cues and conceptual perspective function as crucial variables for comprehension. These kinds of tests, therefore, create an inherent bias against the normally developing child whose only difference is a difference in rate of acquisition. Moreover, they bias the truly learning-disabled child whose test score may be interpreted as

reflecting less mental ability.

From an intervention point of view, when the child is presented with a picture in which a garage is located in the distance and a car in the foreground and asked the simple question "Where is the car?" to which he responds "On the front" or "Near here," that response, although an error, derives from the child's application of a logically consistent topological strategy. In other words, the response is indicative of the fact that the child is evaluating the location and direction of the car only in reference to himself in terms of the external relationship, or proximity, of the car to himself as the obligatory frame of reference. The internal, or projective, relation in which objects can be considered in relation to either the child's viewpoint or of other objects onto which his viewpoint is projected has not been taken into account in this particular context or may not have emerged yet. Therefore, in this instance, the child's interpretation is essentially two-dimensional.

The strongest theoretical generalization evolving from this study would be that developmental difficulties in the construction and reconstruction of a representational spatial structure are necessary and sufficient to account for the failure to acquire and master written language. A generalization of this kind would be consistent with the position taken by Inhelder (1966, 1971). The Inhelder thesis states that the shared invariant underlying language disorders and dyslexia

consists of problems in the organization of spatio-temporal relations (the infra-logical operations) which are dependent on physical forms of knowledge. Language, as a specific object of knowledge, would constitute another example of physical knowledge since it must be directly experienced to be acquired. The meaning-bearing elements of language, as realized by the semantic function of the word, are characterized further as "designators" for conceptual relations (see Piaget and Inhelder, 1971). What the Inhelder Hypothesis fails to explain satisfactorily is how the failure to construct and reconstruct semantic relations contributes to the failure to acquire written language competence. That developmental problems in organizing a representational spatial system of reference may be necessary for an adequate account of the synonymy of disorders of spoken and written language appears to be a reasonable inference from the data. However, to claim that it is both necessary and sufficient can be neither confirmed nor disconfirmed by the data.

The results of the study leave unresolved three major issues: (1) the specific role of visual (and, indirectly, auditory) imagery in a learning disability; (2) the failure to acquire more complex communicative functions as an integral component of a learning disability; and (3) the increasing independence of spoken and written language and its implications for written language mastery.

Visual Imagery

A primary issue which remains to be resolved is the kind of prerequisite cognitive and semantic spatial knowledge which the child must bring to the two-fold task of acquiring and mastering written language. If the goal of written language competence is to be understood as comprehending the printed word, then comprehension must be as the reconstruction of meaning relations as represented orthographically. The role of both auditory and visual imagery in the comprehension of printed material would appear to be an important area for future research.

The data from this study show that a group of "slow" readers tended to operate with a more elementary (topological) spatial strategy on tasks involving the graphic reproduction of a series of static Euclidean shapes in which the model was present (the Bender) and in the structuring of projective spatial relations in three-dimensional and two-dimensional mediums in which the model was not present. What the study could not answer was the extent to which the mode of reconstruction (gestural, graphic, or verbal) with respect to the accuracy of the response, reflected the use of static imagery to represent anticipatory movement. Piaget and Inhelder (1971) specify that static images are characteristic of pre-operational thinking and developmentally precede the formation of

anticipatory images which arise from the concrete operational structures of middle childhood and preadolescence. Further exploration of this developmental relationship in slow readers might serve to elaborate additional qualitative criteria to differentiate among children in the "slow" reader category.

Communicative Functions

Despite the quantity of verbal material obtained from the conservation and coordination of perspective tasks, no firm statement can be made about qualitative differences in the spoken language of the experimental group as a whole or of individuals within the experimental sample. With one exception (Subject 6), no child identified on the basis of MTPS performance manifested an overt disturbance of spoken syntax. In a strict sense, then, the majority of the Category 2 subjects and the two borderline Category 1-Group III subjects failed to meet criteria for a disturbance of spoken language if such disturbances are defined as significant violations in the use of syntactic or phonological structure. However, the verbal justifications for the conservation tasks and the verbal descriptions and rejections for the 3D and 2D conditions of the coordination of perspectives task presented suggestive evidence that the use of language for informational purposes was different for the six

subjects cited above. In other words, the communicative act was not characterized by a systematic attempt to anticipate and accommodate to the informational requirements of a single listener. While the latter achievement appears to be consolidated during the preadolescent period (Flavell, 1968), Halliday (1975) has proposed that a proto-type of this socio-semantic function emerges earlier in the language acquisition process and presupposes that the child can engage in dialogue. It may be the case that learning disabled children encounter more difficulty in integrating different meaning functions into a single utterance particularly those meaning functions, such as the use of language to convey information, which are dependent upon the child's more formal awareness that another perspective other than his own must be taken into account in the verbal representation of what is known. The relationship between the capacity to coordinate perspectives at least partially and the ability to use language for informational purposes would seem to be a fertile area for intensive investigation in refining criteria for what constitutes a disorder of spoken language particularly in middle childhood and pre-adolescence.

Independence of Spoken and Written Language

The final issue pertains to the general relationship between spoken and written language. The spatial perspective data are interpreted

as indicating that, in the normal course of mental development, children construct a three-dimensional representation of spatial perspective which permits the anticipation of possible points of view despite changes in objective object dimensions and distances. The key concept is "anticipation," which implies a more objective awareness of what "might be" possible rather than "what is." The developmental data from this study indicate that by approximately eight years of age, children are able to reconstruct certain kinds of meaning equivalences between different mediums of representation. In contrast, the diagnostic data showed that maintaining the same meaning equivalences between different mediums of representation were more difficult for some of the older experimental subjects. This suggests that these subjects were not as able to utilize graphic imagery, or pictorial representation, as an alternate medium of representation. What is unknown is the degree to which the learning disabled child has developed a more explicit awareness of reading and writing which are, according to Mattingly (1972), activities that the child must be capable of more formally anticipating or "thinking" about. In other words, what seems essential for formalizing the developmental relationship between spoken and written language is exploration of the progressive capacity to not only be more explicitly aware of the products of the primary linguistic system (speaking and listening) but also the explicit awareness that written linguistic symbols function as an alternate

mode of representation. The beginning stages for the assumed dis-association of spoken from written language does seem to coincide with the emergence of concrete operations (see Briggs and Elkind, 1973) but the point at which written language achieves autonomy from spoken language remains a matter for future research. It is entirely likely, however, that the preadolescent period becomes crucial for the attainment of the autonomy property. Indirect evidence from this study and from a limited number of other investigations (Ajuriaguerra, 1966; Myklebust, 1973; Semel and Wiig, 1975) suggest the possibility that the preadolescent language disordered or learning disabled child may fail to reach cognitive preadolescence. Whether these children do ever attain this apparently critical transitional phase between operational and formal operational stages--and whether they ultimately attain formal operations--would appear, then, to have important theoretical consequences for considering disorders of spoken and written language as synonymous.

Summary

The purpose of the study was to explore the Piaget and Inhelder (1967) representational space model as an alternate approach to defining a learning disability. Review of previous research indicated that few

studies had explored the acquisition of spatial knowledge as a three-dimensional system of spatial coordinates and perspectives in children with either a disorder of spoken or written language.

Four hypotheses were proposed in order to investigate the construction of a three-dimensional system of spatial perspectives in a sample of "poor" readers in the six to ten year age span. The first three hypotheses pertained to the invariant order of acquisition in pictorial space of the three projective relations (before-behind, left-right, and above-below) and the three conventional perceptual depth cues (familiar size, overlap, and perspective). The third hypothesis predicted that IQ factors should be unrelated to the invariant sequence of acquisition of the projective relations in pictorial space. These three hypotheses were tested by means of the Modified Test of Pictorial Space (MTPS), a screening measure designed specifically for the investigation and administered to three hundred sixty-eight subjects in Grades 1 to 4.

The first two hypotheses were confirmed: (1) order of acquisition in pictorial space for the projective semantic relations--in front of-in back of, left-right and to the left (right) of, and closer to--followed their emergence in three-dimensional space and (2) interpretation of pictures containing overlap cues was easier than

interpretation of perspective cues. Furthermore, in the age span under study, the ability to utilize the three conventional pictorial depth cues varied with (1) conceptual perspective and (2) question category. These results were interpreted as indicating that while the perceptual pictorial depth cues were necessary for interpretation of pictorial content, they were insufficient. In other words, non-context sensitive comprehension must involve the systematic mental representation of all three projective relations.

The third hypothesis could not be confirmed for females in Grades 2 and 4. The relationship between MTPS performance and IQ effects was interpreted as reflecting a possible sampling bias.

MTPS performance also correlated with a test of reading readiness for Grade 1 subjects and performance on two standardized measures of academic achievement for Grade 1 and 4 subjects.

The fourth hypothesis predicted that poor readers would produce significant qualitative differences on tasks designed to assess the manner in which children construct a projective spatial structure and encode terms referring to aspects of relative position. This hypothesis was tested in the individual testing phase of the study. Eighteen experimental subjects were randomly selected according to three criteria: (1) MTPS performance placed them within the lower quartile for their age or grade; (2) previous performance on standardized

tests of reading and mathematics achievement indicated a "poor reader" status; and (3) previous teacher rating had described learning difficulties. With one exception, none of these eighteen subjects presented overt disturbances in spoken language. Ten control subjects in Grades 1 to 4 were also selected according to MTPS performance and "achieving reader" status.

The fourth hypothesis was supported. Analyses of the diagnostic data found consistent performance differences on the three visual perceptual tasks (lateral dominance testing, the Bender, and the Kohs) and four cognitive tasks (conservation of number, global substance, and liquid quantity and constructing the projective straight line, absolute and relative left-right tests, and coordinating perspectives). However, only cognitive task performance permitted a further subdivision within the experimental group when stage rather than age was used as the classifying criterion. Qualitative analyses of cognitive task performance suggested that only four of the eighteen experimental subjects could meet a strict definition of learning disability.

