

FIELD DEPENDENCE AND WORKING MEMORY CAPACITY IN CHILDREN'S
ABILITY TO COPY FIGURES WITHIN A MISLEADING CONTEXT

by

CAROL A. COTÉ

A Dissertation submitted to the
Graduate School-New Brunswick
Rutgers, The State University of New Jersey

In partial fulfillment of the requirements

For the degree of

Doctor of Philosophy

Graduate Program in Education

Written under the direction of

Angela M. O'Donnell

And approved by

New Brunswick, New Jersey

May, 2008

ABSTRACT OF THE DISSERTATION

FIELD DEPENDENCE AND WORKING MEMORY CAPACITY IN CHILDREN'S ABILITY TO COPY FIGURES WITHIN A MISLEADING CONTEXT

by

CAROL A. COTÉ

Dissertation Director:

Angela. M. O'Donnell

Visual motor abilities are a concern for many elementary age children. Design copying tasks are often used to assess development in this area. The purpose of this study was to investigate the influence of field dependence on a design copy task and to test the theory that this influence has a quantitative explanation. New tasks were created which required copying designs within the misleading context of either a tilted frame or a different size frame. Field dependence would be demonstrated if the participant was influenced by the misleading frame and constructed copies that are oriented to the frame rather than to a more appropriate external frame of reference. Working memory capacity would be shown to be related to ability on these tasks if there was a greater influence of the frames on items that involved more complex figures to be copied. The Block Design Test and Corsi Block Tapping Test were used as standard measures of field dependence and working memory capacity.

Participants included 105 children between the ages of 6 and 11 years, including 19 identified as learning disabled, and 39 adults. Results showed that constructions made by participants were significantly affected by the misleading frames and accuracy of constructions correlated significantly with Block Design, thus providing support for the new tasks as measures of field dependence. Adults were significantly more accurate than children but they too were influenced by the misleading frames. Support for working memory capacity as an underlying factor was less consistent; a significant increase in the influence of the tilted frames was found with an increase in complexity of the figures, but no correlation with the memory span test was found. The validity of a recall test as a working memory assessment is discussed. An interactive model of working memory and inhibition as proposed by Roberts and Pennington (1996) might better account for results.

A case study illustrates the inconsistency of performance by children and how a dynamic systems model can be used to consider the role of working memory, inhibition and ongoing goal-directed action on the study tasks.

TABLE OF CONTENTS

ABSTRACT	ii
TABLE OF CONTENTS	iv
LIST OF TABLES	vi
LIST OF FIGURES	vii
INTRODUCTION	1
Developmental Processes in Field Independence.....	3
Piaget's Theory of Action in Perception	4
Motor Control or Perceptual Ability	12
Factors Influencing Perceptual Analysis	13
Field Dependence and Cognitive Style	16
Kindergarten Study.....	20
Block Design Test	23
Working Memory in a Visual Analysis Task	25
Short-Term or Working Memory?	26
Working Memory and Inhibition in Field Dependence	28
Summary of the Literature Review	32
Present Study	33
Study Tasks	36
Participants	42
Hypotheses	43
METHODS	45
Participants	45

Procedure	46
Misleading Frames Tasks	46
Standardized Tests	50
RESULTS	51
Misleading Frames Tasks	51
Tilted-Frames Tasks	51
Frame-Size Tasks	55
Standard Measures: Block Design and Corsi Block Tapping	57
Design, Span and New Task Measures	58
Awareness of Strategy Use	60
DISCUSSION	63
Misleading Frames Tasks	63
Field Dependence and the Misleading Frames Tasks	63
Working Memory and Inhibition in the Misleading Frames Tasks	65
Developmental Level of Performance	70
Learning Disabled Children's Performance	73
Placement versus Drawing Responses	73
Summary of Study Findings	74
Titled-Frames as a Dynamic Process: A Case Study	75
Future Directions	79
CONCLUSION	81
REFERENCES	83
CURRICULUM VITA	89

LIST OF TABLES

Table

1. Means and SD of deviation errors for each type of figure in Tilted-Frames compared to Baseline measures.	52
2. LD participants ($n = 19$)/total of all children ($n = 105$) for scores on each measure by quartiles.	55
3. Frame-Size Task: Means of the differences in height of drawings made in misleading frames from baseline measures.	56
4. Percentage of responses in the four options on the Frame-Size Choice tasks.	57
5. Correlations among standard tests and total errors on tasks.....	60

LIST OF FIGURES

<i>Figure 1.</i> Example of block design pattern	24
<i>Figure 2.</i> Items for Tilted-Frames placement tasks	37
<i>Figure 3.</i> Items for Tilted-Frames drawing tasks.....	38
<i>Figure 4.</i> Items for Frame-Size tasks	39
<i>Figure 5.</i> Items in the Frame-Size Choice tasks	41
<i>Figure 6.</i> Number of participants at each grade level	45
<i>Figure 7.</i> Mean errors on Misleading-Frames Task.....	53
<i>Figure 8.</i> Corsi Block Tapping Test scores for all participants	59
<i>Figure 9.</i> Block Design scores for all participants	59
<i>Figure 10.</i> Responses made by a 9-3 year-old girl on Tilted-Frames	78

FIELD DEPENDENCE AND WORKING MEMORY CAPACITY IN CHILDREN'S ABILITY TO COPY FIGURES WITHIN A MISLEADING CONTEXT

INTRODUCTION

The experience of vision is not a passive process. It is not like a camera opening its lens and taking in the scene. Rather it is an active, constructive process that is both perceptual, coming from the eyes, and intelligent, finding meaningful structures (Kandel, Schwartz, & Jessell, 1991). The sensory part of perception probably does not change much through childhood. By one year children are “visual geniuses” (Hoffman, 1998, p. 12). However children do differ greatly from adults in their ability to perform visual tasks. The development of such abilities is commonly assessed through standardized tests that have their roots in neurological studies of brain injured adults (Salvia & Ysseldyke, 1995). A typical test involves making copies of line figures (e.g., Beery & Beery, 2004) which show that with increasing age children, on average, can copy complex figures more accurately. However, when a child performs poorly on one of these tests we cannot conclude that it is for the same reason that a WWI soldier with a gunshot wound performs poorly. Although these tests do show developmental trends they are not necessarily based on developmental constructs and thus are difficult to interpret. Salvia and Ysseldyke have harsh criticism for these tests, “For the most part they are neither theoretically nor psychometrically sound” (p. 556).

Yet visual-motor and visual-spatial skills are an area of concern in education. Some children have difficulty acquiring facility with handwriting, for example, or early geometry worksheets, or on the spatial organization of work. These children might be

characterized by teachers as having performance difficulties. A better understanding of the nature of these difficulties could lead to appropriate support for the children experiencing them and it could be helpful for designing age appropriate materials for all children.

The purpose of this study is to investigate one developmental component, the decrease in field dependence (or increase in field independence), that may explain performance on certain tasks. Field independence is an increasing ability to perceive a visual target not only as it immediately appears but with the flexibility to consider and integrate multiple interpretations or multiple contextual features, resulting in an increased ability for analytical thinking within the task (Elkind, 1975; Witkin, Oltman, Raskin, & Karp, 1971/2002). This may be evidenced in ability to perceive both global and featural aspects (whole-part) of a figure or ability to inhibit some contextual information in favor of other more task-relevant information. This clearly improves with age through childhood (Elkind, 1975; Piaget, 1969), but what is it that is changing? The argument to be put forth in this paper is that the amount of information that can be considered at one time is a key component of what is changing during childhood to allow for improved ability on these tasks. This quantitative aspect has been termed working memory (e.g., Baddeley, 2002) or attentional capacity (e.g., Cowan et al., 2005) and is believed to be fundamentally tied to both general cognitive development (Kail, 2000) and to specific areas of achievement (Gathercole & Pickering, 2000). In this review I will consider how performance on perceptual analysis and construction tasks may be related to limitation in working memory capacity. The main hypothesis for this study is that measures of field

independence are strongly related to measures of working memory and together these can predict performance on certain visual perception tasks.

Developmental Processes in Field Independence

Several theorists have addressed the issue of field dependence. Piaget (Piaget, 1969; Piaget & Inhelder, 1956) looked at it within the framework of general cognitive development and many of his insights were further investigated by Elkind and his associates. Witkin (Witkin et al., 1971/2002), in a different approach, viewed field dependence/independence as a matter of cognitive style rather than ability, an approach to understanding intelligence and thinking. This work has been found to be problematic in many ways (Newcombe, 1991) and was not tied to the developmental work such as that of Piaget (Zigler, 1963). However two important contributions germane to the present study come from the cognitive styles approach. First the tests developed by Witkin to assess field independence, the Embedded Figures Test (Witkin et al., 1971/2002) and Rod-and-Frame Test (Witkin & Asch, 1948) have been and continue to be widely used as the presumed measure of this construct. Second is the adoption of the cognitive style model by another group of theorists, the neo-Piagetians (e.g., Case & Globerson, 1974; Pascual-Leone, 1987), who view field independence as a critical component of certain cognitive abilities and as being related to working memory capacity which is a position very similar to that taken in the present study. Although field independence is viewed as a developmental ability in the present study, the characterization of it as a cognitive style dominates the psychology literature on this topic even when developmental processes are being investigated (e.g., Alevriadou, Hatzinikolaou, Tsakiridou, & Grouios, 2004; DeLisi, 1983; Huang & Chao, 2000; Morra, 2002, 2005).

The literature review that follows includes research on several types of tasks that illustrate the impact of field dependence. In general they challenge a child's ability to simultaneously consider the parts of a figure, the relationship of the parts to each other and to the overall structure, and the figure's relationship to the surrounding context. Piaget provided the most comprehensive analysis of the development of field independence, therefore his model will be the starting point and will provide a framework for presenting his as well as subsequent research findings.

Piaget's Theory of Action in Perception

Piaget (1969) believed that to understand developmental changes in visual perception we have to understand the action of perception, the increasing ability to explore and coordinate multiple takes on a visual scene. The qualitative changes seen from the preschool to early childhood years were described by Piaget in a variety of ways: from centration to decentration, perceptual to representational, topological to Euclidean, and figurative to operative. The essential mechanism of change underlying all is the onset of operational thinking.

Centrations and Field Effects

Piaget explained the development of perceptual ability (referring to tasks that are purely visual, often involving illusions) in terms of "field effects": the immediately available interactions of the object being viewed with any closely related elements, a term taken from Gestalt psychology (Piaget, 1969). Perception in early childhood is limited and centered on field effects. This is simple perception, a centration requiring no exploration or coordination of the various other elements that are available, and may be considered relatively passive perception (Elkind & Scott, 1962). With development

children become able to coordinate multiple centrations and to extend perception to objects not necessarily simultaneously present within the same field of centration, thus becoming decentered (Piaget, 1969).

The influence of field effects on a young child's perception was illustrated by Piaget (1969) using a horizontal line drawn within a square that was tilted off center. The child's task was to judge whether or not it was truly horizontal. The younger children used the immediate frame of reference, the off-center square, to make their judgments and consequently misjudged the line. Older children were able to use the external frame of reference of the paper edges or table and made more accurate judgments. These findings were found to correlate highly with the classic water level judgment task in which young children predict that the water line in a tilted jar will be perpendicular to the jar's side rather than parallel to the ground (Piaget & Inhelder, 1956). In both tasks the child's perception is centered on the most immediate features available in the task. Later, coinciding with the ability for operational thought, children are able to consider other frames of reference and come to a different conclusion. The operational child can choose an appropriate frame of reference for the object being viewed. The tendency toward field independence corresponds to operative thinking in Piaget's terms (Flexner & Roberge, 1980).

A more recent study found similar developmental changes in a child's choice of reference. Duffy, Huttenlocher and Levine (2005) found that 4-year-olds differed from 8-year-olds in their methods and ability to encode the length of two dowels for the purpose of making size judgments. The younger children appeared to rely on the immediately available standard, in this case the relative proportion of the dowel and its

container, to judge which size dowel matched the original. They were misled in the matching task by choices that were proportionally identical to the target but were in fact the incorrect size. The 8-year-olds were not as easily misled; instead they were able to base their judgments on an external standard and made more correct judgments.

Errors in judgment may be evidence of insufficient perceptual exploration. However the errors do not simply decrease with development, rather there is an initial increase during the transition from pre-operations to operations as children begin to consider a frame of reference but one which may be misleading. Prior to this stage no references would be considered, only the isolated figure. This progression was described by Piaget (1969) in the experiment using a line within a tilted frame: “Between 5 and 6 years there is an increasing relation to the side of the figure (resulting in an increasing number of errors). Between 7 and 9 years a compromise occurs between relations with the figure and with the external frame of reference; at 10 to 11 years, or adulthood, the external frame of reference dominates” (p. 174). This “compromise” seen during the period of concrete operations may in part explain the differences in ability found among school-age children, some have a greater ability for considering and coordinating multiple frames of reference than others. The nature of these individual differences is the key issue to be explored in the present study.

Our perception of a particular stimulus figure can in some instances be so strongly affected by the visual information surrounding it that it is impossible to view the figure correctly. Optical illusions such as those commonly found in psychology books are quite interesting and universally effective. These happen because our vision actually constructs what we see and these constructions follow universal rules (Hoffman, 1998).

By manipulating a scene to take advantage of those rules illusions can be reliably created. In some cases children are more susceptible to illusions because they do not explore the entire field and are thus influenced by local misleading information, in other cases it is the adults who are more strongly influenced precisely because the adults integrate surrounding information to a greater degree than children (Kovács, 2000; Piaget, 1969; Stiles, Delis, & Tada, 1991).

Perceptual versus Representational

Piaget (Piaget & Inhelder, 1956) described the change from perceptual to representational thinking as the difference between a simple direct imitation of what is in view and the construction of a new figure based on coordination of several fields. Thus a simple straight line can be either perceptual or representational depending on the nature of the task. Very young preschoolers can recognize whether a line-up of objects creates a straight line or not. Creating such a line-up, however, develops much later. This change was illustrated with a construction task: A child attempts to make a straight line-up of small plasticine balls on a table, the starting and ending points of this line-up were provided. At ages 4 to 7 children were fairly successful if the line to be constructed ran parallel to the table's edge. Here, the straight line is perceptual, a simple imitation of a line along the edge provided. However, if the line to be created ran obliquely from a given starting point to an ending point, or if done on a round table, the child at this age "finds it quite impossible to break away from the perceptual influence of the table edge" (p. 158) and consequently makes an "L" shape on the rectangular table and a curve on the round table even though they could recognize a straight row when they saw it. "The poverty of children's exploratory activities" (Piaget, 1969, p. 141) leaves them to rely on

imitating the line created by the table's edge. A representational straight line, on the other hand, is made by coordinating all points of view, a characteristic of operational thinking. This entails creating a new relationship rather than imitating what is present. By around age 7 a child can use the two endpoints provided, which Piaget termed sighting, to arrange the balls in a straight line. The ability to perceive a straight line is perceptual; the ability to create a straight line according to a chosen frame of reference is representational.