Interpretation of these performance differences presented arguments for considering these differences as qualitative differences in stages of spatial perspective organization rather than as a developmental lag. It was suggested that visual perceptual task requirements

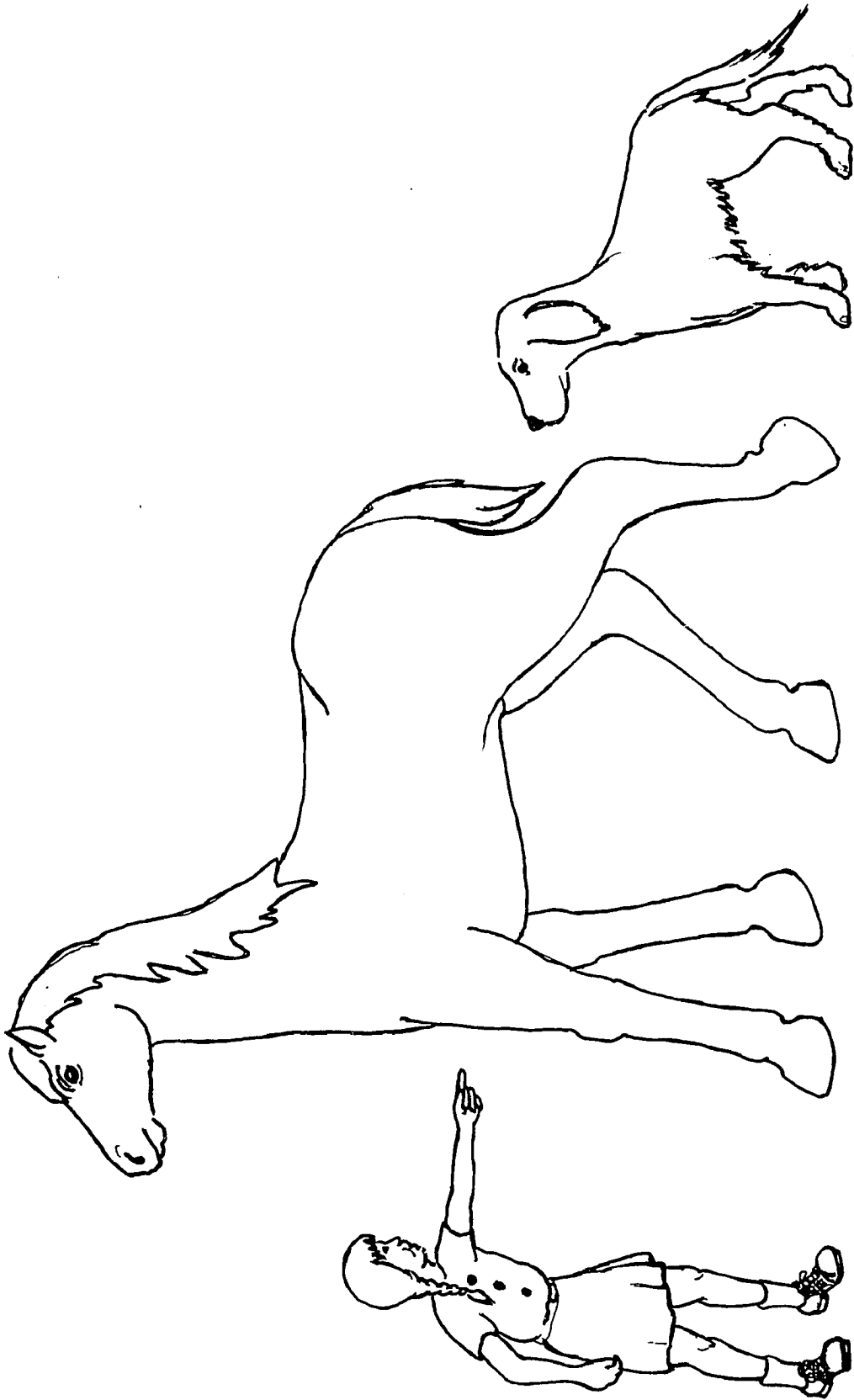
differed from cognitive task requirements with respect to the mode, level, and medium of representation. Because of this distinction, differences in performance patterns between the experimentals and controls could not be accounted for on the basis of individual preferences for non-verbal versus verbal modes of response.

Findings suggested further that lateral dominance status was not predictive of stage of spatial knowledge. Furthermore, poor performance on a shape copying task such as the Bender was considered as cognitively relevant only if interpreted within the broader context of the capacity to reproduce graphically static versus anticipatory images.

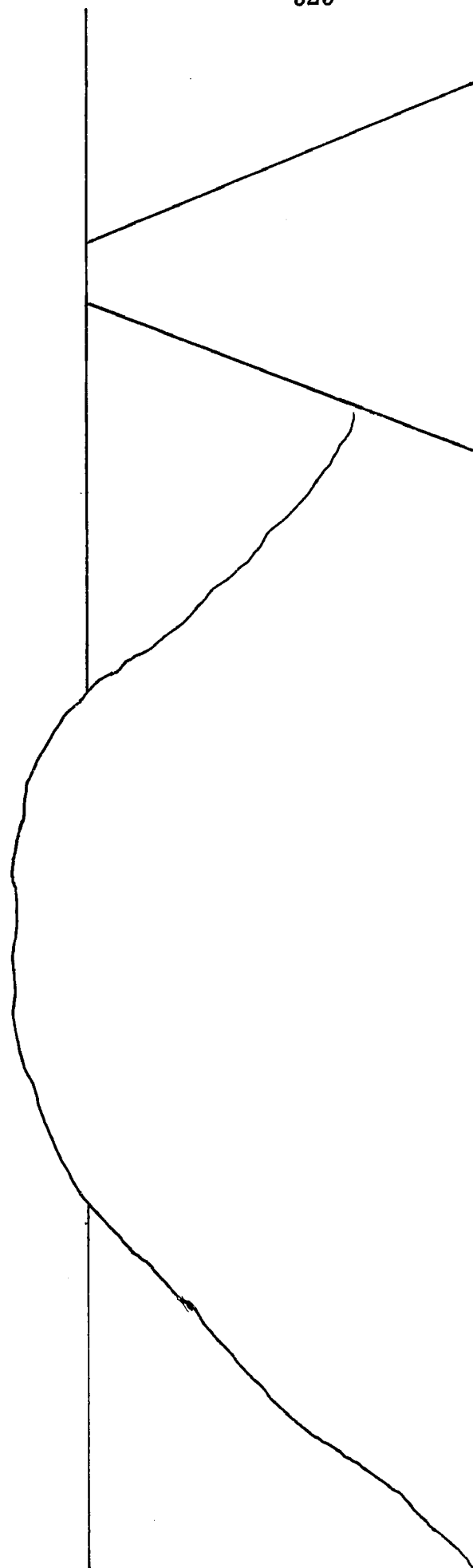
Cognitive task performance was interpreted as challenging the more traditional description of learning disabled children as spatially disoriented. Rather, it would appear that "directional confusion" is a product of either (1) the complexity of a given transformation independent of the mode and medium of representation or (2) the complexity of the transformation interacting with both the mode and medium of representation.

APPENDIX A - MTPS PICTURES AND ANSWER SHEET

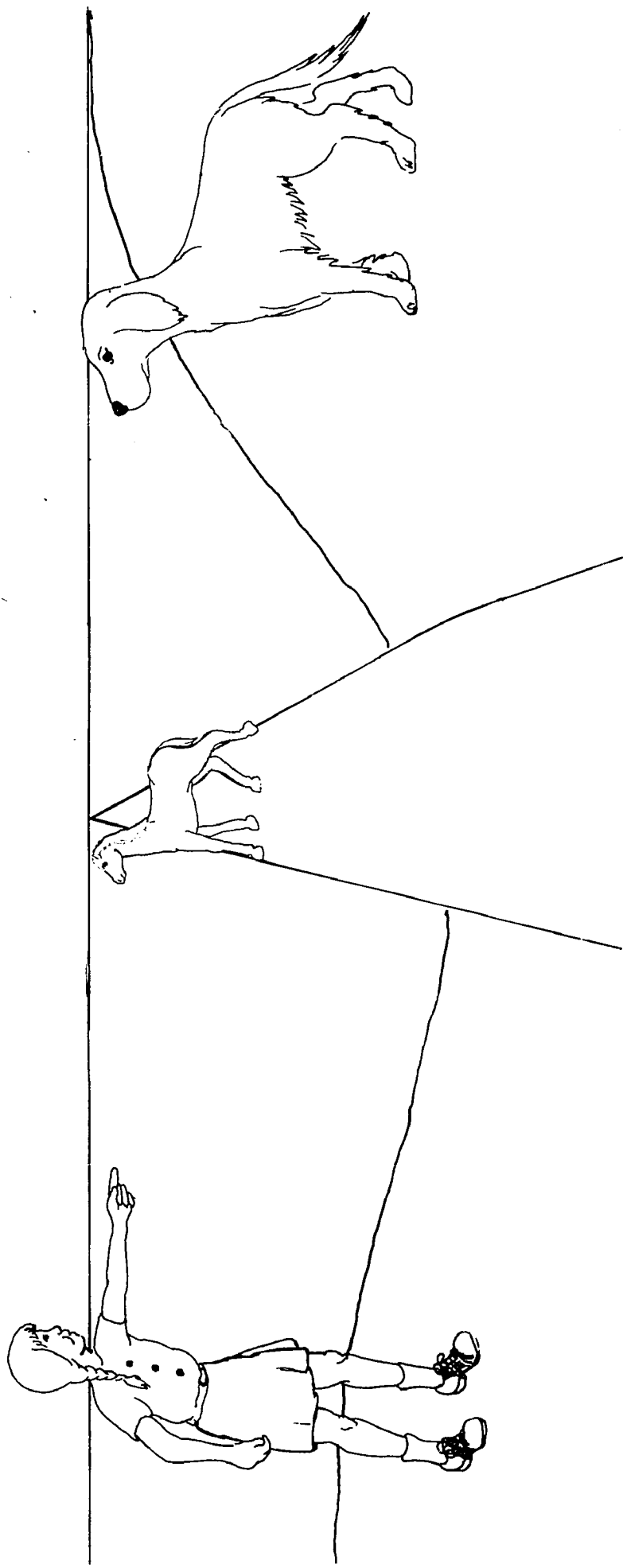
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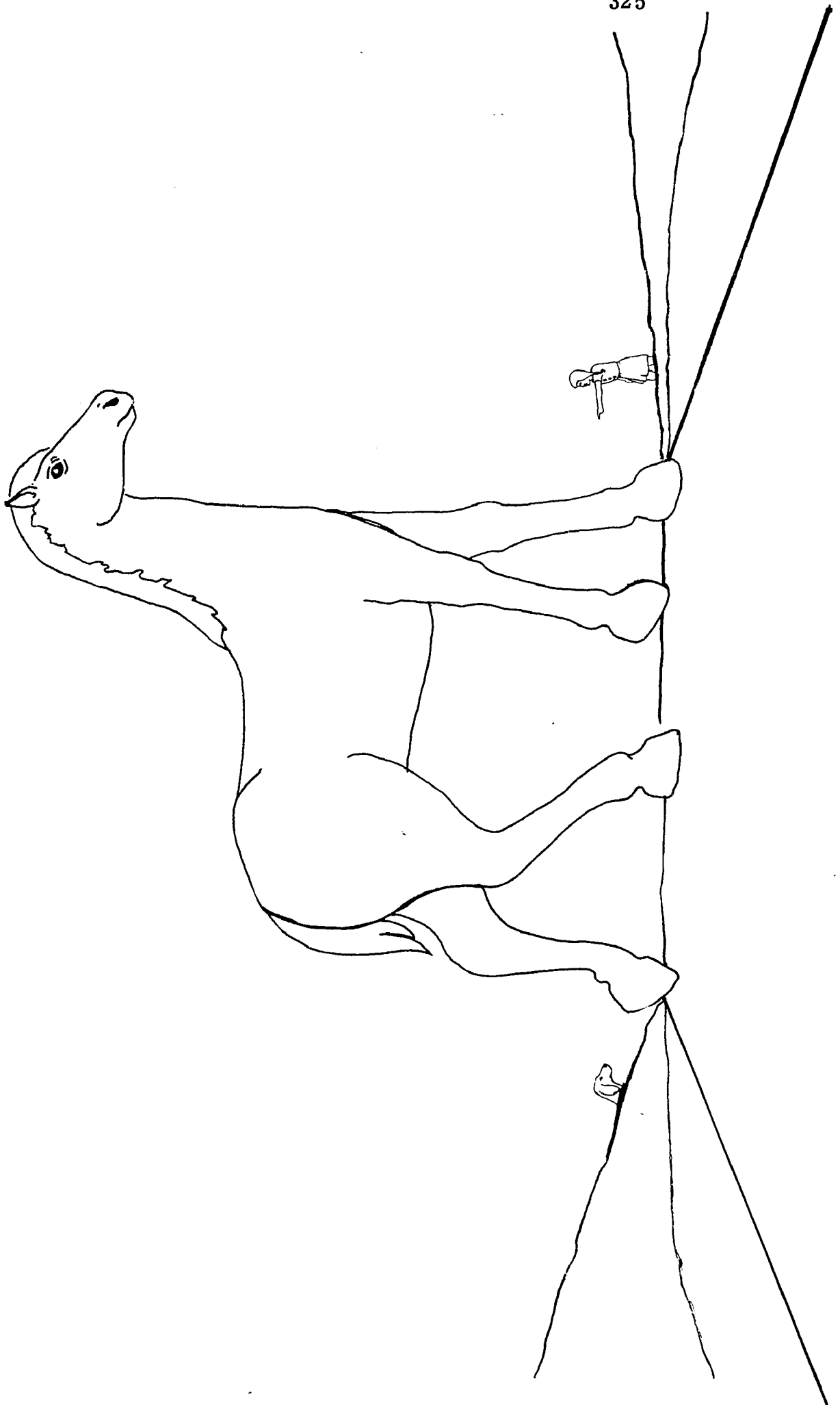
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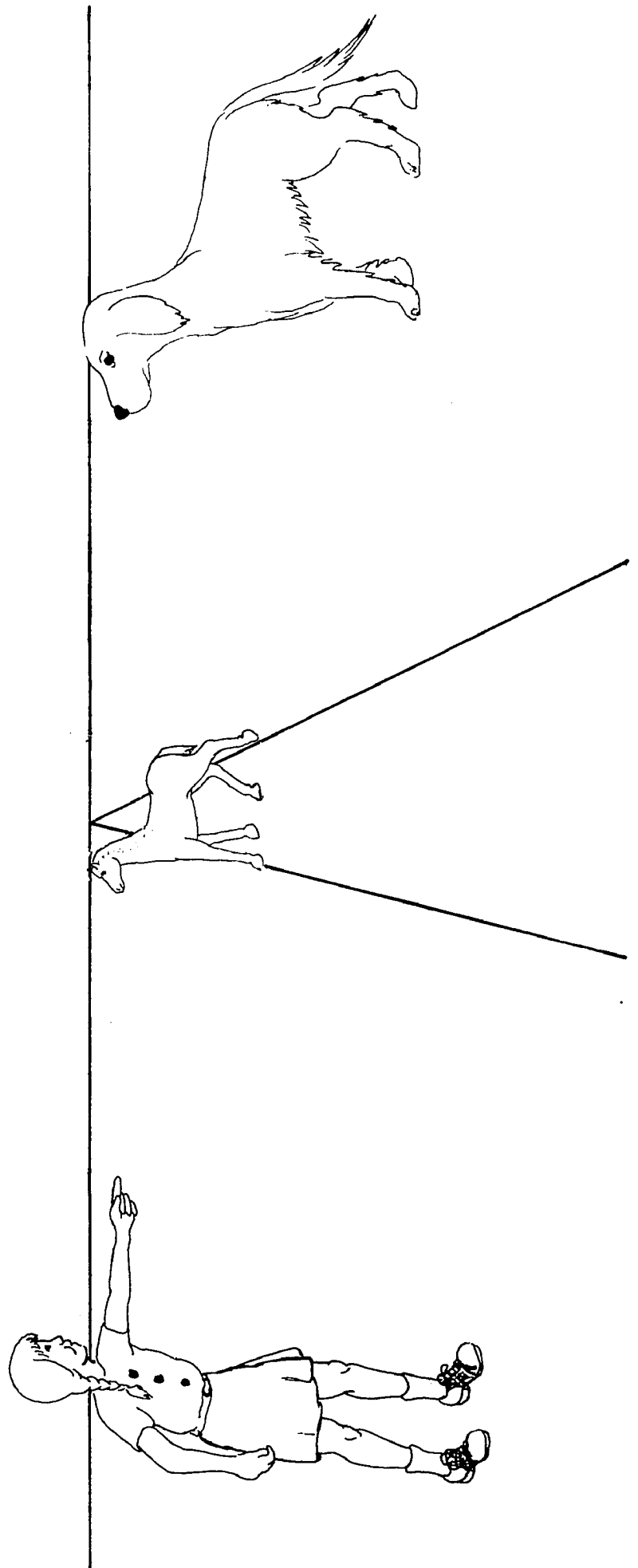