The progression from topological to Euclidean spatial concepts was also studied extensively by Piaget (Piaget & Inhelder, 1956; Piaget, Inhelder, & Szeminska, 1960) and is particularly relevant to understanding the development through the concrete operational years to maturity. Topological space involves singular takes on an object and its immediate relationships; it is the sensory data that is part of any perceptual experience. Representational space, which is the intelligent activity of coordinating relationships, allows for Euclidean organization space. "When a child learns to use systematic points of view, he can construct projective straight lines out of topological notions of order" (Piaget, 1969, p. 390), marking the beginning of coordinate systems of Euclidean space, again related to the onset of operations. The full elaboration of reference systems making true Euclidean notions is slow to develop throughout childhood (Piaget et al., 1960)

Figurative versus Operative

The figurative aspects of a visual task (those characterized as perceptual, centered or topologic) are primitive and subordinate to the operative aspects (the activity of coordination, representations, multiple frames of reference), but the figurative is never

replaced by the operative, at all times they interact. The figurative is tied to the here-and-now which provides the data for operative actions. However, “If the figurative aspect were left to itself and had to rely on its own capacities, it would give rise to all sorts of systematic illusions” (Piaget, 1969, p. 357). An operational child can select from possible frames of reference to construct what is necessary for the task.

Part-Whole Perception

The impoverishment of perceptual activity in early childhood Piaget wrote about can be observed in the analysis of a single but complex figure that has both overall structure and constituent parts, or part-whole perception. In this case the field effects are determined by the particular quality of a figure that is most salient to the child. The overall configuration might be most salient if the structure is strong and obvious or it could be parts or details if those are more readily observed than the overall structure (Piaget 1969). Once his or her attention is caught by one aspect it is difficult for the young child to decenter and to consider a different understanding. This limits the child’s ability to see the parts and the overall structure in coordination. Part-whole analysis is more commonly addressed in the literature and in perceptual assessments than the perceptual tasks described above.

Common pencil and paper tasks such as figure copying can reveal developmental changes in local (part) versus global (whole) analysis. The local part of analysis is the ability to identify segments within the figure to be copied and global analysis is then necessary to integrate the segments into a coherent whole (Akshoomoff & Stiles, 1995). For example, when copying a “+”, young children were likely to draw four separate short lines while adults drew two longer intersecting lines. The young children in these studies

were clearly able to see the parts (lines) and the whole (+) because the end product was correctly arranged, but they lacked ability to coordinate the relationship of the parts to make crossing lines and instead organize them in an isolated fashion around the center (Tada & Stiles, 1996). Similarly, when the task was to copy a complex figure (one including many subdivisions and features) the younger children parsed the figure into segments which were then coordinated only two at a time, generally being drawn next to each other but not with a common boundary. The overall figure was approximated but with many redundant lines and some distortion. Again, these children were capable of seeing, but not coordinating or integrating the details with the overall scheme (Akshoomoff & Stiles, 1995).

To investigate the developmental changes in ability to perceive structure and features, Elkind (1975) showed children ages 4 to 9 years pictures which can be perceived by parts for one interpretation or as a whole for a different interpretation. For example, one picture created a man made of fruit: an apple for the head, bananas for the legs, bunches of grapes for the arms and a pear for the body. He found that young children were usually centered on the dominant feature of the scene, in this case the parts (fruit), with a whole (man) perceived at a later age. The different aspects could be pointed out to a child who then could see the other meaning. However it was not until age 9 that the part-whole integration of being able to see “a man made of fruit” was reliably observed.

Different results were reported in a more recent study that was aimed at challenging the ages at which part-whole analysis develops. Boisvert, Standing and Moller (1999) used a task similar to that used by Elkind (1975) but presented it in a

multiple choice format to young children. When 5-year-olds were asked to find a “cat made of triangles” from among four choices they were much more successful (nearly sixfold) compared to when they had to reply to the question, “what do you see?” as in Elkind’s studies. Boisvert et al.’s conclusion was that part-whole integration is possible at a much younger age than generally believed. However, an argument can be made to their conclusion because the multiple choice format provided a very supportive condition in which the part-whole analysis was demonstrated. The child had only to recognize it and could do so possibly through processes other than part-whole analysis, for example finding the picture that satisfied both the category cat and triangles without necessarily actively integrating the two. In many of Piaget’s experiments on perception, recognition was seen at an earlier age than active construction (Piaget, 1969). This disparity illustrates the need for a careful task analysis of any assessment task. The present study focuses specifically on active construction or active analysis to investigate perceptual development.

Motor Control or Perceptual Ability?

A child’s level of perceptual analysis is very often judged by his drawing or some other paper-and-pencil response. The question then arises as to whether errors found are due to errors in perception or to immature motor control of the pencil. This issue has been addressed by several researchers. For example, Piaget had children recreate figures using matchsticks in addition to pencil drawings (Piaget & Inhelder, 1956), Tada & Stiles (1996) used strips of paper, and Bouaziz and Magnan (2007) used pre-printed overlays to compare children’s organization of a complex figure in a motor-free versus paper-and-pencil method. All found that children used the same organization and made

the same errors in both drawing and motor-free conditions. Another way researchers have circumvented the motor control issue is to construct tasks in multiple choice format so that no motor response is needed at all (e.g., Boisvert et al., 1999; Feeney & Stiles, 1996). However such a task involves recognition rather than reconstruction and may reflect perceptual rather than representational abilities. Therefore, direct comparisons between drawing and choice tasks must be interpreted carefully.

The present study includes all three methods of responding to the same or very similar problems: direct copy of a figure using a marker, figures recreated using bars or discs, and a multiple choice judgment task. Even though previous studies have found little difference between the use of manipulatives and drawing in figure copying, the goal of the tasks in this study is not to copy the figure accurately but to make the figure in a correct orientation within a misleading context. An orientation task may be easier using moveable pieces which can be corrected than with a marker which cannot. Comparison of motor and non-motor responses in this type of task has not (to my knowledge) been done but could provide insight into the strength of the perceptual influences of the misleading context.

Factors Influencing Perceptual Analysis

Piaget's theory holds that perceptual analysis develops from an increased ability to consider and select from among the various frames of reference inherent in the context of a scene. Simply having achieved the stage of operations, however, does not fully explain the selections made; operational thinking only makes such activity possible. What constitutes a frame of reference or determines what catches a child's attention varies from task to task and from child to child. Not all details, relationships and frames of reference

are equal; some are more perceptually salient than others. But what determines saliency? An exhaustive list of the factors that may affect perceptual analysis is probably not possible, but the samples that follow give an indication of the complex nature of even seemingly simple tasks.

A visual object can never exist without a context, and typically the surrounding context is rich in information both relevant and irrelevant to the goal of a task. In Piaget's experiment with the line-up of plasticine balls the edge of the table had a strong influence on the task, facilitative if the goal was to make a parallel line but interfering if the line was to be oblique. Competing visual information can attract attention and be difficult to overcome in order to see the less attractive but task-relevant information. Bouaziz and Magnan (2007) found that children organized their copies of a complex figure one way when all parts of the figure were of the same line thickness, but organized them differently when one part had bolder lines. Even adults are susceptible to contextual interference as seen in the optical illusions and everyday errors of judgment.

Gestalt properties (e.g., closure, continuity) of a scene might bias perceptual understanding toward a certain organization. For example the effect of grouping by similarity has been found to have an effect on children's drawings of partial occlusions; when the two objects are identical more errors are made than when the objects are different (Morra, 2002; Morra, Angi, & Tomat, 1996). Other factors identified by Piaget (1969) include proximity in space with near items having more influence than far items and proximity in time with recent preceding tasks biasing the perception of subsequent tasks.

Habitual or learned ways of analysis influence how a child coordinates perception. Japanese and American children were found to differ in perception of a figure within a frame. When the task required synthesis of the figure within its context, Japanese children showed stronger performance, but when the task was to separate the figure from the context, the American children performed better (Duffy, Toriyama, Itakura, & Kitayama, 2007). Another example is the left to right bias in western cultures that comes from reading practice which has been found to contribute to an overestimation of the size of an object on the left, particularly at younger ages (Farkas & Elkind, 1974). Similar tasks show a right side bias when children in Israel were the participants (Elkind, 1975). On a child's version of the Stroop test it was found that children were slower to report the color (as opposed to naming the item) when the item was the very familiar Big Bird or Barney than a common apple; familiarity appeared to make inhibition of the identity more difficult (Prevor & Diamond, 2005).

When two figures are separated in space perceptual judgment is hindered even though both figures remain available to vision. Piaget (1969) found that when making size comparisons younger children overestimated the size of the first figure attended to, another instance of being centered on that which first attracts attention. As the distance between the two figures increases the effect becomes greater. Elkind tested this with children between the ages of 5 and 9 using pairs of unequal lines placed at varying distances of separation and, consistent with Piaget, found that with increasing age children were less affected by increased distance (Farkas & Elkind, 1974). Success on this task, in Piagetian terms, requires not only an ability to decenter and thus consider both lines equally, but also to make comparisons from the first to the second line and

back to the first line again. It was concluded that a young child's analysis does not include the second comparison, possibly due to limitations in attention.

The above are only samples of the myriad factors involved in perceptual analysis. To understand developmental changes in this ability we need to consider both the operational level of the child and the factors affecting perception that are inherent in the task. In Piagetian terms this would be the interaction between the figurative and the operative qualities of perception. In the present study the difficulty of the tasks used were designed based on some of these findings. For example stimulus items are made distant from the response frame, the closest frame of reference (in the sense of boundaries) is misleading, and the misleading frame is bold black lines against white background.

Field Dependence and Cognitive Style

In the literature on field dependence, the work of Witkin and the idea of cognitive style are far more commonly found than the developmental theory of Piaget. Witkin used the term field dependence-independence to describe the tendency of people to be influenced by the immediate context of a scene (field dependent) or to be able to overcome the context and make judgments based on other references (field independent) (Witkin et al., 1971/2002). Two tasks are commonly associated with this theoretical model, the Embedded Figures Test (Witkin et al., 1971/2002) and the Rod-and-Frame Test (Witkin & Asch, 1948). A data base search of field dependence in psychology will with rare exception find studies that use one of these tests. Witkin proposed a continuum of normal ability, characterized as cognitive style, ranging from field dependent to

independent as measured by these tests and that performance on these tests is related to a wide range of psychological constructs (McKenna, 1984).

The Rod-and-Frame Test was developed to assess a person's ability to overcome the strong visual cue of an off-center frame in order to judge the verticality of a rod placed inside. In the original test the subject sits in a dark room and sees an illuminated rod within an illuminated frame. Both rod and frame can rotate. In the test conditions the frame is rotated to 28° either to the right or left and the rod starts in an oblique position. The examiner moves the rod in increments of 3° until the subject believes the rod to be vertical. A modified version, one that is most commonly used in recent literature, is the Portable Rod-and-Frame Test which consists of a box that the subject must look into so that no visual cues are available and only the rod and frame can be seen. The premise of this test is that without any other visual referents available the subject must rely on gravitational cues to make a judgment of the rod's position independently of the visible misleading frame. A field dependent person would tend to rely more on the more salient and immediately available visible frame and therefore make poorer judgments than a field independent person who can overcome that visual effect and judge by gravitational cues.

The Embedded Figures Test measures field dependence in a different way. Participants look for a simple target shape hidden within a larger complex and cohesive configuration. Field independence is demonstrated by an ability to break up the organized, and therefore salient, configuration in order to separate out the target. Witkin et al., (1971/2002) reported that this test is comparable to the Rod-and-Frame, in each case the strong influence of the surrounding field affects how one part is perceived. Both

tasks were believed to reflect the level of field dependence of the participant. However, several researchers have noted that the two tests do not correlate highly enough to be considered measures of the same factor (Amador-Campos & Kirchner-Nebot, 1999; McKenna, 1984; Morra, 2002). Morra (2002) reported a general correlation of $r = -.40$ found in other studies (negative correlations because the higher scores on the Rod-and-Frame mean greater error), but in his own study with children the correlation was $r = -.30$ and Case and Globerson (1974) reported $r = -.33$.

The validity of the Embedded Figures Test as a specific measure of cognitive style has been challenged. Miyake, Witzki & Emerson (2001) used an embedded figures test with adult participants under dual-task conditions, a classic working memory research paradigm. Participants who were tested while concurrently engaged in a spatial task as well as those engaged in a concurrent executive task were significantly impaired in their performance, while those who were given secondary tasks that were of a verbal nature or a control task were not similarly disrupted in their performance on the test. The conclusion was that performance depended on the visual-spatial and executive components of working memory rather than cognitive style. Zhang (2004) compared measures on this test with a thinking styles inventory and found no significant relationship between them. The only task that was found to be related was the score on a geometry test suggesting that field independence as measured on the Embedded Figures Test represents perceptual ability rather than cognitive style. In a review of research, McKenna (1984) concluded that the test is more likely a measure of fluid intelligence than of cognitive style.

There is evidence that that field independence as measured by the Embedded Figures Test is a positive developmental achievement; a perceptual ability not a style. Scores on the children's version were found to reliably increase with age (Amador-Campos & Kirchner-Nebot, 1997) and were lower in mildly mentally retarded children even when matched for mental age with normal children (Alevriadou et al., 2004). Scores on the standard test for older children were found to be significantly lower in learning disabled high school students than non-learning disabled (Huang & Chao, 2000) and to be related to IQ scores in middle-schoolers (Flexer & Roberge, 1980). Even Witkin (Witkin et al., 1971/2002) noted the developmental change in ability on this test.

From a Piagetian viewpoint, field independence is not incompatible with measures of intelligence because the ability for perceptual analysis is dependent upon operational thinking. If the Embedded Figures is a measure of perceptual ability (Zhang, 2004), fluid intelligence (McKenna, 1984) and of developmental achievement, it could be a useful tool for investigating field dependence as it relates to perceptual development and valuable to the overall purpose of the present study.

Perhaps there are other reasons why the Embedded Figures does not show a strong relationship with the Rod-and-Frame. It may be that the different modalities, visual and postural, are not supported by identical underlying processes. While the Embedded Figures has been the subject of criticism in research in the psychology literature, the Rod-and-Frame seems to be more widely accepted as a measure of field dependence and of cognitive style (Tinajero, Paramo, Quiroga, & Rodriguez-Gonzalez, 2000). However, the requirement of making judgments based on postural cues could be questioned.

An assumption appears to be made in the design of the Rod-and-Frame that the availability of postural cues is constant across participants and therefore differences in performance would be accounted for by cognitive style. However evidence from physiological studies suggests that postural sensitivity might vary. The sense of upright comes from three highly integrated sources: visual cues, vestibular cues, and neck proprioception (Bagust, 2005). In the portable version all three are severely compromised because visual cues are eliminated except for the rod and frame and the stabilization of the head within the box would likely depress sensations from the inner ear and neck muscles which rely on movement for activation (Kandel et al., 1991). Therefore, it is unclear as to what people use to make judgments of upright in the portable test. Also, posture is not necessarily experienced in the same way by all people even under optimal conditions. For example there have been documented age- and sex-related differences in the integration of postural systems (Nolan, Grigorenko, & Thorstensson, 2005), and lower scores on the Rod-and-Frame were found to be related to simple neck pain (Bagust, 2005). The postural sense of vertical may be a source of variability that is not accounted for in the research on this test.