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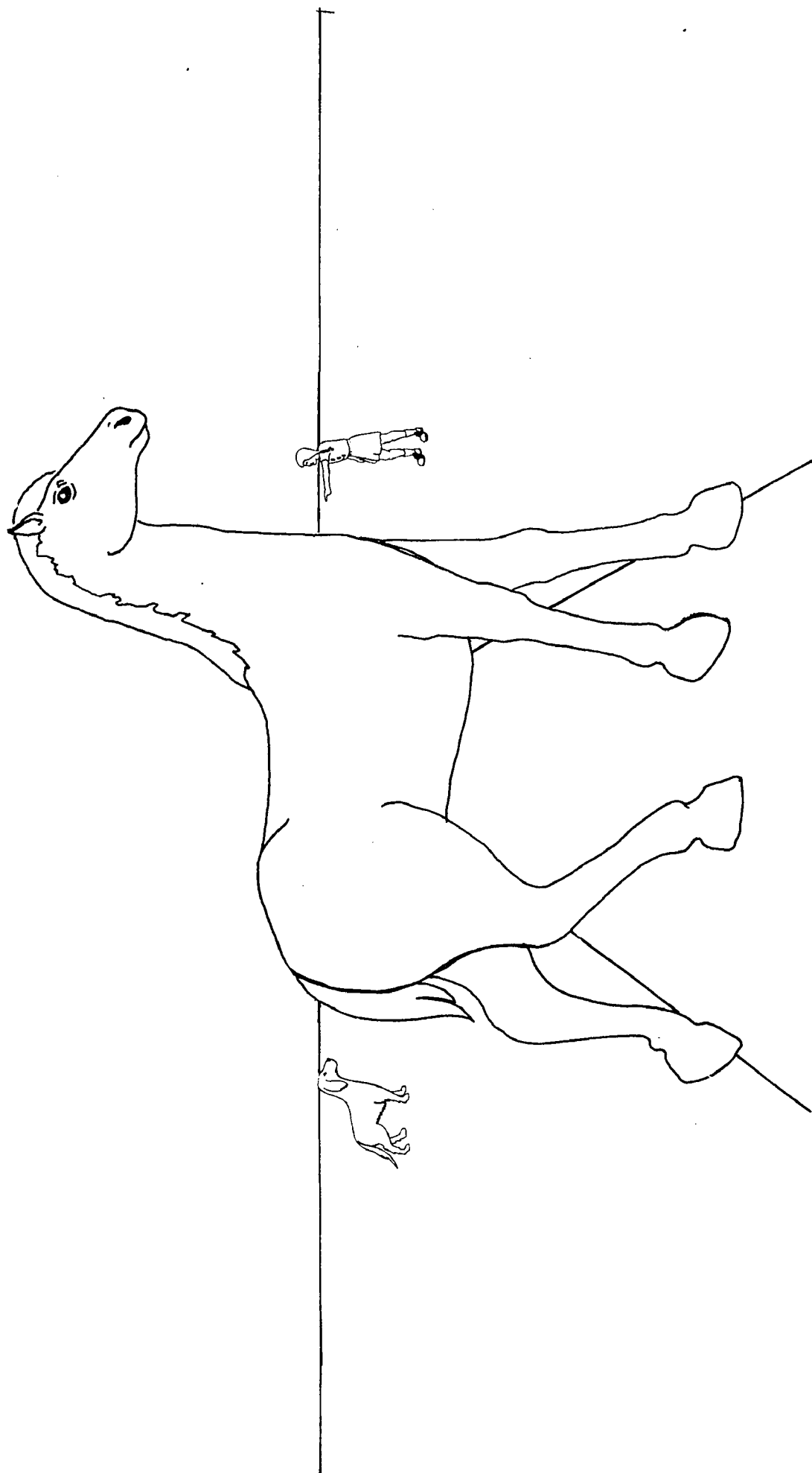
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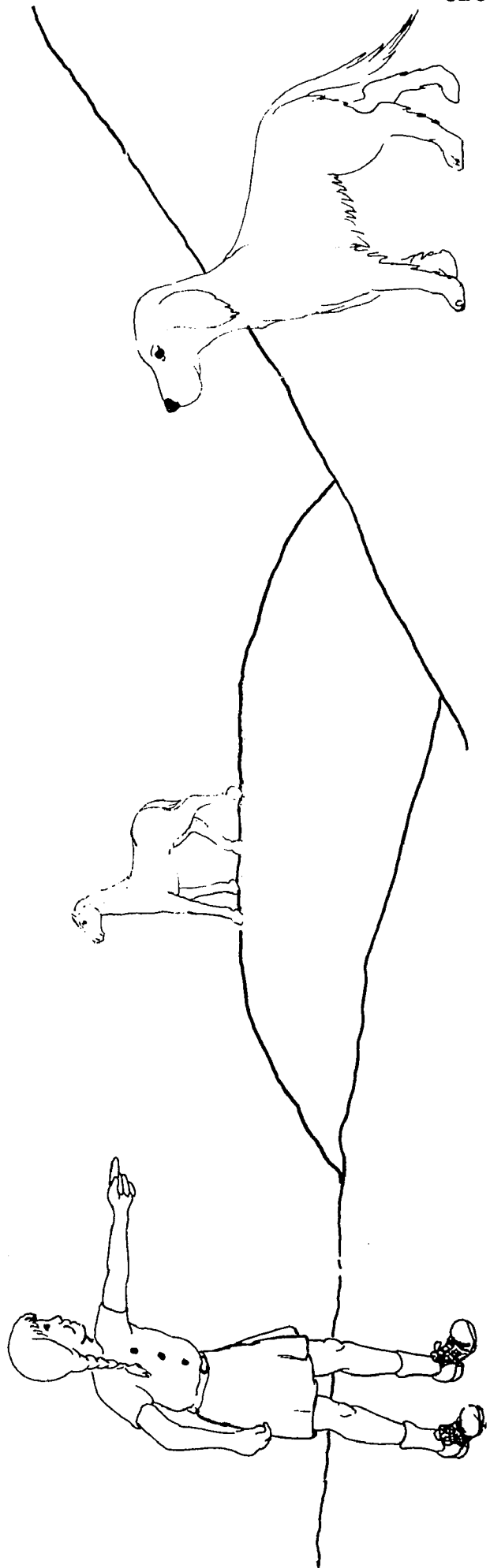
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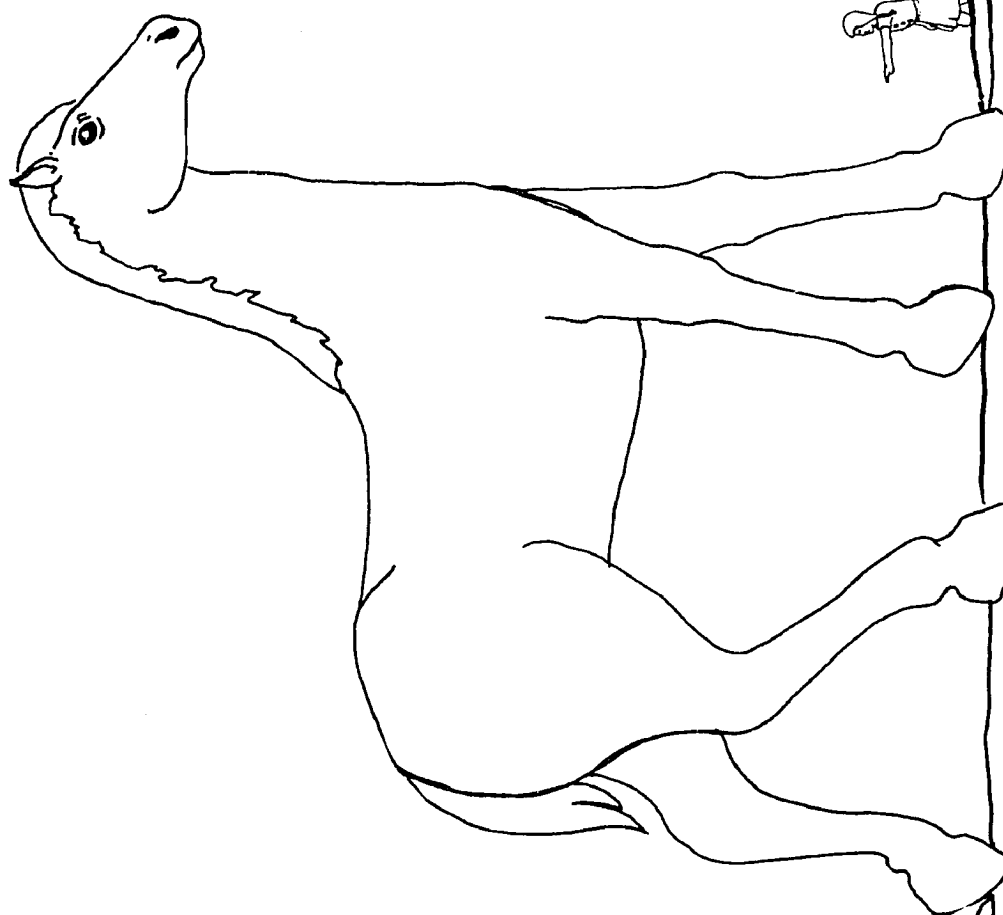
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5.

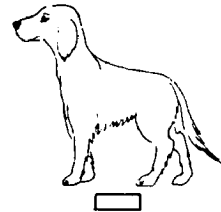


6.

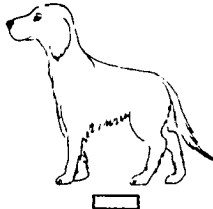


NAME _____

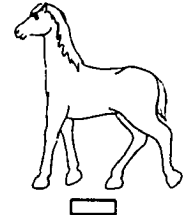
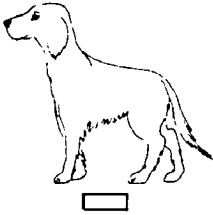
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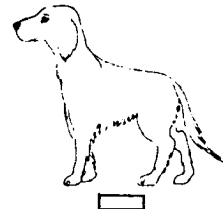
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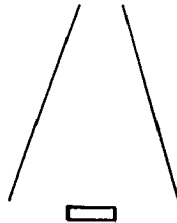
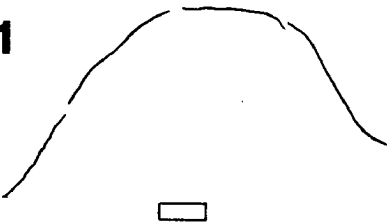
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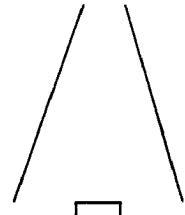
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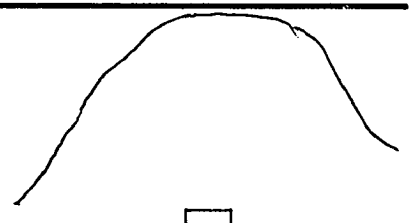
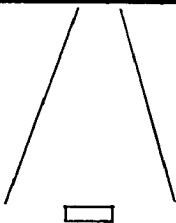
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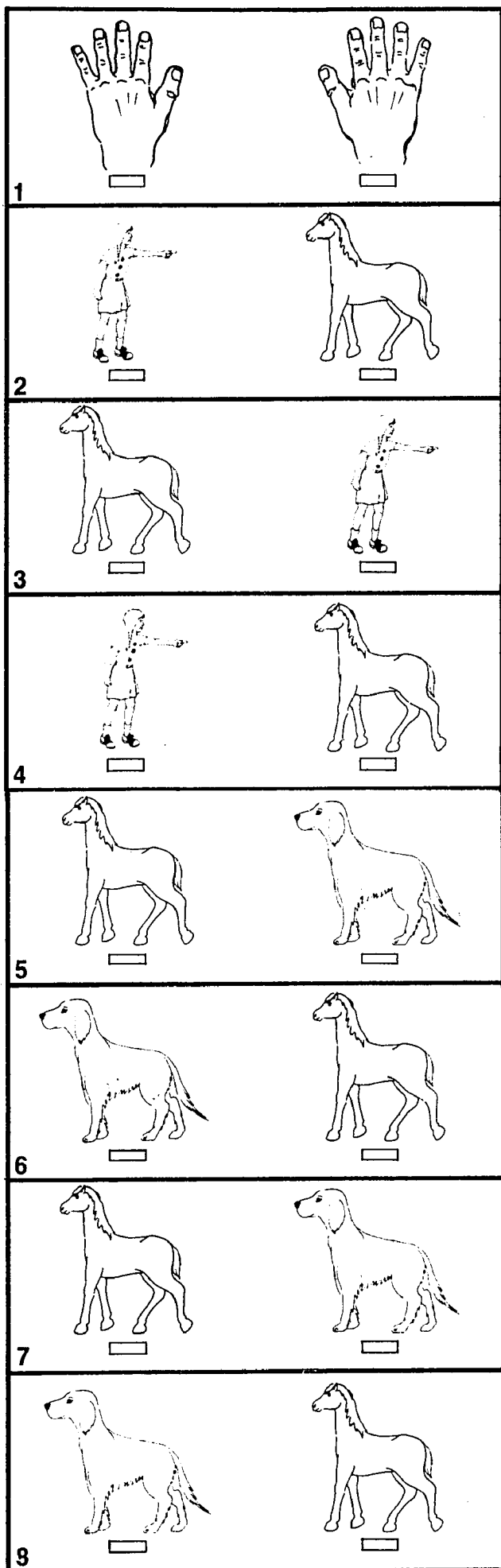
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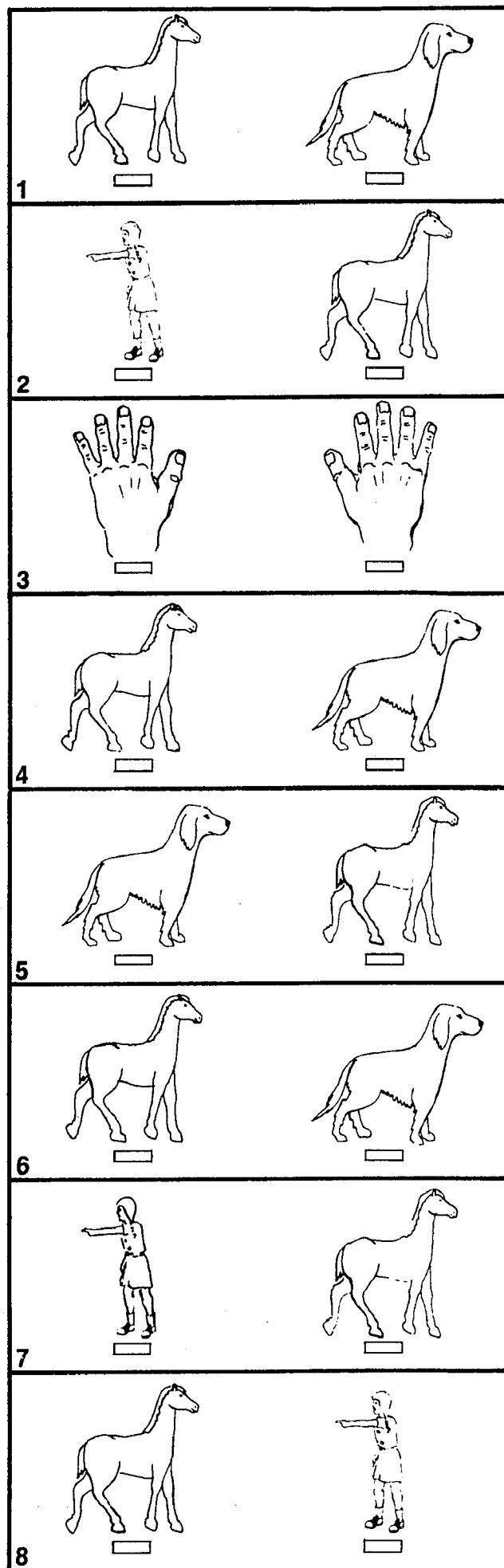
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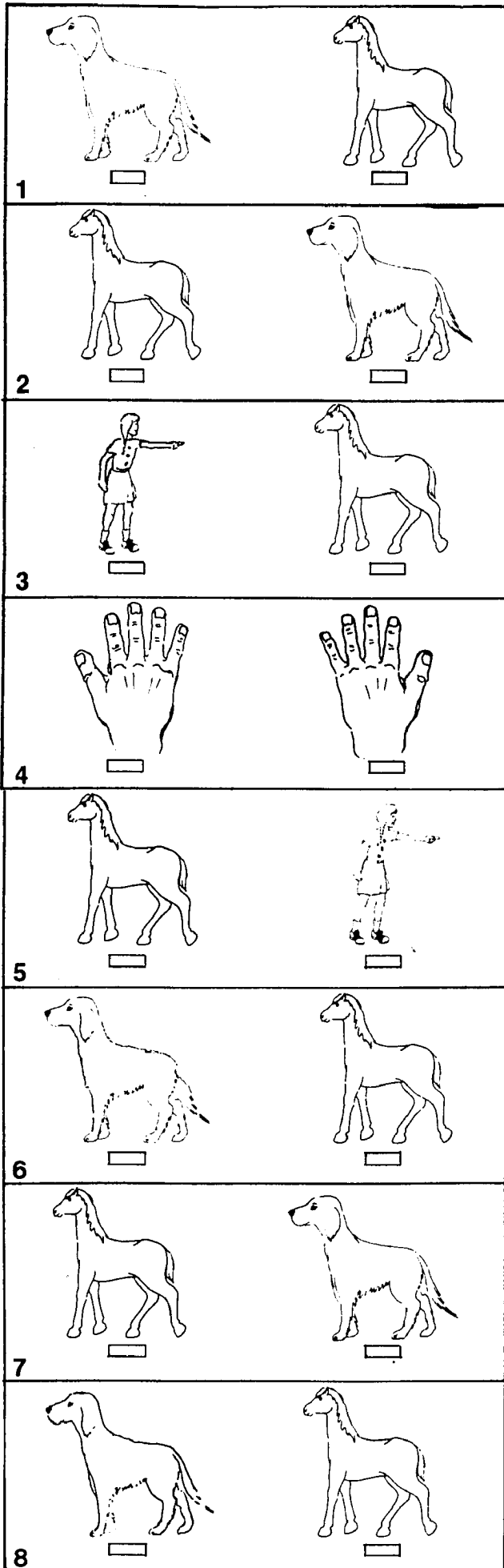
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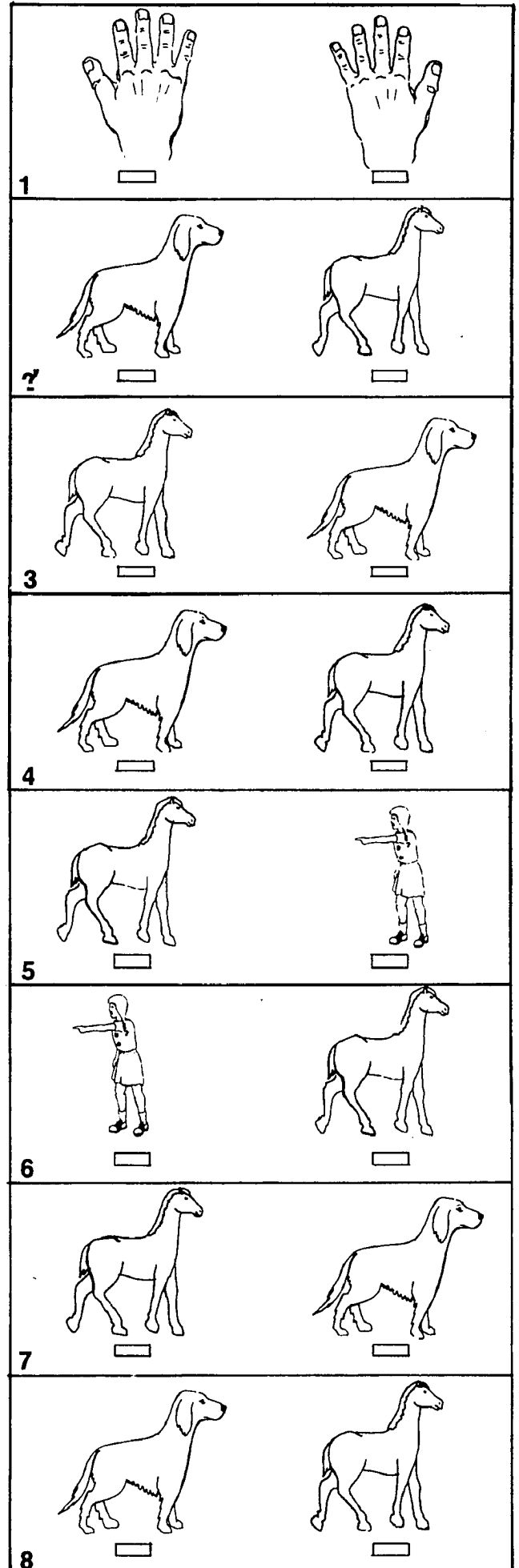
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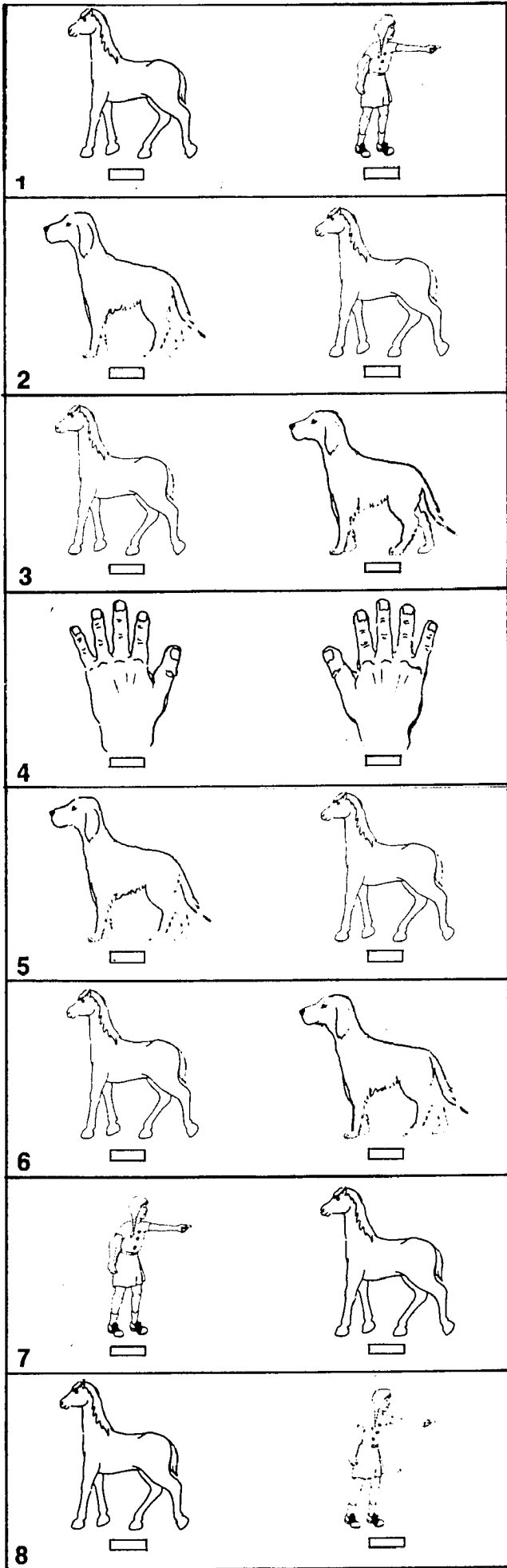
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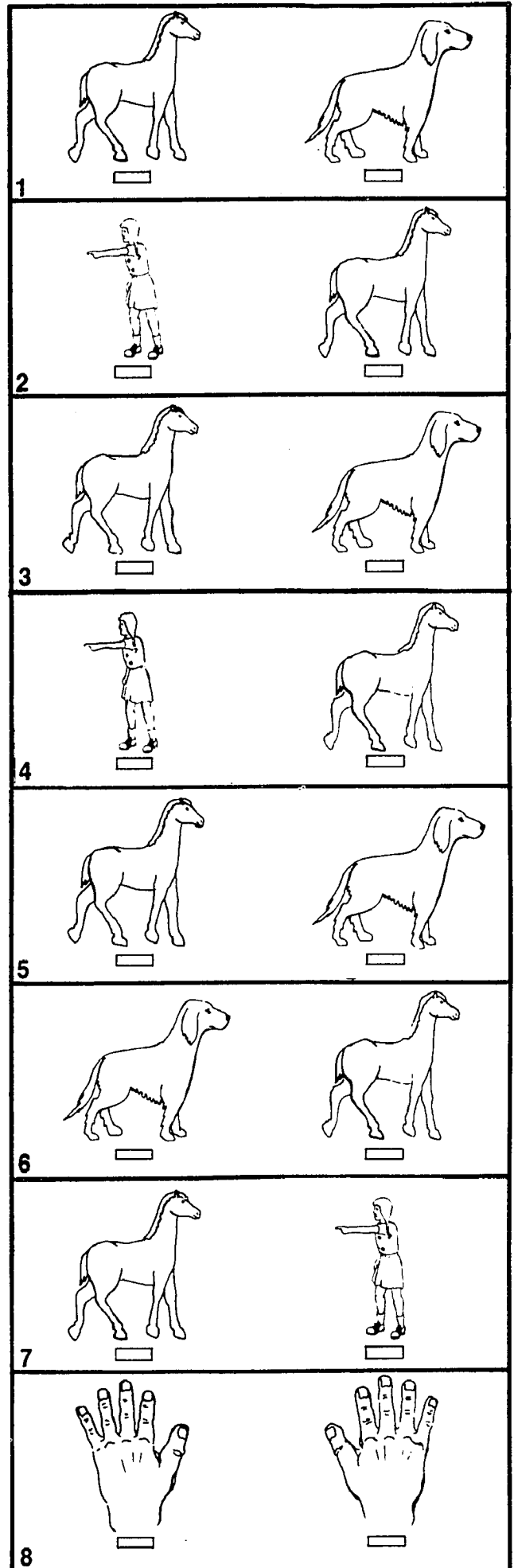
4



5



6



APPENDIX B
MODIFIED TEST OF PICTORIAL SPACE
INSTRUCTIONS & QUESTIONS

Instructions for pictures A & B

Picture A

- Look at these pictures. Please write your name on the line here.

- Let's look at the pictures again.

- Look at the first set of pictures here.

1. Find the picture of the horse. Color in the box under the picture. Go to the next set of pictures.

2. Find the picture of the girl. Color in the box under the picture. Go to the next set of pictures.

3. Find the picture of the dog. Color in the box under the picture. Go to the next set of pictures.

4. Find the picture of the hand. Color in the box under the picture.

Picture B

- Let's look at the next set of pictures. They are different.

1. Find the picture of the road. Color in the box under the picture. Go to the next set of pictures.

2. Find the picture of the horizon. Color in the box under the picture. Go to the next set of pictures.

3. Find the picture of the hill. Color in the box under the picture.

Instructions for pictures 1 to 6

- Now, turn the page on your answer sheet. Fold over the page like this (demonstrate). We are going to look at some sets of pictures. All the pictures have the same girl, the same horse, and the same dog. I want you all to pretend that you have a camera and you are taking a picture of what you see. The picture is going to look different depending on where you stand. Now, does everyone have their camera ready? Turn the page of your Big Set of Pictures (Demonstrate). Let's look at the first picture.

Pictures 3 & 4

- Turn the page over on your answer sheet. Let's look at the next set of pictures.

Pictures 5 & 6

- Turn the page over on the answer sheet. Let's look at the last set of pictures.

Picture 1 - (size + overlap + perspective)

- (1) Is the girl pointing with her left or right hand?
- (2) Who is to the right of the dog, the girl or the horse?
- (3) Who is closer to the dog, the horse or the girl?
- (4) Who is the dog in front of, the girl or the horse?
- (5) Who is the girl looking at, the horse or the dog?
- (6) Who is closer to you, the dog or the horse?
- (7) Who is the girl pointing at, the horse or the dog?
- (8) Who is in back of the girl, the dog or the horse?