Is it necessary to eliminate all visual cues in order to create the perceptual conflict that is the essence of this test? Piaget's studies with children on similar tasks did not preclude environmental visual cues, only made them less accessible with distance and interference. The ability to overcome the more salient visual cues and instead choose a less salient but more accurate reference point, even with the lights on, is a very important ability to consider in the present investigation of children's perceptual activities. Perhaps

a vision-only rod-and-frame-like task would correlate more strongly with the visual Embedded Figures. This idea was investigated in a study involving kindergarteners.

Kindergarten Study

A modified rod and frame task was designed for a study (Coté & O'Donnell, 2007) which incorporates the challenge to field independence by the misleading context of a tilted frame as in the standard test, but one that is solved visually. A stimulus figure to be copied was printed at the top of a paper and participants drew the figure inside a tilted frame printed at the bottom of the paper. (These are similar to the tasks used in the present study which can be seen in Figure 5.) The goal for the participants was to make the figure in the same vertical and horizontal orientation as the stimulus figure. To be successful a frame of reference other than the immediately surrounding frame must be found and used to orient the figure correctly. It was assumed that a field dependent person would be strongly influenced by the nearby obvious tilted frames and consequently they would construct figures that deviated from true vertical. A field independent person would be able to find a different and more accurate reference and thus be able to correctly orient the drawing. Comparing drawings made in tilted frames to drawings made in true square frames provided an estimation of the effect of the misleading context. Two groups of participants were involved: kindergarteners who are just at the beginning of operational thinking which would enable some perceptual coordination; and an adult group who would provide an example of mature performance. It was found that the kindergarteners were more affected by the misleading frames than the adults. Adults, however, were also somewhat affected by the frames and significantly more so when the figure to be copied was a more complex dot configuration.

Ability on this new task was compared with scores on the Embedded Figures Test, the children's version was used with the kindergarteners and the group format with adult participants. The expectation was that a stronger correlation would be found than that which had been reported with the Rod-and-Frame because both the study task and the Embedded Figures are highly influenced by field effects and both require visual exploration for success. However, no significant relationship was found with either kindergarteners or with adults. These findings prompted a closer analysis of the assumptions underlying this study.

Performance on the copy tasks seemed to exemplify the influence of field effects in varying degrees on different individuals, yet performance on the disembedding task was not similarly affected. It may be that success on the Embedded Figures depends on abilities other than field independence. Short-term memory is involved in both the children's and adult's levels of the test because the shape to be found is not available to view during the search. Persistence may be another factor because there is no time limit for responding on the children's test and some children are quicker to give up than others. Case and Globerson (1974) reported a significant examiner effect possibly due to examiners use of different degrees of encouragement to "keep trying." A potential problem with the adult version is that it can be figured out strategically; a participant might be able to find one obvious segment that belongs to the target form then once that is penciled in it creates an anchor for finding the remaining lines. Participants can erase and can look back to check the match, seeing an error can help to illuminate the correct lines. It is not necessary to be able to see the entire hidden shape within the test figure in order to be successful. This may be why Zhang (2004) found that scores on this test

correlated most highly with geometry scores and others have found high correlations with intelligence measures in general.

The copy tasks designed for this study may also have been insufficient for measuring field dependence. The number of task items was limited and the reliability of these tasks is unknown. Also the age range of the participants was limited; a wider range of ages of children might reveal a stronger correlation. These concerns are addressed in the present study.

An interesting finding from the kindergarten study is that the complexity of the figures to be copied was related to extent of deviation of the constructions. This suggests that a working memory component may be an important factor in field independence. Instead of a person having a set level of field dependence, the degree of influence may vary with changing task demands. This idea is explored further in the present study.

The results of the kindergarten study suggested that the drawing task may be useful for demonstrating field dependence in visual perception. However, the lack of correlation with the standard measures did not provide the concurrent validity expected with these participants. Because the impact of field dependence on the Embedded Figures may be obscured by the other factors it will not be used as the standard measure of field independence in the present study. Instead the Block Design Test from the WISC III (Wechsler, 1991) which has also been considered a measure of field independence (Case & Globerson, 1974; Dempster, 1992; Morra, 2002) will serve as the standard measure.

Block Design Test

Several researchers have analyzed the Block Design Test in terms of the type of perceptual organization that is relevant to this study. The test consists of plastic blocks that have some sides that are a solid white or solid red and other sides that are bisected diagonally creating red and white triangles. The blocks are used to recreate a stimulus design (Figure 3). The challenge of this test is to shift conceptualization of the stimulus design from a square format to a solution based on diagonals (Lezak, Howieson, & Loring, 2004). Morra (2002) explains the appropriateness of this test for assessing field independence as it involves “misleading figurative field effects, because stimulus patterns are cohesive Gestalten that must be broken into constituent parts” (p. 424).

Akshoomoff and Stiles (1996) did a thorough analysis of the types of strategies children used for solving each of the stimulus patterns in the test. They found that the improvement with age was due to an increased use of an analytic strategy. A less successful approach is the synthetic strategy which is attempting to match block-by-block the pattern shapes. This would be comparable to a topological analysis in Piaget’s terminology. When the designs had a local structure, one that did not have a cohesive pattern spanning multiple blocks, the synthetic strategy could work for the younger children. However, when the pattern had a global configuration such as that shown in Figure 3, such a strategy resulted in block configurations that lost the overall square shape. Success was associated with an analytic strategy which involves mentally segmenting the cohesive designs into units corresponding to the available blocks.

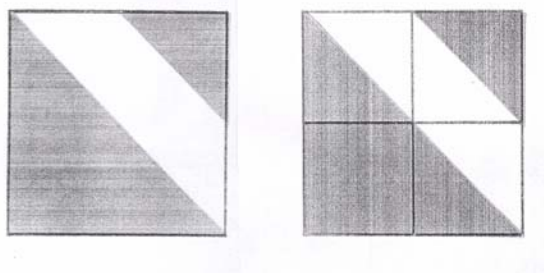


Figure 1. Example of block design pattern (right) and block solution (left) similar to those found in the Block Design Test.

The Block Design Test may have an advantage over the Embedded Figures Test for measuring field dependence in visual perception because it involves little else than perceptual analysis. There is no searching or memory component, and it is time limited so persistence is less of a factor than in the Children's Embedded Figures Test. It also has a range of task items that progress from simple to complex thus providing an estimate of level of performance whereas the Embedded Figures uses multiple items of a similar level of difficulty. It is generally recognized as a measure of visual-spatial organization (Lezak et al., 2004), and it has the benefit of it being a widely used and well researched tool that can be found in the files of most children who have been referred for learning assessment.

Working Memory in a Visual Analysis Task

What is changing in the child that allows for increasing ability to analyze and organize visual information? Several areas of research propose that quantitative changes in the form of increasing capacity for attention (Cowan et al., 2005; Kane & Engle, 2003), working memory (Gathercole, Pickering, Ambridge, & Wearing, 2004) or speed (Kail, 2000) are the fundamental elements. Piaget did not address development of

operational thinking directly in quantitative terms. “Piaget understood very well this idea of a mental capacity but did not like it. He could not see how a quantitative construct could possibly explain the many compelling qualitative differences found in mental processing (through development)” (Pascual-Leone, 1987, p. 533). However, quantitative explanations seem to be implied in Piaget’s writing. The major accomplishment in operations is the ability to consider and coordinate multiple frames of reference rather than isolated perception or simple one-to-one relationships, but the number of such relationships was not the focus of his work.

The term working memory is most often associated with a theory proposed by Baddeley and Hitch in the 1970’s (Baddeley, 2002). In their view working memory is a limited cognitive resource that is involved in the temporary maintenance and manipulation of information. Verbal information and visual-spatial information are believed to have separate capacities, each being quite limited, as evidenced by the observation that a person can more easily engage in two tasks if one is verbal and the other is visual than if the tasks are of the same type. This is a popular model and has provided the framework for many studies. Not all agree, however. Cowan (Cowan et al., 2005), for example, proposes a single attentional capacity rather than a dual component system. In all models and references to working memory an overriding characteristic is its marked limitation, a limitation that eases with development.

Research in working memory has historically focused mainly on the processing of verbal information with the visual-spatial component more poorly understood (Baddeley, 2002; Pickering, 2001). Some research coming from this information processing model aims to force visually based tasks into the verbally based research paradigms (e.g., Logie

& Pearson, 1997; Van Leijenhorst, Crone, & Van der Molen, 2007). For example, digit span is the classic measure of verbal working memory and researchers have created its equivalent in the visual-spatial area in the form of a memory task for patterns; with increasing age children can accurately remember the exact locations of an increasing number of items presented either simultaneously or in sequence (Gathercole et al., 2004; Logie & Pearson, 1997; Pagulayan, Busch, Medina, Bartok, & Krikorian, 2006; Pickering, 2001).

Short-Term Memory or Working Memory?

It is not very clear where the dividing line between short-term memory tasks and working memory tasks can be drawn. In general, short-term memory refers only to storage and is measured by retrieval tasks whereas working memory is storage plus manipulation of the information (Baddeley, 2002; Roberts & Pennington, 1996). The classic measure of verbal working memory, the backward digit span, is shorter in both children and adults than forward digit span because of the additional processing needed to keep the numbers in mind and reverse the order (Baddeley, 2002). A common visual-spatial task involves remembering the locations of filled in squares within a matrix. This is sometimes considered a measure of short-term memory (Miles, Morgan, Milne, & Morris, 1996) and other times of working memory capacity (de Ribaupierre & Bailleux, 2000; Kemps, de Rammeleare, & Desmet, 2000; Morra, 1994). The matrix pattern task has been used in several studies and consistently showed an increase from a span of about three locations at 5 years to a span of about eight at 9-11 years (Logie & Pearson, 1997; Pickering, Gathercole, Hall, & Lloyd, 2001). Although interestingly, that span was found to be halved when instead of a matrix pattern an appealing cartoon figure, Mr. Peanut,

had spot locations be recalled (de Ribaupierre & Bailleux, 1994; Kemps et al., 2000).

One explanation offered for this disparity was that the Mr. Peanut figure contained irrelevant but attractive information which the child must inhibit thus adding to the working memory load and compromising the memory span for the dots (de Ribaupierre & Bailleux, 2000). The Mr. Peanut finding suggests that perhaps a more useful way to think about visual-spatial working memory capacity is the quantity and complexity of the relations that go into the perceptual activity rather than simply memory for isolated locations.

Another commonly used measure of visual-spatial working memory (or memory, depending on the author) is the Corsi Block Tapping Test (Lezak et al., 2004) and it will be used in the present study as the standard measure of working memory. It was developed in the early 1970's as a spatial alternative to the digit span (Berch, Kirkorian, & Huha, 1998). The task uses nine blocks attached randomly to a board. An examiner taps out a sequence and the respondent must repeat the sequence in order, the highest number of blocks recalled correctly is the person's span. Interestingly, the length of span on the Corsi Block task in a backward recall format showed very little if any difference in length of span compared to forward recall (Vandierendonck, Kemps, Fastame, & Szmalec, 2004). This finding may suggest that the task is comparable to working memory tasks such as backward digit span. Still, some researchers characterize this task as short-term memory recall (Bayliss, Jarrold, Gunn, & Baddeley, 2003; Chuah & Maybery, 1999).

Most of the research studies on developmental measures of visual-spatial working memory reviewed used either the Corsi Block Tapping Test (or something very similar)

or a matrix pattern task for estimating capacity. In studies that used both matrix location and block tapping tasks with children across a range of ages it was found that the span on the block tapping was the lower one (Gathercole et al., 2004; Logie & Pearson, 1997; Pickering et al., 2001). Perhaps this reflects a greater processing demand on working memory for block tapping because it requires maintaining the pattern sequence in mind while generating a response and the attention to the tapping of the first blocks of a sequence may interfere with the storage of the later part of the sequence. Block tapping tasks have also been used as a measure of working memory in standardized intelligence tests including the Stanford-Binet and Wechsler Scales (Salvia & Ysseldyke, 1995). For these reasons the Corsi Block Tapping Test will be used in the present study as the measure of visual-spatial working memory capacity.

Working Memory and Inhibition in Field Dependence

Some theoretical models of working memory capacity include an inhibitory mechanism in accounting for the overall demands in a given task. The total cognitive load includes not only the number of details, relationships and references to be coordinated, but also the effort to overcome salient but irrelevant or misleading information while maintaining the goal of the task (Kane & Engle, 2003; Morra et al., 1996; Roberts & Pennington, 1996). Piaget also recognized the importance of inhibition in understanding a child's ability on a perceptual as well as other types of cognitive tasks (Dempster, 1992). The models connecting working memory and inhibition vary among researchers. For example they may be viewed as two separate but additive components within an overall capacity (Pascual-Leone, 1987) or as part of a single attention control capacity (Kane & Engle, 2003). However Roberts and Pennington (1996) present an

interactive model that is the most applicable to the purpose of the present study. They characterize working memory as the maintenance of information for the generation of upcoming action and inhibition of prepotent inappropriate responses as a separate area, both within an overall executive function. Working memory and inhibition interact such that if working memory is functioning optimally the need for inhibition is not great because correct responses will be actively generated. If, on the other hand, there is a lapse in working memory, the task overtaxes working memory, or the prepotent response is particularly strong, then the need for inhibition is greater.

The design of the present study aims to demonstrate the interaction of working memory and inhibition in a design copying task. It is proposed that the phenomenon of field dependence may be understood in these terms. Others have explored the relationship among working memory, inhibition and field dependence, but field dependence is usually viewed as a separate factor perhaps because it is accepted in this research as a cognitive style (Case & Globerson, 1974; Morra, 2002; Pascual-Leone, 1987). In a review of research on the relationship between field dependence and inhibition Dempster (1992) reports evidence that people who were identified as more field dependent were more susceptible to misleading visual cues than those who were more field independent even when performance on the task was identical when misleading cues were not present. DeLisi (1983) found field dependence measures to be related to children's performance on Piaget's water level task beyond what is accounted for by age, and Morra (2002) found field dependence to be an underlying factor in children's ability to draw partial occlusions. All consider field dependence to be a separate factor that a person brings to an analytic task. In contrast, the position taken in

the present study is that field dependence is not only related to working memory and inhibition, but can it be explained in these terms; and ability rather than a style.

Connecting working memory, inhibition and field independence is an approach to cognitive development most commonly associated with the neo-Piagetian theorists. This approach to investigating visual-spatial abilities is appealing and may be a way to bring Piaget's work up to date. They seek to explain the "Piagetian child" in quantitative terms (Pascual-Leone, 1987). Rather than changes in logicomathematical structures explaining growth, constraints on attentional capacity which lift with age is the general mechanism for change (Case, 1999). As mental capacity increases the child is able to coordinate more schemes and thus is able to succeed at more complex tasks and an important consideration is that included in the total load of schemes are schemes for inhibiting irrelevant information. The child not only has to deal with keeping various aspects of a scene in mind, he also must actively inhibit aspects which may call his attention but do not help with the goal of the task. This, I believe, is compatible with Piaget's explanations of developmental change in perceptual analysis.

The neo-Piagetians differ from Piaget in many ways and the contrast that is most germane to the present study is their characterization of field dependence as a cognitive style. They recognize that field independence develops with age along with improved task performance, yet they maintain the cognitive style position put forth by Witkin (Witkin et al., 1971/2002) rather than a developmental accounting. The fairly low correlations often found between measures of field dependence and other developmental tests have been interpreted as "consistent with the usual characterization of field independence as a style rather than an ability" (Morra, 2002, p. 430). Support for this

view is largely derived from factor analytic studies which found separate loadings for working memory measures and field dependence measures (Case & Globerson, 1974; Morra, 1994). The statistical procedures used in that research were later challenged by Pulos (1997) who recalculated the test measures and found evidence that the two factors may be more strongly related than reported and possibly have an underlying common factor such as speed of processing or executive processes which are generally considered part of working memory (Baddeley, 2002; Kail, 2000).

Research from the neo-Piagetian theoretical viewpoint aimed to quantify working memory capacity according to the number of schemes that a child can hold in attention at one time. Several studies made use of the recall tests (e.g., Mr. Peanut or Corsi Block Tapping) to give an estimate of a child's capacity. This was then used to predict performance on more complex tasks which could be analyzed according to the schemes involved (Kemps et al., 2000; Morra, 2002, 2005). Efforts were also made to reduce ability on certain visual tasks to algorithms in which all schemes are of equal weight and only the number of schemes that can be held in mind changes with age (Morra, 1994; Pascual-Leone & Baillargeon, 1994). However, in a more recent study Morra (2005) recognized that schemes do not necessarily tax working memory equally. He found, for example, that previous experience or having an available model improved children's ability on a complex drawing task even though the number of schemes would be considered to be the same. Therefore it seems to be an oversimplification to assess working memory in terms of absolute and measurable numbers of schemes. This research does however provide a very useful way to consider the working memory requirements for a certain task including the number of objects, relationships, and the

inhibition of interfering or misleading information. Their finding that capacity as measured by traditional working memory tests relates to success on visual analysis tasks is important to the rationale for the present study.

Summary of the Literature Review

Field dependence, or the influence of field effects on perception, is an important factor in understanding developmental changes in children's ability to analyze and construct figures. Although some view field dependence as a style that is related to but independent of ability, the premise of the present study is that field dependence is a phenomenon that results from a limited ability to coordinate multiple frames of reference while inhibiting misleading but salient influences. This is both a quantitative and a qualitative issue. The qualitative part is best describe in Piagetian terms as the ability to choose from among possible frames of reference to construct a coordinated response; an example of operative thinking. This can be seen in developmental changes in ability to perform a wide variety of tasks including part-whole analysis, figure copying and representing a Euclidean coordinate system of spatial relationships. The quantitative aspect involves the amount of information that can be held in working memory, including both relevant details and inhibition of irrelevant details, which allows for constructing a coordinated response.

The present study aims to connect the development of field independence with changes in working memory. This will be investigated in two ways. First the tasks designed for this study involve both changes in working memory demands by increasing the complexity of stimulus items with the simultaneous demands of inhibition of a misleading context. These tasks incorporate an interactive model of working memory

and inhibition (Roberts & Pennington, 1996) along with the classic field dependence assessment of orienting a figure within a tilted frame. Second, the classic memory for locations used in information processing research will be used as an independent measure of capacity.

Present Study

A series of tasks were created for this study based on findings from the research summarized above and from the findings of the kindergarten study. They have been designed to assess field independence in that successful performance requires the ability to overcome the misleading context of the frame surrounding the response area. Working memory becomes a factor as some of the figures to be copied are more complex than others; therefore a participant may be capable of inhibiting the misleading context when the figure is simple, but less able when attention is engaged in the organization of the figure itself. These tasks were shown to be successful at revealing the interaction of field independence and working memory in an earlier study using the tilted frames (Coté & O'Donnell, 2007). The present study expands on those tasks and adds a task which uses a different sized frame as the misleading context.

The tasks were carefully designed to address the goals of this study according to the following criteria:

The activities must maximize the challenge to field independence while minimizing other influences. All measures and activities in this study are entirely visual in nature thus avoiding a potential confound of the postural component used in the Rod-and-Frame Test. Stimulus figures are simple and easy to draw making the main challenge of the task to match the orientation or the size of the stimulus figure. An

obvious concern arises in that the motor control of the pencil is very unlikely to be perfect; lines may be drawn inaccurately simply because people, particularly children, do not draw accurately and the misleading frame might not be the source of error. Therefore control items using a facilitating frame (true square frame or same size frame) are included to serve as a baseline from which to judge the effects of the misleading context.

The activities involve a construction response rather than a judgment response.

Many visual-spatial tests require participants to make a judgment about a stimulus item, such as locating a shape in the Embedded Figures Test, or choosing from among potential answers. Although these provide some information about perception, they do not necessarily reveal the range of children's ability to act on a particular problem or how they perceive the task. Piaget (1969) noted that young children can sometimes see that a response is correct or not, but in the process of creating a response they have difficulty coordinating the various aspect of a task. In terms of working memory capacity, a construction task requires keeping in mind the perceptual judgment while simultaneously planning and executing the response. Construction tasks are also more ecologically relevant; classroom work, particularly in early grades, often involves paper and pencil responses.

Tasks can be modified to increase working memory load. An important goal of this study is to investigate how working memory capacity is related to field independence, not only as a related but separate measure, but also within the demands of the task itself. Keeping all other aspects constant, the complexity of the figure to be reconstructed can be manipulated to be more demanding of working memory in two ways: by using oblique lines and using figures with multiple parts.

Stimulus figures containing oblique lines are more difficult to create accurately. The oblique effect, our ability to more accurately discriminate vertical and horizontal than obliquely oriented stimuli, is well documented (Chen & Levi, 1996). Oblique lines might be more demanding because direct reference frames are not available, and, compounding the difficulty, the perpendicular reference lines that are present are misleading and so must be inhibited in order to infer the correct placement of the oblique. Oblique figures are used as stimulus items some developmental assessments and correct drawing of them has been shown to improve with age (Beery & Beery, 2004).

Figure complexity was also increased by using dot designs. These were inspired by Piaget's (1956) task of lining up plasticine balls which requires coordinating the dots with each other (topological analysis) as well as with the overall structure (Euclidian analysis). Both of these changes to the stimulus figures were found to impact participants' ability to correctly orient figures in the pilot study.

Study Tasks

Misleading Frames Tasks

Four Misleading Frames Tasks were created for this study. The first two use tilted frames as the misleading context with the goal for the participants to create a correctly oriented figure inside. One is a placement task in which bars or disks are used to recreate stimulus figures and the other is a drawing task that is very similar to the placement task but requires a drawn response. The third task is also a drawing task using different sized frames as the misleading context and the fourth is a non-motor judgment task using different sized frames.

Tilted-Frames Tasks: placement and drawing. The Tilted-Frames Tasks were inspired by both the Rod-and-Frame and the line judgment tasks used by Piaget (1969). Like the Rod-and-Frame participants must work within a frame that is tilted 28° which creates a salient but misleading perceptual cue. The challenge is for the participant to copy a simple figure inside the frame but attempt to make it true to the orientation of the figure in spite of the misleading context. The immediate visual cues of the frame must be overcome and a more accurate standard, such as the stimulus figure or the paper's edge, must be intentionally chosen and coordinated to guide the drawing. In the placement task (Figure 2) thin brass bars like Popsicle sticks that are the exact length of the lines in the stimulus figures are used for line construction and brass washers are used for the dot figures. These pieces can be adjusted within the frame until the participant is satisfied with the result thus avoiding the potential problem of motor control.

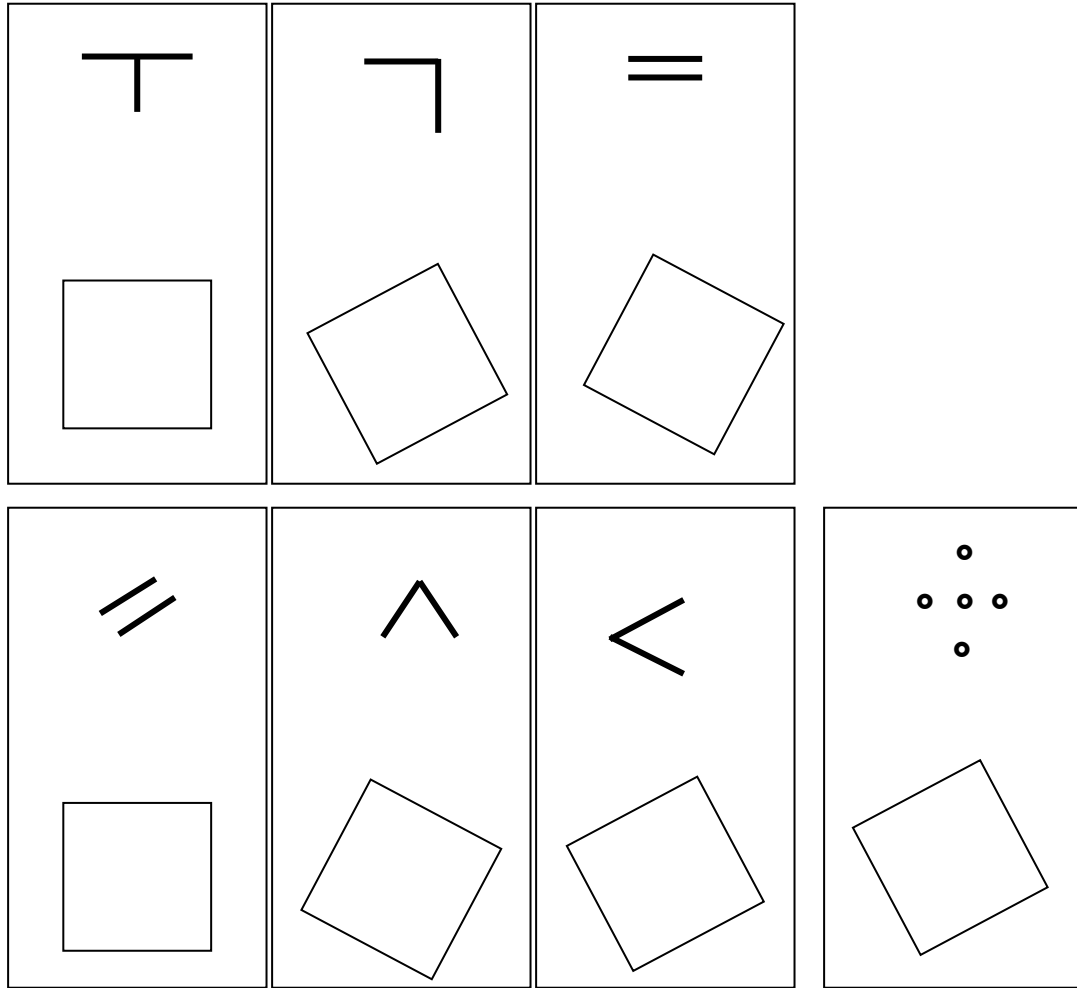


Figure 2. Items for Tilted-Frames placement tasks. Actual size 8 ½ x 14 inches.

The drawing tasks (Figure 3) are similar to the placement tasks except that the participants draw the figures within the tilted frames using a marker. Here no corrections can be made. Performance on this task can be compared to performance on the placement task to determine if pencil control or motor planning is a factor in ability to create accurate copies. Stimulus figures include three made of perpendicular (to the paper edges) lines, three made of oblique lines and two dot configurations.

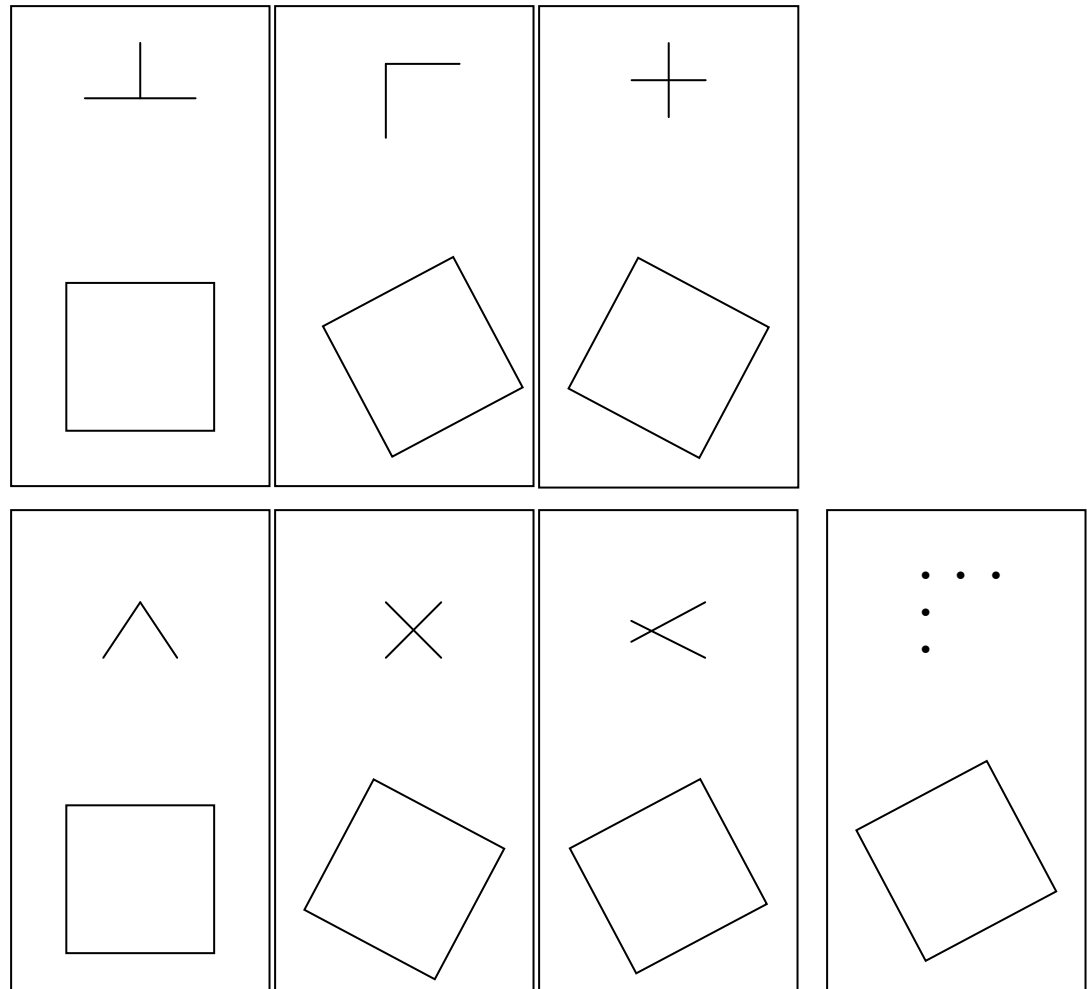


Figure 3. Items for Tilted-Frames drawing task. Actual size 8 ½ x 14 inches.