Picture 2 - (reversed viewpoint - size + overlap + perspective)

- (1) Who is the girl looking at, the horse or the dog?
- (2) Who is in front of the dog, the girl or the horse?
- (3) Is the girl pointing with her left or right hand?
- (4) Who is closer to you, the horse or the dog?
- (5) Who is the girl pointing at, the dog or the horse?
- (6) Who is the girl in back of, the horse or the dog?

(7) Who is to the right of the dog, the girl or the horse?

(8) Who is closer to the dog, the horse or the girl?

Picture 3 - (size + perspective)

(1) Who is the girl in front of, the dog or the horse?

(2) Who is to the left of the girl, the horse or the dog?

(3) Who is closer to you, the girl or the horse?

(4) Is the girl pointing with her right or left hand?

(5) Who is in back of the dog, the horse or the girl?

(6) Who is the girl looking at, the dog or the horse?

(7) Who is closer to the girl, the horse or the dog?

(8) Who is the girl pointing at, the dog or the horse?

Picture 4 - (reversed viewpoint - size + perspective)

(1) Is the girl pointing with her right or left hand?

(2) Who is the girl looking at, the dog or the horse?

(3) Who is in front of the girl, the horse or the dog?

(4) Who is to the left of the girl, the dog or the horse?

(5) Who is closer to you, the horse or the girl?

(6) Who is the dog in back of, the girl or the horse?

(7) Who is the girl pointing at, the horse or the dog?

(8) Who is closer to the girl, the dog or the horse?

Picture 5 - (size + overlap)

(1) Who is closer to the dog, the horse or the girl?

(2) Who is the girl looking at, the dog or the horse?

(3) Who is the girl pointing at, the horse or the dog?

(4) Is the girl pointing with her left or right hand?

(5) Who is in back of the girl, the dog or the horse?

(6) Who is closer to you, the horse or the dog?

(7) Who is to the right of the dog, the girl or the horse?

(8) Who is the dog in front of, the horse or the girl?

Picture 6 - (reversed viewpoint -
size + overlap)

(1) Who is closer to you, the horse or the dog?

(2) Who is in front of the dog, the girl or the horse?

(3) Who is the girl looking at, the horse or the dog?

(4) Who is to the right of the dog, the girl or the horse?

(5) Who is the girl in back of, the horse or the dog?

(6) Who is the girl pointing at, the dog or the horse?

- (7) Who is closer to the dog, the horse or the girl?
- (8) Is the girl pointing with her left or right hand?

APPENDIX C

INSTRUCTIONS TO TEACHERS FOR ADMINISTRATION
OF FROSTIG POSITION IN SPACE SUBTEST AND
HUMAN FIGURE DRAWING

Teacher Administered Tests

- Please mark or have each child mark the first page of the Position in Space Subtest and the Human Drawing paper with his/her first name.

- In the case of two children sharing the same first name, please have them add their last initial, that is, JOHN W.

Frostig Position in Space Subtest (from Frostig, 1966, p. 16)

- Children are allowed to erase answers.

Materials. --For each child, a primary pencil or #2 (for kindergarten and above) or crayons. Demonstration cards.

Examiner holds up demonstration card. "Look at this row of arrows. One of the arrows is not like the other arrows because it points in a different direction (indicate). We must mark it like this." (Show.)

For group testing, it is often helpful to ask the class which one is "different," and then to let a child explain why.

This subtest should be administered as briskly as possible.

Item 1. Tables. --Examiner holds up answer sheet. "Look at this first row (point). These are tables. Most of the tables are right side up. But one table is upside down. Mark the one that is upside down. Now do it." (Check that the children put their pencils down.)

Item 2. Chairs. --Examiner holds up answer sheet. "Look at this row. These are chairs. Most of the chairs are turned the same way, but one is turned the wrong way. Mark the one that is turned the wrong way." (Check that the children put their pencils down.)

Item 3. Moons. --Same directions as for the previous item.

Item 4. Ladders --Same directions as for the previous item.

Now let's turn the page...Examiner holds up demonstration card. "Look at the first girl--the one in the box. Now look at this row of girls. One girl is just like the one in the box. She is turned the same way (show). The others are facing the other way. This one over here is the one you mark, because she is just the same as the

one in the box. Like this." (Show.) It is often helpful to make the example more concrete by saying, for example, "The girl in the box is facing the windows." Examiner holds up test booklet.

Item 5. Flowers. --"Now look at your book. Look at this row of flowers. Put your finger on the one in the box, and then find the one that is just like the one in the box. Now take your pencil and mark it." (Check that the children put their pencils down.)

Item 6. Snowmen. --Same directions as for previous item.

Item 7. Beachball. --Examiner holds up answer sheet. "Here are balls with drawings on them. Put your finger on the first ball. Find one which is just like it over here and mark it. Go ahead." (Check that the children put their pencils down.)

Item 8. Boxes. --Same directions as for previous items.

Human Figure Drawing

- Please distribute paper so that the long side of the paper is facing the child; that is,  not this .

- Once the paper is properly placed before the child, if the child rotates the paper, do not correct the position.

- After the instructions are given, if a child asks whether he/she can draw more than one person, respond only with the statement, "You are to draw a whole person. . . etc. "
- If after the initial directions or repeated instruction, the child proceeds to draw more than one figure, do not correct him.
- Children are allowed to erase all or part of their drawing.

Administration of HFD Test (from Koppitz, 1968, pp. 6-7)

"On this sheet of paper I would like you to draw a **WHOLE** person. It can be any kind of person you want to draw, just make sure that it is a whole person and not just a stick figure or a cartoon figure. "

- Please collate both tests so that the tests of each child are together in the order in which he/she appears on the data sheet.

APPENDIX D
GUIDELINES FOR TEACHER
COMMENTS

1. Teacher comments are important. There is no need to mark observations about every child; rather, you may confine your comments to only those children about whom you have concern regarding their classroom performance academically, socially and/or emotionally. The types of comments to focus on could include:

- Performs below IQ
- Performs above IQ
- Reading below grade level
- Receiving remedial reading and/or other assistance
- Inadequate writing skills
 - Letter reversals
 - Rotations
 - Cannot stay on line
- Inadequate word attack skills
- Inadequate comprehension of written material
- Quality of oral language expression

- Existing speech defects
- Receiving speech therapy
- Difficulty in understanding verbal instruction
- Math skills below expectation (specify)
- Hyperactive
- Behavioral problems (specify)
- Immature
- Overly passive
- "Day-dreams" excessively
- Not well coordinated
- Lacks ability to concentrate
- Socially isolated by peers

2. Please note on data sheet those children who have been retained this year and/or who began 1st grade a year later than usual.

[illegible][illegible]

APPENDIX E

INDIVIDUAL TESTING FORM, INSTRUCTIONS, AND QUESTIONS FOR ADMINISTRATION OF THE VISUAL PERCEPTUAL AND COGNITIVE TASKS

NAME:

SCHOOL:

B. D.:

GRADE:

CA:

CLASS:

DATE:

A. Visual-Perceptual Tests

(1) Harris Tests of Lateral Dominance

Test 2 - Hand Preference

SHOW ME HOW YOU . . .

. Throw a ball	. Turn door knob
. Wind a watch	. Hold eraser
. Hammer a nail	. Use scissors
. Brush teeth	. Cut with knife
. Comb hair	. Write

R	_____	%
L	_____	%
M	_____	%

Test 3 Simultaneous Writing

I want to see how well you can write numbers with both hands together at the same time. When I say go, I want you to write the number with both hands at the same time; then below it write the number two with both hands at the same time; then number three, and so on down to twelve. Go as fast as you can, and remember that you must write with both hands at the same time. (Before starting, place large stiff piece of paper before S and say:) **THIS MAKES IT A LITTLE HARDER. READY, GO!**

#R Hand reversals	_____
#L Hand reversals	_____

Test 4 Handwriting

Hand used _____
 R _____ sec.
 L _____ sec.

(Tests 5 and 6 omitted if S shows same hand preference in Test 2, 3, 4)

*Test 5 Tapping

I want to see how quickly you can make dots with a pencil, like this (demonstrate on first row). Take the pencil and try one row for practice (second row).

When I say go, make one dot in each square as fast as you can. When you get to the end of the line, go back the other way.

Ready, Go.

Time 30 sec.
 R Score _____
 L Score _____
 Best coordination _____

*Test 6 Dealing Cards

Make believe that the two of us are playing cards. Deal out the cards as fast as you can, first giving me one and then giving yourself one (allow S to deal out six cards for practice).

Ready, Go.

Test 8 Monocular Tests8.1 Kaleidoscope

If you turn it like this, you will see some interesting color changes.

R _____
 L _____

8.3 Sight Ruler

I want to see how well you can aim. Aim the ruler so as to hit me right on the tip of the nose.

Eye Preference _____
Shoulder Preference _____

Test 11 Foot Dominance

11.1 Kicking

Make believe that this is a football. Show me how you kick it.

Now kick it with the other foot.

Dominant Foot _____
Opposite Foot _____
Best Coordination _____

11.2 Stamping

Make believe there is a fire. Show me how you would put it out with your foot.

Foot Preference _____

(2) Bender Gestalt Test for Young Children

I have nine cards here with designs on them I want you to copy. This is the first card, now make one just like it. . . Make it as much like this one on the card as you can. (*Discourage counting of dots on Fig. 5. Say:) You do not have to count those dots, just make it look like it.

Time _____

A _____	
1 _____	5 _____
2 _____	6 _____
3 _____	7 _____
4 _____	8 _____

(3) Modification of Form A Benton Test of Right-Left Discrimination

3.1 - Own Body Part Designation

	R	L
(1) Show me your right hand	_____	_____
(2) Show me your left leg	_____	_____
(3) Show me your right ear	_____	_____
(4) Show me your left hand	_____	_____
(5) Show me your right leg	_____	_____
(6) Show me your left ear	_____	_____

3.2 - Other Person Body Part Designation

	R	L
(1) Show me my left hand	_____	_____
(2) Show me my right ear	_____	_____
(3) Show me my left leg	_____	_____
(4) Show me my right hand	_____	_____
(5) Show me my left ear	_____	_____
(6) Show me my right leg	_____	_____

3.3 - Doubled Crossed (x) Uncrossed Commands
(eyes open)

	C	I
(1) Touch your <u>left</u> ear with your <u>left</u> hand	_____	_____
(2) x Touch your <u>right</u> eye with your <u>left</u> hand	_____	_____
(3) Touch your <u>right</u> knee with your <u>left</u> hand	_____	_____
(4) Touch your <u>left</u> eye with your <u>left</u> hand	_____	_____
(5)x Touch your <u>right</u> ear with your <u>left</u> hand	_____	_____
(6)x Touch your <u>left</u> knee with your <u>right</u> hand	_____	_____
(7) Touch your <u>right</u> ear with your <u>right</u> hand	_____	_____
(8)x Touch your <u>left</u> eye with your <u>right</u> hand	_____	_____

(4) Kohs Block Design

For Ss
Under
CA 8

Design A: (Take four blocks in hand say:) You see these blocks have different colors on their different sides. I am going to make something with them. Watch me. (Demonstrate, then give four other blocks and say:) Now make one just like mine.