Frame-Size Task. This is a version of the Framed-Line Test used by Duffy et al. (2007). In this task (Figure 4) a different contextual cue, the size of the frame, provides the challenge for creating accurate copies of the perpendicular, oblique and dot figures. Here the response frames are all square to the edge of the paper but are either smaller than or larger than the stimulus figure's frame. The participant's task is to create a same size copy of the figure despite a different size frame, thus the context of the size must be inhibited and other references must be used to accurately construct the design. As with

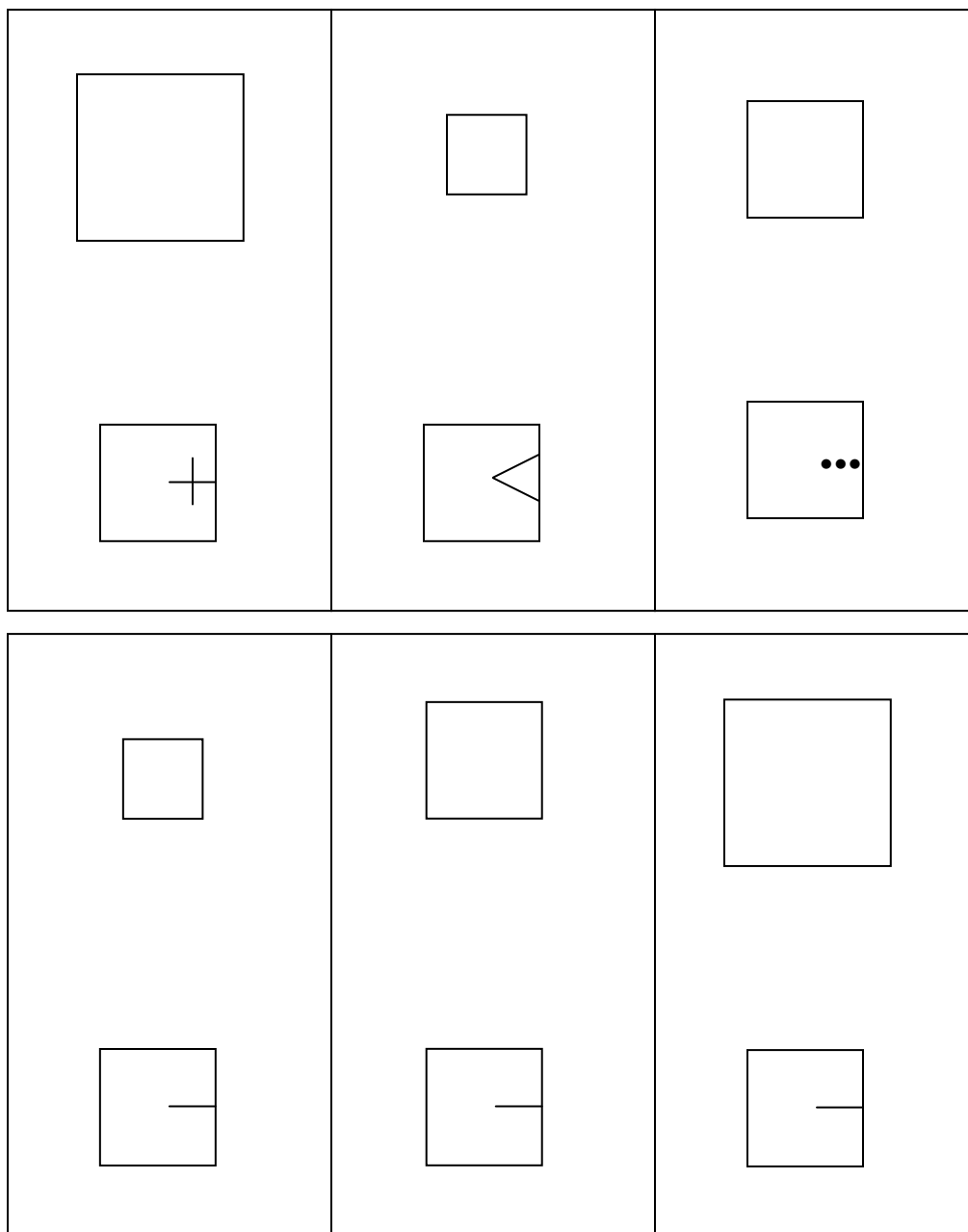


Figure 4. Items for Frame-Size Tasks. Actual size 14 x 8 ½ inches.

the previous two tasks the creation of the more complex figures is expected to detract from ability to overcome the reference of the frame.

Frame-Size Judgment Task. To estimate the effect of drawing ability as compared to perceptual judgment within the different size frames, four multiple choice tasks were created (Figure 5). Two items require the judgment of a line's size and two of a more complex figure's size. Four choices are available: correct, proportionally correct relative to the frame but not actually the same size, and two incorrect choices. Participants view the stimulus figure for about one second, then the stimulus is hidden and the choice is made.

Strategy Interview

A sampling of participants will be asked to explain how they organized the construction of figures within the tilted frames. The purpose of this inquiry is to reveal the strategies that children and adults may use, or perhaps their awareness or assumptions about their own strategic behavior. Of interest is whether children are aware of the difficulty posed by the tilted frames or if their perception is only on the figure itself.

Standard Assessments

Working memory capacity will be measured by the Corsi Block Tapping Test. This test consists of a board with nine randomly placed blocks, "random" in the sense of no particular pattern although faithfully constructed according to the original diagram. Many researchers have used this test and the exact procedures vary considerably

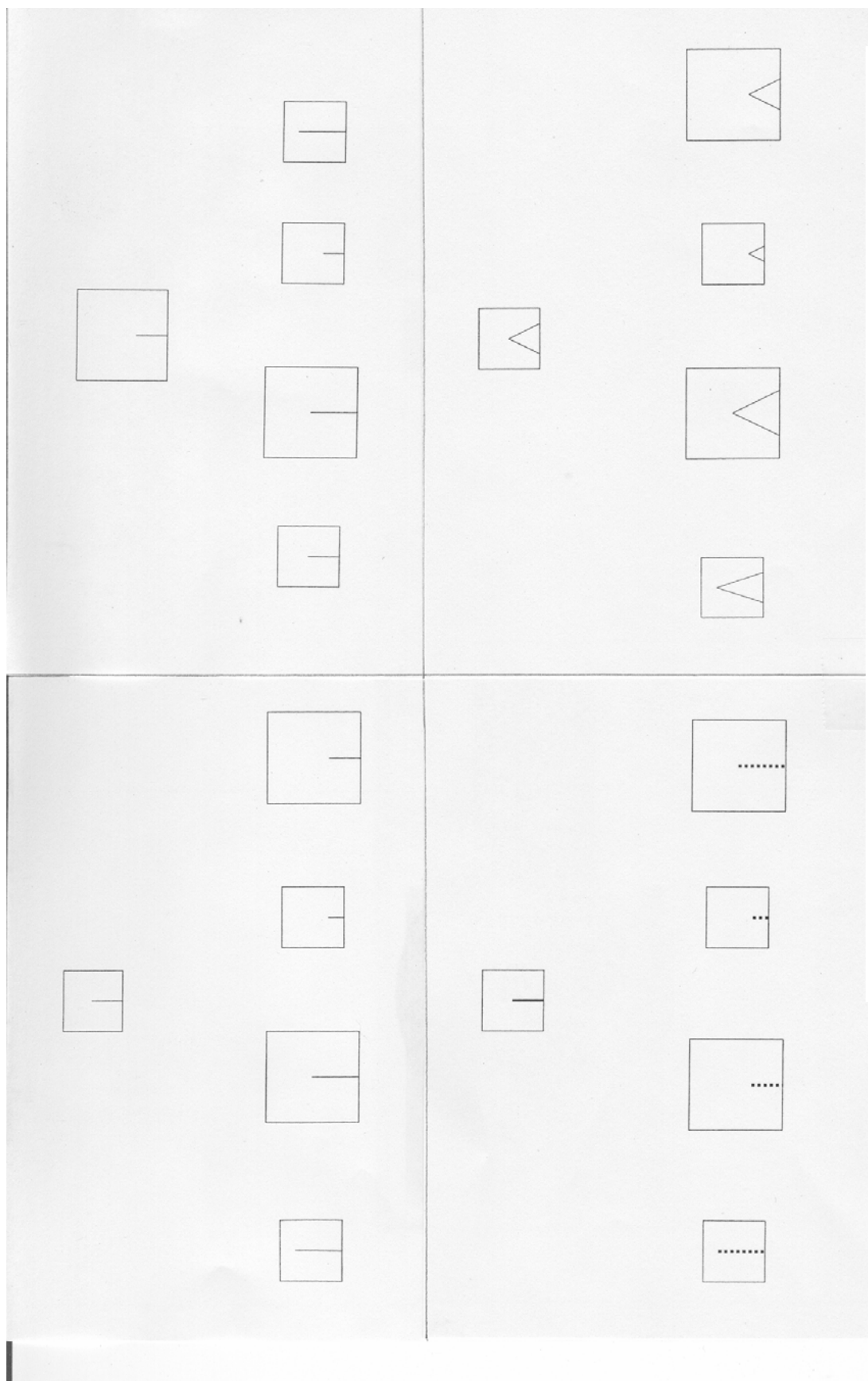


Figure 5. Items in the Frame-Size Choice Tasks. Actual size 8 ½ x 11.

(Berch et al., 1998). In this study the sequences used are those developed by Pagulayan et al. (2006) in a normative study with elementary school children.

The Misleading Frames Tasks are new and consequently no reliability or validity data exist. The Block Design Test from the WISC III (Wechsler, 1991) will be used to establish concurrent validity of the tasks as measures of field dependence. Scoring on this test is based on both accuracy and speed. Higher scores are attained by producing a correct response quickly. One modification to the scoring procedures was made for the purpose of this study: no penalty was given for block constructions that are more than 30° from the orientation of the stimulus figure. For the purpose of this study it is the participants' ability to correctly analyze the construction and not the precise position on the table that is of primary importance. Additionally, it is also not known whether the tables that will be available for working with participants will be consistent in size and shape, because this might affect the orientation of the block structure on the table it will not be considered in scoring.

Participants

Three groups of participants were recruited for this study. Children in elementary grades form the first group and are expected to be at a concrete operations level of cognitive development. This is an age when perception impacts school performance and assessment of visual analysis and visual motor skills is common. The second group includes learning disabled children who are expected to provide examples of lower level performance in order to test the theory that field dependence and working memory account for deficits in ability on the copy tasks. Finally a group of adults was included to provide examples of mature performance in order to evaluate developmental progression.

Hypotheses

The purpose of this study is to test the effectiveness of new tasks at demonstrating the influence of field dependence and to investigate the role of working memory capacity on field dependent behavior. Several hypotheses will be tested. For all analyses the significance level is set at $p = .05$.

On the Misleading Frames Tasks, figures created inside misleading frames will deviate significantly more than those created in the baseline conditions, thus demonstrating the effect of field dependence. The more complex figures (dots and oblique) will be significantly more deviant than the simpler perpendicular (line) figures, thus demonstrating the effect of increased working memory load on field dependence. It is expected that errors on the placement items will not differ significantly from errors on comparable drawing items because it is perception and not motor control that is the source of error. Finally, errors in the Tilted-Frame and Frame-Size tasks will significantly correlate because errors are related to level of field dependence in both tasks.

Validity of the Misleading Frames Tasks as measures of field dependence and working memory capacity will be demonstrated by correlations with standard measures of these constructs. It is expected that scores on Block Design and Misleading Frames tasks will be significantly correlated providing concurrent validity of the tasks as measures of field dependence. Scores on Corsi Block Tapping Test and Misleading Frames tasks will be significantly correlated thus demonstrating a working memory component to the level of field dependence for the participants.

Another goal of this study is to demonstrate that field independence is a developmental achievement. Therefore scores on Block Design, Corsi Block Tapping Test and measures on Misleading Frames tasks are expected to significantly correlate with age, and significant differences will be found in performance between learning disabled and non-disabled children.

METHODS

Participants

Three groups of participants were included in this study. The School group included 86 (47 male, 39 female) public school students in grades K through 5 (6 to 11 years old) who were enrolled in after-school programs in each of the four elementary schools in a suburban New Jersey school district. The LD group included 19 (15 male, 4 female, ages 7-2 to 13-2 years) learning-disabled children who were recruited from a pool of children that receive occupational therapy services for a documented disability in the area of visual-perception or visual-motor skill development. The Adult group included 39 (8 male, 31 female) undergraduate students who volunteered for this study in fulfillment of a course requirement. Figure 6 shows the distribution of participants by grade level. Approximately 90% of the school-age groups and 90% of the college students were white.

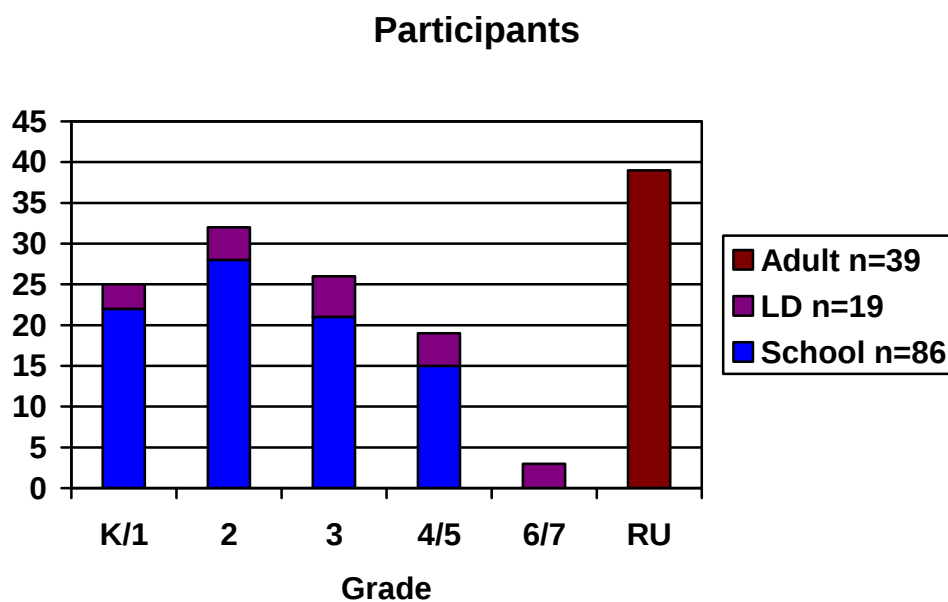


Figure 6. Number of participants at each grade level.

Participants were seen individually by the author. The after-school students worked at a table in the corner of the general purpose room where the program is run. The LD students were seen in their therapy room during one of their regularly scheduled therapy sessions. Adults were seen in a testing room at the university. All participants received the same set of tasks in the same order. Sessions lasted between 20 and 40 minutes depending largely on how far the participant could go on the two standard tests. Tasks were administered in the following sequence:

Misleading Frames Tasks

Tilted-Frames Task administration. A familiarization task was used to demonstrate the procedure for the Tilted-Frames Tasks. The examiner presented a sample task item along with two 2 ½” brass bars placed over the stimulus figure at the top of the paper and said, “See how these sticks match the lines of this design?” The bars were then moved to inside the tilted frame and the design was recreated. “I can use the sticks to make the same design inside this crooked box. Notice that I made it straight like the design, not crooked like the box.” Straight and crooked were both demonstrated. The participant was then given the bars and instructed “Now I want you to make this design nice and straight inside the box.” The examiner corrected if necessary until the participant understood the goal of the task.

The series of placement task items was given next (Figure 2). For each item a stimulus figure was printed on the top half of an 8 ½ x 14 inch page and the response frame printed on the bottom half. Response frames were tilted 28° either toward the right or left, or square for baseline items. Five items had a tilted response frame: two figures

with perpendicular lines, two with oblique lines and one perpendicular dot configuration. Two additional items served as baselines: one with a perpendicular figure and one with an oblique figure. The perpendicular baseline served as the baseline for the dot configuration also because they both have a perpendicular orientation. The stimulus figure serving as the baseline item was rotated among the three figures in each section generating three different protocols which were given in rotation to participants. Participants were given the two bars with instructions to use the bars to make the line figures inside the frame. Metal washers were provided for the dot figure. When the participant was satisfied with his or her response the examiner used a felt-tip marker to mark the ends of the bars or the center of the washers to record the construction.

The drawing task items followed next and participants were told that they now had to draw their responses using a marker. The stimulus items are slightly varied from the placement tasks to maintain interest and avoid practice.

Measures for Tilted-Frames Tasks. Measures for the Tilted-Frame Tasks are the deviations from true horizontal or vertical of the figures created by participants. A grid printed on a transparency and a protractor were used to measure deviations of the constructed lines using the nearest reference line (e.g., the paper's edge) as the standard. For the dot figures a line on the transparency was placed along the best estimate of the direction of a line formed by the row of dots. The oblique figures were measured by the deviation of a bisecting line through the vertex of the figure to assess its overall orientation. All measures were recorded in positive degrees following Tinajero et al. (2000). Within each method (placement or drawing) the two line constructions and two oblique constructions were averaged to create four composite scores. Dot figures

involved only one response in each method so no averaging was needed. Some children created figures that were very far off from correct either because they oriented the figure to the side of the frame that had the greatest tilt or because of no apparent orientation at all. In order to avoid the effect of very large errors on data analysis the deviation measures were capped at 28° , the angle of the tilted frame. Reliability for the measuring procedures was demonstrated in the Kindergarten study by a second reviewer, unaware of the purpose of the study, recording measurements that were about 90% consistent.

Strategy question. Following the drawing task, some participants were asked to explain their approach to the task. “That was pretty tricky, but you did a good job. How did you do it? How did you make the design straight when the box was crooked?” Responses were recorded in writing by the examiner. Shrugs and most “I don’t know” comments were not recorded because the purpose is to get a sampling of the insight into the effort or strategy employed by those who can verbalize an explanation.

Frame-Size Task administration. In a training task participants were shown a paper with two squares printed side by side, a large square on the left and small square on the right. A 3 cm line was printed inside both squares perpendicular to the bottom. Using a plastic stick the same length as the lines, the examiner demonstrated and explained that the two lines were exactly the same, even though the different size squares may make them look different. On a second trial item the lines inside the squares were not the same length. The participant was given the plastic measure to check the lengths. Finally two different size squares containing a line made of a row of three dots was shown and the participant was asked to decide if the two were the same in overall height.

The examiner said, “It’s a little tricky to tell if they’re the same because the boxes are different sizes.”

For the test items (Figure 4) the participants were told, “Now I want you to draw lines that are exact the same length as the one in the square.” A total of six task items were presented. The first three had lines to be copied and the other three had complex figures to be copied. Each set of three included one baseline in which the two squares were the same size. All stimulus figures were 3 cms in height and presented in the left side square. The figure that serves as the baseline for the complex figures was rotated generating three different protocols.

Measures for the Frame-Size Task. Measures were derived by subtracting the height of the line or figure drawn within the baseline (same size) frame from the heights of the lines and figures drawn in the misleading (large or small) frames. Measurements were made using a ruler and rounded to the nearest millimeter.

Frame-Size Choice. This is a multiple choice task in which participants judged which of four choices contained a figure that was the same size as the target. Four task items, two with lines and two with more complex figures, were printed on 8 ½ x 11 inch paper (Figure 5). All participants received the same items in the same order. A sample of a line choice was given first for the purpose of explaining the task. Participants were asked, “Which one of these lines (pointing to four choices) is exactly the same size as this (top figure).” The stimulus figure remained visible as the participant inspects and makes a choice. Corrections and further instruction were given as necessary. After the participant understood the task the test items were given with these instructions. “When I turn the page you will see a similar task. Your job is to find the line on the bottom that is

the same size as the line on the top. However, you will only see the top one for about a second then I will cover it up and you will make your choice.” The page was turned revealing the test item and a card was placed over the stimulus item after about a one second pause. Choices were recorded on a separate score sheet.

Standardized Tests

The Corsi Block Tapping Test was administered beginning with the 3-block sequences for children and the 4-block sequences for adults. Participants were instructed to watch the examiner and then point to the same blocks in the same sequence. The examiner pointed to a sequence of blocks at a rate of one block per second. If the participant was correct on at least two of the three items at a level, the next level which included one additional block was given. Participants were told how many blocks would be in each sequence and whether they were correct or not. A span score was calculated by averaging the last three items recalled correctly.

Finally, the Block Design Test was administered to all participants starting with Trial 2. No participants did the trial incorrectly so no further instruction was necessary. Administration was stopped when two consecutive items were incorrect or not completed within the time allotted. A stopwatch was used to record the time taken to complete each item.

RESULTS

Two main areas of analyses were conducted: participants' performance on the tasks designed for this study as measures of field dependence and working memory capacity, and comparison of these measures to measures on the standard tests of field dependence and working memory. Because the number of participants in each of the three groups differed greatly, direct comparison of group means would not be valid. Instead the LD participants' scores were evaluated in terms of frequency within quartiles of scores for all children and the means for the Adult group were compared to the means of a selection of the oldest 39 of the School group.

Misleading Frames Tasks

Tilted-Frames

All types of figures created within the tilted frames were significantly deviant from their respective baseline measures (Table 1). The effect sizes for the line and dot figures were strong, but for the oblique figures the effect size was low. When the Adult group was considered separately no difference was found between the baseline and tilted for the oblique figures (placement: paired-samples $t_{39} = 1.216$, $p = .23$; drawing $t_{39} = 1.45$, $p = .15$). It appears that the baseline square frame was nearly as misleading as the tilted frames for figures that included oblique lines. Because it cannot be stated with confidence that errors on the oblique figures were due to the misleading context of the frame, these measures will not be included in further analyses involving comparison of these tasks to other measures.

Table 1.

Means and SD of deviation errors for each type of figure in Tilted-Frames compared to Baseline measures.

	<u>Placement</u>			<u>Drawing</u>		
	Lines	Dots	Oblique	Lines	Dots	Oblique
Baseline	1.40	1.40	4.46	2.33	2.33	4.66
	(1.42)	(1.42)	(4.13)	(1.70)	(1.70)	(5.54)
Tilted	3.61	5.09	5.96	4.88	5.62	6.07
	(2.76)	(4.42)	(4.06)	(3.36)	(4.48)	(3.79)
<i>t</i>	10.13***	10.45***	3.09**	8.87***	8.71***	2.63**
<i>d^a</i>	1.56	2.60	0.36	1.50	1.94	0.25

^a Effect size *d* calculated using standard deviation of baseline measures

Paired-samples *t* : ** $p < .01$, *** $p < .001$, ($n = 144$).

Placement versus drawing. The deviation measures in the tilted frame items over the deviation measures in the baseline items for the three groups are shown in Figure 9. Comparing the total deviations in each of the two methods (placement and drawing) and the two types of figures (lines and dots) in a 2 x 2 within-subjects ANOVA, a significant main effect of the method was found with the School (not including LD) group ($F_{1,86} = 4.98$, $p = .03$), and the Adult group ($F_{1,39} = 40.90$, $p < .001$). The drawing method resulted in greater deviations for both groups. There was also a main effect of the type of figure for both groups, School ($F_{1,86} = 10.82$, $p < .001$), Adults ($F_{1,399} = 10.78$, $p = .002$),

with dot figures resulting in greater deviations. The LD group ($n = 19$) did not show a main effect for either method or figure.

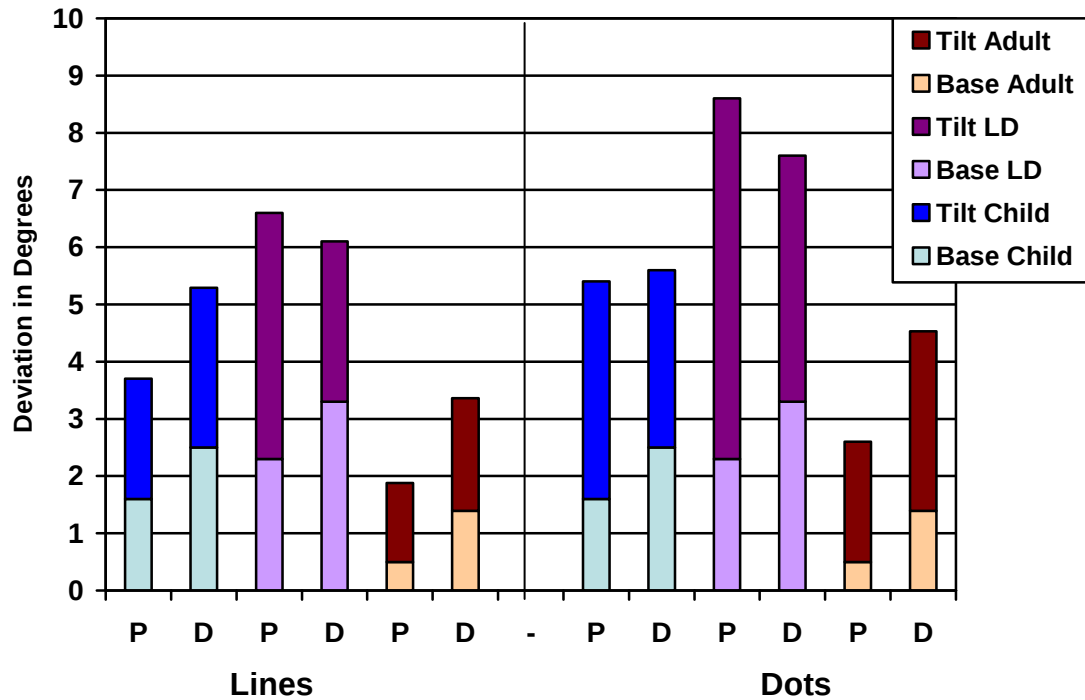


Figure 7. Mean errors on Misleading-Frames Task by method (P = placement, D = drawing) and participant group with baseline measures and tilted-frame measures differentiated.

Placement was more accurate than drawing on the baseline items (paired-samples $t_{144} = 6.225, p < .001$). Considering only deviation measures over and above the baselines of the tilted-frames, and thus removing the baseline error so that the effect of the tilted frame can be better isolated, a 2 x 2 ANOVA yielded a different pattern than when total deviations scores were used. Now the School group showed no main effect of method ($F_{1,86} = .012, p = .91$). Figure 7 illustrates the similarity of errors in both methods for the

School group when the baseline measures are taken into account. For the Adult group, the main effect of method remained significant ($F_{1,39} = 7.49, p = .009$). An interaction effect was found with the School group ($p = .04$) with the placement of dots showing greater error.

Age and group differences. No sex differences were found in any of the misleading tasks with the children's group, therefore all comparisons are pooled. The Adult group had too few males to make sex comparisons. To make between-subject comparisons, a total error score on the tilted-frames was calculated by summing a participant's deviation measures of line and dot figures constructed in both placement and drawing conditions (baselines and oblique figures were not included). Accuracy of orientation of constructions improved with age. This was only a trend within the School group with correlation between age and total errors just missing significance ($r = -.21, p = .06$). A significant difference was found between the oldest participants in the School group and Adult participants ($t_{39} = 3.50, p < .001$). The LD group made greater total errors than the School group on both the baseline and tilted-frames tasks as shown in Figure 7. With all children considered ($n = 105$) and ranked according to total errors on tilted-frames, this group was significantly more likely to be in the last quartile (Table 2).

When specific Tilted-Frame items were considered, the dot placement task did show a significant correlation with age for the School group ($r = -.32, p = .002$). In this task the oldest quartile (9-4 years to 10-10 years) differed significantly from the younger quartile (6-7 years to 7-7 years), ($t_{22} = 2.53, p = .02$). The two middle age quartiles did not differ significantly ($p = .08$).

Table 2.

LD participants ($n = 19$)/total of all children ($n = 105$) for scores on each measure by quartiles. 1st quartile = highest performance.

	1 st	2 nd	3 rd	4 th
Tilted-Frame ^a	2/26	2/27	3/26	12/26
Frame-Size ^b	2/26	2/27	5/26	10/26
Corsi Block Tapping ^c	4/26	3/26	5/27	7/26
Block Design ^d	2/26	3/26	2/26	11/26

^a $\chi^2 = 16.46, p < .005$; ^b $\chi^2 = 8.99, p = .05$; ^c $\chi^2 = 1.84, ns$; ^d $\chi^2 = 12.67, p = .01$.

Frame-Size Task

The size of the response frames influenced the size of drawings made by School group participants across all items (lines and figures), but Adults made significantly smaller figures in small frames only. Measures from each group and each task are listed in Table 3. Overall, no difference in the height measures was found between the lines and figures in either the large frames (paired-samples $t_{144} = .18, p = .86$) or in the small frames ($t_{144} = -.13, p = .90$).

Table 3.

Frame-Size Task: Means of the differences in height of drawings made in misleading frames from baseline measures.

	Large - line	Small - line	Large - figure	Small - figure
School ($n = 86$)	-.27 ^{***}	.24 ^{***}	-.27 ^{***}	.27 ^{***}
LD ($n = 19$)	-.43 [*]	.40 [*]	-.47 [*]	.28
Adult ($n = 39$)	-.01	.20 ^{***}	-.05	.22 ^{**}

Paired-samples t : ^{*} $p = .05$ ^{**} $p = .01$ ^{***} $p = .001$

Age and group differences. A significant difference in accuracy was found between the mean scores of the oldest of the School group and Adult participants ($t_{39} = 3.11$, $p = .003$). A non-significant age trend was found within the School group ($r = -.18$, $p = .10$). The children in the LD group had total scores that were more likely to be in the last quartile of all children's scores than in the other quartiles (Table 2).

Frame-Size Choice. Group totals for the four choice tasks (two line items combined and two figure items combined) are presented in Table 4. Fewer errors were made on the figure choices than on the line choices; $\chi^2(1, n = 144) = 12.12$, $p < .005$. When errors were made it was more often the error of choosing the line or shape that was proportional to the frame, this was close to significant for the line choices, $\chi^2(1, n = 144) = 5.75$, and significant for the shape choices, $\chi^2 = 19.63$, $p < .005$.