Design B: (Assemble behind screen; present to S in completed form saying:) Now make one like this. Do it yourself. Discontinue if has failure on both trials of Design B.

Design C: This time we are going to put the blocks together by making them look like this picture. Watch me first (construct design). You see, the top of these blocks looks the same as this picture (brush up blocks and say) Now you look at the picture and make one just like it with these blocks. Go ahead.

. Discontinue if fails on both trials.

(Use card C and say:) You see these blocks have different colors on their different sides. They can be put together to make a design like the one you see on this card (brush up blocks and say) Now make one like this. Go ahead. Tell me when you have finished (give S four blocks).

For Ss
CA 8 &
Older

. If S fails on both trials, administer A & B.

Design 1 to 4 (Place card before S and say:) Now you make one like this (*No second trials are given)

Directions for
designs
1-7 for
all ages

Design 5-7 (Use 9 blocks) Now make one like this, using 9 blocks.

. Discontinue - 2 consecutive fails

B. Cognitive Tasks

1. Conservations Tasks

1.1 Substance (global quantity)

1.1a (E gives S a ball of clay and says:) I want you to make another one exactly like this one. It is to be just as big and just as heavy. Is it just the same?

Ans. 1.1a -

1.1b Sausage transformation - Is there still the same amount of clay? How do you know?

Ans. 1.1b -

1.1c Segmentation transformation - Is there still the same amount of clay? How do you know?

Ans. 1.1c

1.2 Number (Single row correspondence constructing equal value sets)

1.2a Spaced-out model: I am going to give you some pennies to buy candy. Take the same number of pennies as I have here. Who is richer?.... Make it so that you have the same number as I have.

Ans. 1.2a -

1.2b Perceptual change (closure model): Now who is richer? How do you know?

Ans. 1.2b -

1.2c Perceptual change (circular model:) Is there still the same number of pennies? How do you know?

Ans. 1.2c -

1.3 Continuous Quantity

1.3a This is my glass of water and this is your glass of water. Are they exactly the same?

Ans. 1.3a -

1.3b (E pours A_2 into B_1 and B_2) I am going to pour your water into these glasses. Do we both still have the same amount of water? How do you know?

Ans. 1.3b -

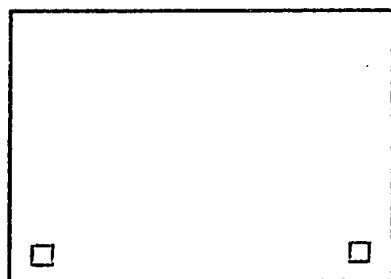
2. Projective Space Tasks

2.1₁ Construction of Projective Straight Line

(Rectangular Board)

(1) Now we are going to play another game. See this is a field. In the field I am placing two houses. Now we have to put the "lights" between the two houses. The lights are here. Do you know what a straight line is? (Demonstrate). This is a straight line, a straight road. And this (demonstrate curved line), is this a straight line? And this (demonstrate crooked line), is this a straight road?

Now you know what a straight line (or a straight road) is and a curved, crooked line (road). O.K., Now you are going to put lights between the two houses. Put pay close attention. You must make a row (like, road, etc.). That is very straight, a row that starts at one house and makes a very straight road to the other house.

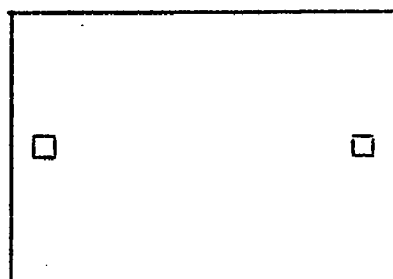


Visual Method _____
 Manual Method _____
 No observable Method _____

Comments

2.1₂

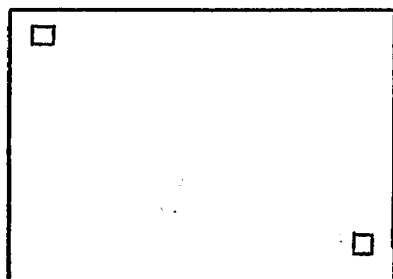
Now you are going to make another nice line with the lights. I am putting the houses here. Now the houses are further apart. But you must still fix the lights and make a very straight row between the houses. Do it just as before.



Visual Method _____
 Manual Method _____
 No observable Method _____

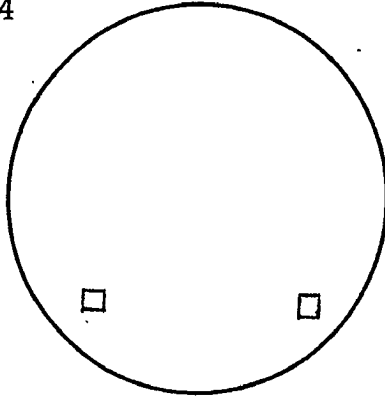
Comments

2.1₃



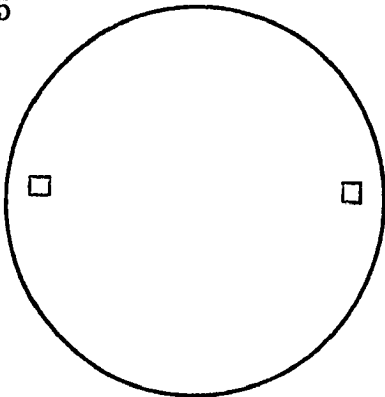
Visual Method _____
 Manual Method _____
 No observable Method _____

Comments

2.1₄

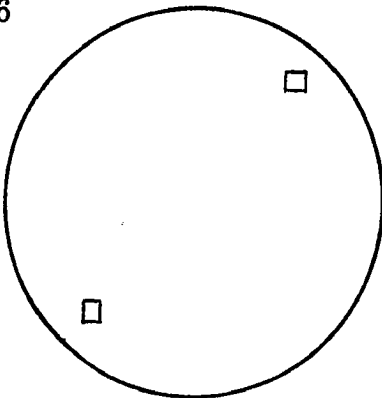
Visual Method _____
Manual Method _____
No observable
Method _____

Comments

2.1₅

Visual Method _____
Manual Method _____
No observable
Method _____

Comments

2.1₆

Visual Method _____
Manual Method _____
No observable
Method _____

Comments

2.2 Concepts of Left and Right

2.2₁ Absolute (see under Benton)

2.2₂ Relative position of three uncovered objects (block, plate, pencil) (1); Same three objects with subject's position reversed 180° (2).

L M R

(1) (3) Is the pencil to the left or to the right of the plate?

1 _____
2 _____

(2) (5) Is the plate to the right or to the left of the block?

1 _____
2 _____

(3) (1) Is the block to the left or to the right of the pencil?

1 _____
2 _____

(4) (6) Is the pencil to the right or to the left of the block?

1 _____
2 _____

(5) (2) Is the plate to the left or to the right of the pencil?

1 _____
2 _____

(6) (4) Is the block to the right or to the left of the plate?

1 _____
2 _____

TOTAL: _____

2.2₃ Hidden objects (horse, ball, boat)

Now you have to pay very close attention. I am putting this (screen) here so you can't see what is on the paper. I took away everything that was there before and I put other toys there. In a minute I am going to remove the cardboard. I am going to ask you questions to see if you can remember how the objects are arranged on the paper. Pay close attention. I am only going to let you see them for a few seconds.

LMR

- (1) Is the horse to the left or to the right of the ball?

- (2) Is the ball to the right or to the left of the boat?

- (3) Is the boat to the left or to the right of the ball?

- (4) Is the horse to the right or to the left of the boat?

- (5) Is the ball to the left or to the right of the horse?

- (6) Is the boat to the right or to the left of the horse?

TOTAL: _____

2.3 Coordination of Perspectives

Now we are going to play with some mountains. I have three mountains: a red one, a small blue one and then the yellow one which is very small. I also have a little man. See how small he is. So the mountains are very big for him because he is very small.

The man, right now is going for a walk around the mountains. He is going to take some pictures of the mountains. He has his camera with him to take the pictures. Now, you have to guess what will be in the pictures the little man is going to take.

Pre-test₁ - Position A

Watch, I am putting the man here. Tell me what the little man sees? What will the picture look like when he takes it?

Ans. Ex. 2.3 -

(Present cards A & D). Try to find which of these pictures the little man sees from here.

A _____

D _____

The little man is placed in front of you. He sees the red mountain in the back, the blue one to the left here and the yellow one to the right here. He sees this picture (Card A). On this picture the red one is in the back, then the blue one is to the left, and the yellow one is to the right, in front of the red one. On the other picture (Card D), the red one is in front of the yellow one, and the blue one is on the wrong side. To see this, he would have to stand somewhere else, do you understand?

2.3_a Card Recognition

Problem F (man, position F; child position A)

Now the man is there and he is taking a picture. Tell me what the man sees when he is placed there.

Ans. 2.3_{1v}

Here are some pictures of the three mountains. Show me the picture the man sees when he is there.

G ____ A ____ D ____ *F ____ H ____

Problem C (man, position C; child position A)
- verbal description

Ans. 2.3_{2v}

- pictorial choice

E ____ *C ____ F ____ A ____ B ____

Ans. 2.3_{2p}

Pre-Test₂ (child, position E)

Now you are going to sit beside me to see the mountains the way I see them. Make yourself very small like the little man. Look at the mountains carefully. Tell me what you see. Which mountains do you see?

Ans. 2.3_{3a}

Problem B (man, position B; child, position E)
- verbal description

Ans. 2.3_{3v}

- pictorial choice

*B ____ I ____ E ____ D ____ A ____

Ans. 2.3_{3p}

Qualitative Comments

APPENDIX F

EXPERIMENTAL AND CONTROL SUBJECT

IDENTIFICATION FOR SUBJECTS IN

FINAL SAMPLE

	<u>Subject Code Number</u>	<u>CA</u>	<u>Sex</u>	<u>Gr.</u>
<u>Experimentals</u>	1	6-8	M	1
	2	6-10	M	1
	3	6-11	F	1
	4	7-0	F	1
	5	7-5	F	1
	6	7-9	M	2
	7	7-10	M	2
	8	8-1	M	2
	9	8-5	F	3
	10	8-7	F	3
	11	8-10	M	3
	12	9-3	F	3
	13	9-3	M	3
	14	9-4	F	3
	15	10-0	M	4
	16	10-5	M	4
	17	10-6	F	4
	18	10-7	M	4
<u>Controls</u>	19	6-9	F	1
	20	7-0	F	1
	21	7-5	F	1
	22	7-9	M	2
	23	8-2	M	2
	24	8-2	F	2
	25	8-11	M	3
	26	9-4	F	3
	27	9-5	F	3
	28	9-11	M	4

APPENDIX G

SUMMARY OF TEACHER COMMENTS ON FIFTY-TWO EXPERIMENTAL SUBJECTS IDENTIFIED ON THE MTPS

Presented first are comments relating to the sixteen subjects in the tenth percentile.

Grade 1 (N = 4): Three of four were already receiving remedial reading. One subject was described as having "learning difficulties," another (a female) described as simply "passive." The same three subjects receiving remedial reading had C readiness scores on the MRT.