Table 4.

Percentage of responses in the four options on the Frame-Size Choice tasks.

	<u>Line Judgment</u>			<u>Figure Judgment</u>		
	Correct	Relative	Error (2) ^a	Correct	Relative	Error (2) ^a
School ($n = 86$)	76%	13%	5%/6%	90%	7%	1%/2%
LD ($n = 19$)	50%	13%	18%/19%	71%	16%	6%/7%
Adult ($n = 39$)	90%	5%	2%/3%	92%	6%	1%/1%
Total Counts	220	32	18/18	255	23	5/5

^a Two items combined and then split for equal comparison.

Standard Measures: Block Design and Corsi Block Tapping Test

Figure 8 shows the boxplots for scores on the Block Tapping Test (Span) for each group with the School group divided into a youngest half and oldest half. The LD group scores were comparable to the younger half of School group; however the frequency of LD children in the lower quartiles of all children was non-significant (Table 2). The correlation between age and Span for the School group was significant ($r = .37, p = .01, n = 86$) and the adults were significantly better at this task than the oldest children ($t_{39} = 4.34, p < .001$).

The Block Design Test (Design) scores are shown in Figure 9. The correlation of scores with age for the School group was fairly strong ($r = .54, p < .001, n = 86$) and the Adult group had significantly higher scores than the oldest children ($t_{39} = 6.86, p < .001$).

Children in the LD group were significantly more likely to be in the lowest quartile of the all children's scores (Table 2).

Design, Span and New Task Measures

Table 5 shows the correlations among the Span, Design, Tilted-Frames and Frame-Size scores for all participants. The total score for the Tilted-Frames was calculated by adding all error measures on the tilted-frame items (placement and drawing) for each participant to generate an overall score. For the Frame-Size task the error measures from the two line tasks were squared, summed and the square root was taken to give a total for lines. This was necessary because of the negative scores involved. The same procedure was used for the figures, and then both of those totals were summed for an overall total for Frame-Size. Design was more strongly related to both the Tilted-Frames and the Frame-Size totals than was Span and it remained significant when age was controlled. On the separate measures of the types of items in Tilted-Frames Task, the strongest correlation with Block Design was with the dot placement item. This was true of both the Adult group ($r = -.40, p = .05, n = 39$) and the School plus LD groups ($r = -.28, p = .01, n = 105$).

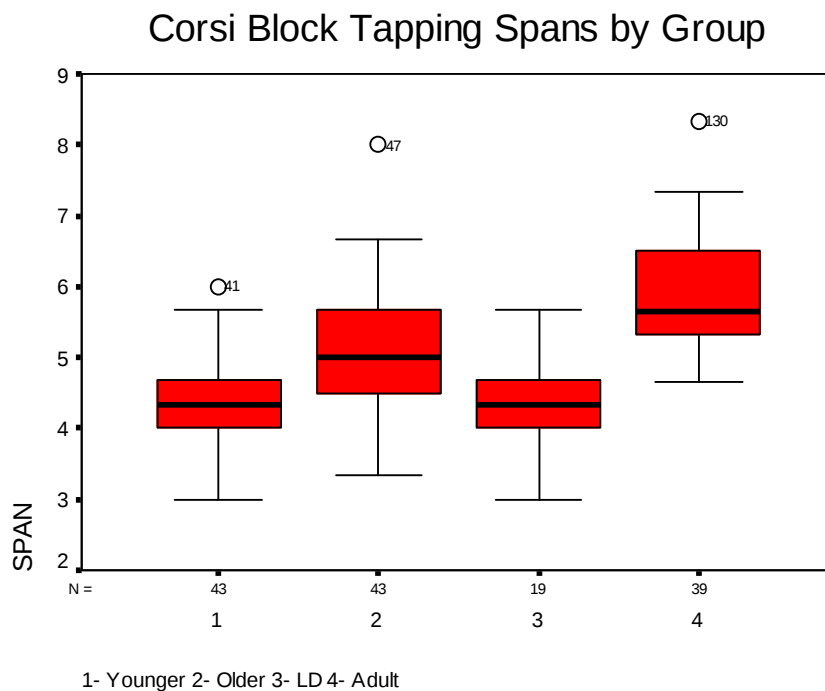


Figure 8. Corsi Block Tapping Test scores (Span) for all participants.

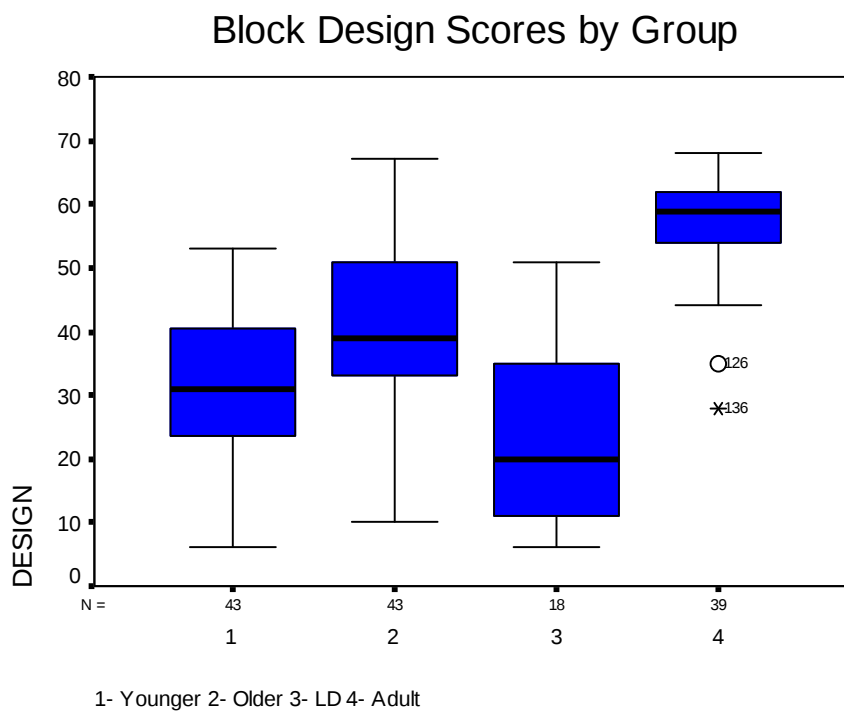


Figure 9. Block Design scores (Design) for all participants.

Table 5:

Correlations among standard tests and total errors on tasks. Below the diagonal age is partialled out.

	Span	Design	Total Size	Total Tilted
Span	--	.64 ^{***}	-.40 ^{***}	-.35 ^{***}
Design	.44 ^{***}	--	-.48 ^{***}	-.52 ^{***}
Total Size	-.25 ^{**}	-.33 ^{***}	--	.38 ^{***}
Total Tilted	-.16	-.35 ^{***}	.27 ^{**}	--

** $p = .01$, *** $p = .001$, $n = 144$

Awareness of Strategy Use

The sample of participants that were asked to explain how they constructed their responses in the Tilted-Frames Task yielded 38 responses given by children and 16 responses from adults. Four categories of responses emerged: two categories indicating lack of awareness of error or of the need for a strategy, and two categories indicating awareness. Children made comments that fit into all four categories but adults' comments fit only in the two awareness categories.

Category 1: Don't Know

Because the purpose of this questioning was to sample the range of insights present with these participants and not to perform statistical analyses, only three "I don't know" comments were recorded and shrugs indicating an inability to comment were not recorded. Had all responses been recorded this would have been by far the most common

among the children. Whether these children truly did not know or they were only unable to verbalize their thinking was difficult to discern. There were some children who clearly used some tactic (e.g., getting eyes down to table level to line up figures) but when asked to comment responded with only a shrug. Examples of this category are: “I don’t know.” (6-11 y. o. female); “Just did it.” (9-4 y. o. male); “I looked at it.” (8-9 y. o. female); “Looked and tried to copy as well as I can.” (8-11 y. o. male).

Category 2: Personal Qualities

The second category that emerged with the children included comments reflecting personal attributes as the explanation for success, but no accounting for how the task was done. Some of these comments may have been unintentionally prompted by the examiner stating “You did a good job.” Some examples from this category are: “Just good at it” (10-5 y. o. female); “My brain tells me the answers (8-6 y. o. male); “I’m good at drawing straight lines” (10-7 y. o. male); “I like drawing so I do stuff really straight” (8-2 y. o. female); “I draw a lot so I know how” (7-8 y. o. male).

Category 3: Awareness of the Need for a Strategy

The previous two categories consist of comments that did not indicate awareness that the tasks were difficult or that the productions may have been imperfect. In this category the comments indicated awareness that some extra effort was required but specific strategies were not offered. Some examples from this category are: “Just made them. It would be easier with a ruler.” (8-0 y. o. male); “Hard because you focus on the box you see and focus on the design.” (7-8 y. o. female); “Kept looking at it directly at the same time (as drawing).” (10-0 y. o. female); “By not looking back and forth – easier

if I concentrate on drawing.” (adult female); “Tried to recall the design exactly.” (adult female).

Category 4: Explain a Strategy

The final category includes comments that described a strategy. Two types of strategies were noted: inhibiting the misleading frame and finding an appropriate frame of reference. Examples of strategies for inhibition are: “Got used to the crooked square, just imagined the crooked square not there.” (8-6 y. o. male); “I tried not to care.” (9-7 y. o. female); “Tried to remove the box . . . tried to rotate the box.” (adult female); “Tried not to look at the box, it was throwing me off.” (adult female). Examples of strategies for finding an external frame of reference are: “Looked at the shape and lined it up.” (9-5 y. o. female); “Used points.” (10-5 y. o. male); “Made it relative to places in the room or toward myself.” (adult female); “Followed parallel of drawing figure – looked at the angle in the figure and try to match it.” (adult male).

Overall adults were much more forthcoming in their explanations than the children and they provided insight into the tasks that confirmed the assumptions of this study: that the immediate context of the frame exerted influence on their productions, that inhibition was effortful and external frames of reference were required for success. Seven children from this sample also commented on using these strategies. They fell into the older half of the group and they were in the lower (more accurate) half of deviation scores on the Tilted-Frames Task. It was noted however that some children who did not verbalize awareness were also in the older group and performed quite well on the tasks. No conclusions can be drawn about the relationship of comments to performance due to the limited sample.

DISCUSSION

The purpose of this study was to investigate the influence of field dependence on a design copy task and to test the theory that this influence has a quantitative explanation. Results were mixed with some hypotheses supported, particularly the effectiveness of the tasks at demonstrating a relationship between stimulus complexity and field dependence, while others were not supported.

Misleading Frames Tasks

The tasks used in this study were designed to investigate the influence of field dependence in ways that extend the measures commonly found in previous research. Participants were required to construct a response rather than make a judgment or choice. It was argued that constructing a response challenges a person's ability to analyze the task and generate a response which requires coordination of multiple frames of reference. This coordination taxes working memory leaving diminished resources for inhibiting the influence of a misleading context. In this way working memory may be an underlying factor in a field dependence task. To further investigate a working memory explanation the stimulus figures in the task were of varying degrees of complexity. A complex figure would require even more cognitive resources and the effect of field dependence would be more pronounced. The results of this study supported this idea.

Field Dependence and the Misleading Frames Tasks

Field dependence in perception was described by Witkin et al. (1971/2002), as the tendency to be influenced by the immediate context of a target item, a characteristic that decreases with development. Similarly, Piaget (1969) described decentration as an ability to consider a target as not only part of its immediate or most salient surroundings,

but also in relation to more distant or otherwise less salient frames of reference. The results of the Misleading Frames Tasks designed for this study seem to fit well into these definitions. Two of the stated hypotheses regarding the ability of the tasks to demonstrate field dependence were supported: the immediate context of a misleading frame influenced perception of both orientation and size during construction of the figures for participants at all ages, and the influence decreased with the age of the participants. Thus there is support for these tasks as a useful and different way to document field dependence in a perceptual task.

Concurrent validity of the new tasks as measures of field dependence comes from the correlation with the Block Design Test, a recognized standard test of perceptual analysis that has been considered to be a measure of field dependence (Case & Globerson, 1974; Dempster, 1992; Morra, 2002). In contrast to the kindergarten study (Coté & O'Donnell, 2007) which used the Embedded Figures Test as the standard and which showed no relationship to the tasks, the Block Design scores were significantly correlated with the new tasks in the present study. This was expected because the Block Design does not involve some of the complications which made the Embedded Figures Test questionable; instead it may be a more direct measure of field independence in perceptual analysis. Although the correlations were significant, they were not very strong. With age partialled out only 11% of the variation on the tasks was accounted for by scores on Block Design.

The Misleading-Frames Tasks and Block Design appear to share some underlying factors, but may be quite different in other ways. Block Design requires the breaking apart of a cohesive design along non-salient partitions (e.g., in the middle of a diagonal).

Similarly the Misleading Frames requires finding references that are less salient than the immediate context. Block Design, however, is a puzzle in which the pieces can be rearranged until the design is figured out and the participant can easily see whether he or she has succeeded. In contrast, the Misleading Frames is a one-shot construction that continues to be influenced by the misleading context even after completion; consequently it cannot be definitively solved. Another area of difference might be in the range of difficulty; the Block Design is sequenced to be increasingly difficult so that a participant reaches his or her ceiling whereas the Misleading Frames essentially involves only two levels, lines and figures. Perhaps these did not exhaust the ability of many participants. Additional items with greater degrees of complexity of construction may show a stronger relationship with the Block Design Test.

Working Memory and Inhibition in the Misleading Frames Tasks

The interaction between working memory and inhibition was proposed as an explanation for field dependent responses and an important factor in the study tasks. When working memory had greater demands, as in organizing more complex figures, it would be harder for participants to inhibit the misleading frames resulting in greater error in their constructions. Support for this was mixed therefore the different types of tasks will be discussed separately.

Tilted-Frames Tasks

The results of the Tilted-Frames Tasks provided evidence of an interaction between inhibition and working memory. In the presence of the same interfering information, constructing a configuration out of dots resulted in greater error compared to constructing a vertical or horizontal line. It may be that the effort of coordinating the

placement of the dots or washers made it more difficult either to inhibit the misleading frame or to keep a correct reference in mind; or both. Other characteristics of these tasks might also account for the difference in performance. For example the amount of time involved in the production of a multipart dot figure is greater than that of a line figure, therefore references for organization or inhibition of the misleading frame might decay with time. This would not necessarily contradict a working memory theory because speed of processing is recognized as a critical aspect of working memory capacity (Kail, 2000). Also, orienting a dot figure may be more difficult regardless of the surrounding context. A limitation of this study is that there was no baseline measure specifically for a dot configuration; the baseline for perpendicular lines was used on the assumption that a perpendicular line made of dots would be the same.