Grade 2 (N = 4): Three of four were reading below grade level. One subject, described as "a slow reader, barely on class level," had been receiving remedial reading instruction. The fourth child, a male with a 129 IQ, functioned well in reading but poorly in math and was described as a child with tendencies towards "impulsivity and poor gross motor coordination." In addition, he had a moderately severe articulation problem and was receiving speech therapy.

Grade 3 (N = 4): Three of four were receiving remedial reading. One female was characterized as a child who needed to "work very hard just to keep up." Although reading on grade level, she tended to

cry easily when unable to meet external standards for performance.

Grade 4 (N = 4): Two of four were described as "immature" with poor word attack skills. One male subject, one year older than his peers because he had attended a pre-first grade, was described as "having a problem focusing his eyes," a problem viewed as the source of his serious learning problems. Despite having undergone a "visual training" program, the teacher saw little difference in his reading and writing skills.

Typical comments of subjects in the twenty-fifth percentile were as follows:

Grade 1 (N = 8): Two subjects were receiving speech therapy while four of them received remedial reading. Descriptions of classroom performance included poor oral expressive skills, poor attention span, poor visual skills, poor listening skills for verbal instruction, letter reversals, etc.

Grade 2 (N = 8): Two received remedial reading. Characterizations included performs below IQ, performs above IQ, immature, shy, home deprivations, verbally limited.

Grade 3 (N = 10): Only one child was designated as receiving supplemental reading help; however, information regarding this group was limited since not all teachers supplied comments. Typical observa-

tions emphasized inability to concentrate, reading below grade level, immature, and learning disability.

Grade 4 (N = 10): Information was again limited because of one teacher's failure to supply comments. Of the three teachers who did comment, it was determined that two subjects received remedial reading.

APPENDIX H

VERBAL DESCRIPTIONS FOR THREE-DIMENSIONAL (3D) AND PICTORIAL CONDITIONS IN PROBLEM C

<u>Verbal Description 3D Condition</u>	<u>Verbal Description Pictorial Condition</u>	
	<u>Choice</u>	<u>Rejection</u>
<u>Stage IIb and a (Strategy X):</u> <u>Subject 22 (7-9)</u> He sees...the blue one. He looks straight ahead and he sees straight here/nothing but then if he looks that way/he sees the big red one and the blue one and the yellow one behind it. He might not even see the yellow one cause the blue one is covering it up.	*(C) He sees the blue one right over here...On the right. And he sees the red one over on the left and he can't see the yellow one because the blue one is behind it. I mean in front of it.	(E) It's good but the red one have to be in front of the blue/not in front of it but over there cause it's bigger. (A) The blue one would have to be...on the left. And/the red one would have to be where the yellow one is....
	(B) (C) & (F) (B) Um/the blue one is a little ...close to the red one (i.e., blue overlaps red). And the yellow...is a little bit far from the red one. (C)// He can see that one (asked	He can see all of them.
<u>Subject 26 (9-4)</u> The blue one first/then the red one/then the yellow one (asked where would the red one be) Um///far.		

* Denotes correct pictorial selection.

(Continued)

APPENDIX H--Continued

Verbal Description 3D Condition

Subject 26 (Continued)

<u>Choice</u>	<u>Verbal Description Pictorial Condition</u>	<u>Rejection</u>

which one he can see better)
This one (B). (Asked why he
can't see C) Because (in the
picture) he can't see the yellow
one.

Subject 11 (8-10)

No yellow/and all of blue and all red.

(E) Looks like it. It's exactly
the picture (Before-Behind
relation is reversed from C).
(Asked where is the red moun-
tain.) The red one's on the left
and the blue one's on the right.

(F) (Marked pause. He'd
have to move the moun-
tain around.

(A) He'd have to be over
here (indicating in front
of himself.)

(B)...The reason is /uh/
move the mountains.

Subject 13 (9-3)

The blue one...to the right. The red
one...left... A little of the yellow.

(A) Cause the blue one's on the
right of em/and the red one's
on the left/and the yellow's
behind the blue (NOTE: His
justification directly contradicts
the pictorial content of A).

(C) The red one's not
supposed to be in the
front. (NOTE: Red is
not in front in C; rather,
he appears to be having
problems with the overlap

APPENDIX H--Continued

<u>Verbal Description 3D Condition</u>	<u>Choice</u>	<u>Verbal Description Pictorial Condition</u>	<u>Rejection</u>
Subject 13 (Continued)			cue, i. e., red is falsely interpreted as sharing the same frontal plane as blue).
			(E) There's not a yellow.
Subject 15 (10-0)			(C) Cause they're spread apart (referring to the board). The blue mountain would have to be right there (closer to the red).
		(E) This one... cause the yellow mountain's behind the blue mountain/and he can't see it.	
Subject 17 (10-6)			(F) (A) (B) Cause the yellow one being shown.
He would probably see this one first (Asked to specify color). (No response. Asked where would the red one be). This one (yellow) would be kinna behind the blue one.			(E) It's not/you know/ it's not/I donno. I just don think so.
		*(C) (Her selection strategy consisted of eliminating those pictures (F, A, and B) in which yellow was present. Selection of C was preceded by a marked pause). This one...if it was right here (pointing to position C)/it would be the same.	

APPENDIX H -- Continued

<u>Verbal Description 3D Condition</u>	<u>Verbal Description Pictorial Condition</u>	<u>Choice</u>	<u>Rejection</u>
Subject 18 (10-7) I'll show you (attempts to demonstrate as a substitution for verbal justification). The red and the blue one... The red is in the front/and the blue and the yellow's in the back (Incorrect structuring of red-blue relation). No/blue's in front. And the red and yellow are in the back.	*(C) If this is behind this one/ can't see this one (yellow). The other one is in the way.	(E) Cause this one is in front of the blue one. (B) The blue/is in front of the yellow (Incorrect). (F) Cause the red and the blue/the red/and yellow are in front of the blue.	(A) This? The red's suppose to be in back of the blue (tapping finger to denote actual location). (D) Red's in front of this (blue) and yellow's in the back.
Subject 18 (Problem B) The yellow one and the blue one. (Asked where are they as the man looks at them). Right there (Asked "right there where?"). Right there. (Again asked where) (Marked pause). On the left side (Incorrect). (Asked what about the blue one). On the right side (Incorrect). (Asked what about the red one) In back.	*(B) Because it looks right (Subvocalizes "It's exactly right") (Repeated why does it look right?) BECAUSE this red one is in back of it (tapping finger on board to designate location)/and this blue one is over here (again using finger for location). And this yellow one (tapping at location) right there.		

APPENDIX H--Continued

<u>Verbal Description 3D Condition</u>	<u>Verbal Description Pictorial Condition</u>
<u>Choice</u>	<u>Rejection</u>
<u>Stage Ib (Strategy Y):</u> Subject 19 (6-9) He sees the red one in front of himself// and he sees this one (blue) at an angle like this (draws an imaginary line between red and blue to demonstrate). To the opposite. And this one (red) next to that one (yellow). The red one next to the yellow one and the blue one opposite from the red one. But the blue one's sorta in front... of the little man. Subject 20 (7-0) The/um/blue is in the front on the left side (Incorrect). The red is in the back and the yellow is in the back.	(B) Because this one looks a little like that (Asked to tell the colors). The red one looks like it's angled to the blue one/and the yellow one looks like it's a little further away from this mountain (red) /like this (indicating relative distance in picture). (A) Because/blue is in the front on the left side/like I said (Systematic but incorrect). The yellow is in the back on the left side like I said/and the red is in the back on the right side (Incorrect). (NOTE: In A, yellow is in the front to the right). (C) Doesn't have yellow. (E) That one has no yellow. (B) The blue and red are in the front and the yellow is in the back (in terms of the actual configuration from position c).

APPENDIX H -- Continued

Verbal Description 3D Condition

Subject 14 (9-4)

The blue mountain...a bit in front of him...
The red mountain will be on a side of him.
And the yellow mountain will be on the other
side of the blue one.

(Problem C)

Verbal Description Pictorial Condition

<u>Choice</u>	<u>Rejection</u>
(B) Because the red mountain is behind the blue one and the blue one's on the side of it and the yellow one's over there.	(E) Cause the red mountain isn't on the left side. (A) (Marked hesitation) Cause the yellow mountain isn't mostly on the right side. It's in the middle. (NOTE: description is inconsistent with her criterion for selecting B).
(F) It's much closer. It's better. (Asked why). Because this (blue) is in front of this one (red) and this one (red) is taller so the man can see it. And this one (indicating all three mountains) he could see too.	(C) And this one/C (based on previous context), he meant man) can't see this picture. (E) He can't. (B) This///could be but it's not...Well/ this is it. Could be but then it doesn't look like it.

Stage Ia (Strategy Z)

Subject 1 (6-8)

(Initially points.) The blue one and the red one. This one's in this one's way. (Asked which one). The blue (indicating that the blue stands in the way of yellow preventing the man from viewing it).

APPENDIX H--Continued

<u>Verbal Description 3D Condition</u>	<u>Verbal Description Pictorial Condition</u>	
	<u>Choice</u>	<u>Rejection</u>
Subject 4 (7-0)	The red one (Asked where) (No response) (Repeated) (Again, no response.) (Third attempt) The blue one...over here (pointing to exact board position).	(B) Cause he can't see the yellow one. (E) Doesn't have the yellow one in it (Asked why she can't pick B instead of C). Cause that one's (blue) in front of it.
Subject 5 (7-5)		(C) Cause he can't see the yellow one. (E) Because here he can see the red and the blue. (A) Because he can see the red one but he can't see the yellow.
The red mountain...Right across from him... He sees the/um/blue. (Asked if he sees the yellow mountain) Yes...right here.	(B) Because he's in front of the red/he sees the blue and he sees the yellow. (NOTE: With this and rejections, her procedure was to itemize pictorial content in terms of the perceptual configuration of the mountains).	
Subject 6 (7-9)	The blue one and the red one on the front and the yellow one's gonna be in back...Nope/nope. The blue one's gonna be in the front and the red one and the yellow one are gonna be in back. (Demonstrates) See//he's in the front and these two are in the back.	(F) Cause the red and the yellow are in the front/this could show them here/and this//(unintelligible) here/and this (unintelligible) out.
(A) He can't see that one or that one (E and C) cause there's only two (mountains).		

APPENDIX H -- Continued

<u>Verbal Description 3D Condition</u>	<u>Verbal Description Pictorial Condition</u>	
	<u>Choice</u>	<u>Rejection</u>
Subject 10 (8-7)		
He kinda see it onna angle (Asked where would he see the mountains). The red and the blue one kind of up first and the yellow one last. Which would be hard to see cause it's right in back of the blue one.	(B) & (E)	(C) It isn't so good cause it's up together (blue and red) when it's not supposed to be.
	(B) Because...if he moves over a little bit/he could probably see the yellow one (i. e., because she sees yellow from her position at A, the man by moving slightly from his position at C, could also see yellow).	(A) Cause...if he got up to over here (in front of her at A) he could see this picture.
	(E) This one... Because it's really really hard to see the yellow little mountain/cause it's the littlest.	

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