The findings from this part of the study support the interactive framework of working memory and inhibition proposed by Roberts and Pennington (1996). The working memory demands of the task were to hold in mind the instructions and the image of the stimulus figure, find and hold an appropriate frame of reference, and generate a response. Inhibition was required to overcome the perceptual influence of the tilted frame. The more complex figure (dots) increased the working memory load and inhibition was compromised. In their research on the interactive model, Roberts and Pennington examined tasks that involved a prepotent response to be inhibited such as is needed in a Stroop test or A-not-B error test. The familiar or habitual response must be inhibited in favor of a new and less familiar response; inhibition is thus required at the time of generating the action. In the Tilted-Frames Task the inhibition must be ongoing through the duration of action. Some adult participants commented that they were able to

plan the correct action but once engaged in the copy task the tilted frame made the execution surprisingly difficult. The Misleading-Frames Tasks may add to the interactive model by demonstrating inhibition demands that are not only called upon at the time of action generation but also in monitoring ongoing actions.

Oblique figures were included in this study as another way to challenge working memory capacity. It was expected that these figures would present a greater challenge to working memory because of the lack of available references. To be successful a participant would need to infer correct placement based on an estimation of the stimulus figure's orientation. However, this proved to be too difficult for participants at all ages. The errors on the baseline items for oblique figures were comparable to the errors on the tilted-frame items for perpendicular line constructions. It appears that a true square frame is actually a misleading context for these figures because it does not give a usable reference and must instead be inhibited just as the tilted frames were inhibited on the other items. A more useful baseline condition might be to use no frame at all. The task items that required constructing oblique figures in a tilted frame compounded the problem, which was the intention of the exercise, but the difference between the baseline and tilted frames was not large enough to assume an effect of the tilted frame. The line and dot figures did demonstrate the effects of both misleading context and increased complexity. Therefore only these tasks were used in further analysis in this study.

Frame-Size Tasks

When size of the frame, rather than its tilt, provided the misleading context the complexity of the figures was not associated with greater errors. Because of this finding a closer analysis of possible differences in the task requirements is warranted. Judging

the height of a figure within a frame may be a direct perceptual task that does not interact with the figure to be copied. In contrast to the ongoing influence of a tilted frame during construction, once the judgment of a starting point for the height of a figure is made the rest of the drawing is independent of the influence of the frame's size. Indeed, the most common procedure observed was for a participant to start the drawing, whether a line or figure, at the point estimated to be the top and then complete it to join with the bottom of the frame. Scores on the Frame-Size items had only a low, although significant, correlation with scores on the Tilted-Frame items (.27 with age controlled). Therefore the hypothesis that these would be related was not well supported. The different demands on inhibition, only at the onset for the Frame-Size and through the duration of the construction for Tilted-Frames, may have been a factor in this inconsistency.

Frame-Size Choice

A somewhat surprising finding was that on the Frame-Size Choice task the complex figures were more likely to be judged correctly than the simple lines. This may be because the figures presented a cohesive form and were perceived separately from the frame whereas the lines may have been perceived as incorporated into the frame and therefore more difficult to see in isolation. Support for this interpretation comes from a finding that children have a more accurate perception of a line's angle when it is perceived as part of a form rather than as emanating from a base line (Davis, DeBruyn, & Boyles, 2005).

Corsi Block Tapping and Tilted-Frames Tasks

While construction of simple line figures were on average more accurately aligned inside tilted frames than the more complex dot configurations, a finding

consistent with a working memory capacity explanation, the attempt to establish concurrent validity with a recognized measure of visual-spatial working memory was not successful. This suggests that either the Corsi Block Tapping Test is not an appropriate measure of the demands on visual-spatial working memory involved in perceptual analysis, or that performance on the tasks was not related to working memory capacity for these participants. Both will be considered.

The difference between a short-term memory task and a working memory task may be a critical issue for this part of the study. Simple recall tasks have been poor predictors of performance on complex cognitive tasks, but when the same recall tasks involve delays prior to recall and interfering information that must be inhibited during that delay, the relationship between recall and other complex tasks increases (Dempster, 1992; Kane & Engle, 2003). Therefore, the ability to manage interference may be important to the concept of working memory in the area of perceptual analysis. An argument was made in the introduction that the Corsi Block Tapping Test might fit the definition of working memory as the maintenance and manipulation of information (Baddeley, 2002) or the holding of information while generating an upcoming action (Roberts & Pennington, 1996) because the task requires a participant hold the sequence plus locations in mind while generating and executing the movements of a response. This seemed closer to the definition of working memory than other tasks such as remembering locations on a matrix that are also frequently cited in previous research (e.g., Logie & Pearson, 1997; Morra, 1994; Morra, 2002). Although this test has been described as a visual-spatial working memory test (Gathercole et al., 2004; Vandierendonck et al., 2004), others characterize it as a short-term spatial memory test

(Berch et al., 1998; Lezak et al., 2004; Pagulayan et al., 2006) . In reconsidering this choice of a standard working memory measure, perhaps the missing inhibition component makes this closer to a simple recall task and so may not be related to the complex analysis involved in the Misleading-Frames Tasks.

Another possibility is that there may actually be a quantitative component shared by the Corsi Block Tapping and the Tilted-Frames, but it was not borne out in this study. The spans for the children in this study had a very limited range of between 4 and 5.66 falling within one standard deviation (illustrated in Figure 8). These results are consistent with average spans in this age range (Pagulayan et al., 2006). Although there was a significant age trend in spans, the difference between the first and fourth graders was only about one block. Therefore this measure may not be sensitive to minor individual differences within a particular age group. Alternatively, the Tilted-Frames may not have sufficiently challenged the limits of working memory capacity with the limited items given. The Block Design and Corsi Block Tapping were fairly strongly correlated even with age controlled; about 20% of the variance in the Design scores was shared with the variance in the Span scores. Yet this relationship was not evident with the new tasks as measures of perceptual analysis. Again, the relationship might be stronger if the Tilted-Frames had more challenging items which could capture the upper limits of a participant's ability.

Developmental Level of Performance

It was predicted that performance on all tasks would improve with the age of the participant. In general this was true when the adults were included in the analyses, but of greater interest here is the change from first grade to fourth/fifth grade children. The only

measure that correlated fairly strongly with the age of School group was the Block Design Test. Both Tilted-Frames and Frame-Size tasks showed only non-significant age trends. It was only when the oldest of the children were compared to the adults that significant differences are found in errors on these tasks. This pattern fits well into the Piagetian stages of concrete operations for the children and formal operations for the adults.

Development through the concrete operations stage was described by Piaget as very slow, with the ability to consider multiple frames of reference beginning around age 5 and efficiency of coordinating frames of reference occurring at around age 9 and often older (Piaget & Inhelder, 1956). In the present study only a small number of participants in the School group were 10 years or older (about 15%), therefore the lack of a significant age trend in the new tasks may reflect the slow development over this age range. One task item, the dot placement, did show a significant difference between the 9 to 10-year-olds and the 6- to 7-year-olds. This item required arranging five metal washers into a configuration to match a stimulus figure; a task similar to the one used by Piaget to investigate inhibition and coordination of reference frames, the lining up of plasticine balls, and may serve as a good illustration of the differences in performance in terms of both operational thinking and working memory capacity.

During the dot placement task some children were observed to initially place the washers in a fairly well oriented manner, but then adjust their placements in order to make the actual design look more like the stimulus figure. In the process of making adjustments the orientation became more displaced. It appeared as if the goal of making it straight was done in one thought and then the correctness of the figure was a separate

thought resulting in loss of orientation due to the influence of the tilted frame. One characteristic that differentiates formal thinking from concrete is the wide range of operations ready for any particular situation (Gruber & Voneche, 1977). The adult participants were better able to keep both straightness and correctness in mind and generally made several adjustments to their configurations before they were satisfied. Comments made by some of the adult participants indicated that they were aware that their final product was sometimes not quite right; no child volunteered that his or her figures were off after completion suggesting that the original goal was no longer in mind. Further support for this explanation comes from the measures on the tasks; children had greater difficulty with the dot placement item than dot drawing, but adults showed the opposite pattern. For children the opportunity to make corrections actually seemed to hinder accuracy. A future study that expands on this particular task may be informative.

Comments made by participants may reveal additional differences between concrete and formal operations on the Tilted-Frames. Adults verbalized their efforts to find an appropriate frame of reference, for example making the figure relative to something in the room, orienting to the position of self, lining up vertical lines with lines in the stimulus figure, or focusing on parallels. Although it cannot be assumed that children did not use these strategies, they were rarely included in their explanations.

The Frame-Size tasks, like the Tilted-Frames, did not show a significant effect of age within the School group, but adults were significantly more accurate than the oldest children. The side-by-side layout of this task may have inadvertently created an additional coordination in perception besides the inhibition of the frame size. A perceptual bias toward making the top of the figures at the same location within the paper

as the top of the stimulus item would result in errors of larger figures in larger boxes and smaller figures in smaller boxes. Adults were likely to have had a greater ability to overcome that influence also and coordinate the top and bottom of the figures. A vertical layout of the boxes, stimulus on top and response on the bottom, would have avoided that complication.

Learning Disabled Children's Performance

The LD participants were more likely to have greater deviation scores on the Misleading Frames Tasks and to make errors on the Frame-Size Choice task compared to the School group. This group was included as a further test of the theory that field dependence and working memory can account for deficits in ability in perceptual analysis as they represent the lower end of ability. These findings support that theory insofar as performance on the tasks showed the same pattern as the other participants but errors were more pronounced. The scores for this group on Block Design were lower than their peers as was expected because they were included in this study based on their identification as having a disability in the visual-perception area. However, the LD group did not perform differently than their non-disabled peers on the Corsi Block Tapping Test. This adds to the doubts about the validity of this as a measure of working memory capacity that is relevant to the constructs under investigation in this study.

Placement versus Drawing Responses

It was predicted that there would be no difference in accuracy between placement and drawing because it is the perceptual judgment involved in the task and the finding of appropriate frames of reference that determines how well a participant performed. Motor control or drawing ability was assumed to not be the determining factor. This was mostly

supported. When the baseline error was taken into account, the accuracy of the School group was very similar in placement and drawing conditions. The Adult group, however, was more accurate with placement, possibly due to the many adjustments made to their placement figures that could not be made to their drawings. Therefore it does not appear that drawing ability is a factor in accuracy, but the ability to make corrections may be. Corrections benefited only the Adult group who may have been better able to keep the multiple goals of the task in mind throughout the task.

Summary of Study Findings

Field dependence appears to have influenced performance on the Misleading-Frames Tasks for all participants. Consistent with earlier work on field dependence the influence decreased with age, most significantly between children and adults, and was a greater influence with learning disabled children. A significant correlation between the Misleading-Frames Tasks and the Block Design Test add to support for the tasks as measures of field dependence in a perceptual analysis task.

A quantitative explanation for the influence of field dependence, that working memory capacity can account for differences in ability, was supported but only within the Tilted-Frames Task. Complex figures were copied with greater deviation of orientation than line figures, suggesting that working memory demands of the figure construction decreased ability to simultaneously inhibit the interfering frame. Size judgment within misleading frames that were larger or smaller was not affected by figure complexity. No meaningful correlation was found between the task measures and the Corsi Block Tapping Task, therefore the connection between working memory capacity and field dependent behavior remains questionable.

Tilted-Frames as a Dynamic Process: A Case Study

The results of the Tilted-Frames Task, when considered at the group level, support a connection between working memory capacity and the ability to construct accurate figures. This connection is less clear when performance on the tasks is examined on an individual case level. If working memory capacity is indeed a critical factor in accuracy then it would be reasonable to assume that an individual who is relatively limited in capacity would have difficulty on all tasks dependent upon this capacity. This, however, was not the case. Some children were consistently good at making their copies well oriented, but no child was consistently off. If performance on these tasks is related to working memory capacity, how could the same capacity enable perfect performance on some items yet poor performance others?

Noisy data may be the result of inadequately designed tasks, or, in the view of dynamic systems theory, may be because variability in performance is expected. Inconsistency may actually be very informative. “It says that the task does not elicit stable performance, that between and within subjects, there is no single attractor. . . . When the task demands are not very constraining, subjects may choose among several or many possible responses” (Thelen & Smith, 1994, p. 68). Perhaps assessment of the final product of the tasks in this study does not reveal the true story. Instead analysis of the process may provide more insight. In a dynamic system, “each thought is an in-the-moment unique event, open to a continually changing world, and the product of the intrinsic dynamics of a nonstationary system” (Smith, 2005, p. 279). The most appropriate way to investigate the dynamics of a specific task is at the individual case study level (van Geert & Steenbeek, 2005).

A thought in a dynamic system is intricately tied to previous states or thoughts and habitual ways of thinking, these then become attractor states which bias future thinking and behavior. Greater effort is required to overcome attractors than to continue thinking in the habitual way. In the copy tasks used in this study the attractors are the easy, obvious or habitual relationships; in other words the field effects or salient aspects of a scene. The Misleading Frames Tasks were intentionally designed to create an opportunity to observe a participant's ability to construct an effortful response. By examining that effort as it unfolds may provide a different understanding of what influences the final product. An important concept in dynamic systems theory is that development is emergent with behaviors assembled in real time. The temporal nature of behavior can be in the seconds and fractions of seconds of immediate behavior as well as in the larger time scale of developmental change (Thelen & Smith, 1994). Although responses to the copy tasks were constructed in a matter of only a couple of seconds, they involved organization and reorganization as the goals and task characteristics changed within the emerging construction. "Solutions are always soft-assembled, and thus are both constrained by subjects' current intrinsic dynamics and potentially derailed or redirected by task conditions" (Smith, 2005, p. 311). Inconsistencies in performance therefore should not be surprising.

Figure 10 presents the responses on the Tilted-Frame Tasks made by a 9-3 year-old girl who was part of the LD group. The errors she made were not unique, other non-learning disabled children made similar errors. Her case was chosen because of the inconsistency of her performance. Her Span score (5.33) was comparable to the mean of the older half of the non-LD participants (5.1), and Design score was lower (35)

compared to the others (42). Her total error score on the Tilted-Frames was more than two standard deviations greater than the mean for all children.

Using the interactive framework suggested by Roberts and Pennington (1996) of working memory and inhibition, and considering inhibition in the dynamic systems sense of attractor states, this girl's productions can be analyzed according to the possible variables influencing the outcome. The effortful working memory components included keeping the goal of the task in mind, finding and maintaining an appropriate frame of reference to guide productions, coordinating the components of each figure in relation to each other and to the overall orientation on the page, and planning and executing the motor action with all components kept in mind through completion. Her productions in the baseline conditions suggest that these components were well within her ability.

The introduction of noise into this process, in the form of the tilted frame, led to a loss of coordination of some of the components. For example in the first drawing item the familiar letter "T" appears to have been an attractor that won out over the perception of a novel inverted T figure. In that item the goal of making the design straight was lost and instead the figure was oriented entirely with the tilted frame. Perhaps the change from a placement to a drawing response, as this was the first in the series of drawing tasks, added to the overall load on working memory and contributed to the lapse in attention. In the two placement tasks it can be seen that the vertical placements were quite correct. This can be achieved perceptually by continuing the line from the stimulus figure down to the response frame. The horizontal placements, however, were not oriented to either an external reference or to the vertical as a perpendicular. Again the lack of coordination is evident when the familiar context is changed.

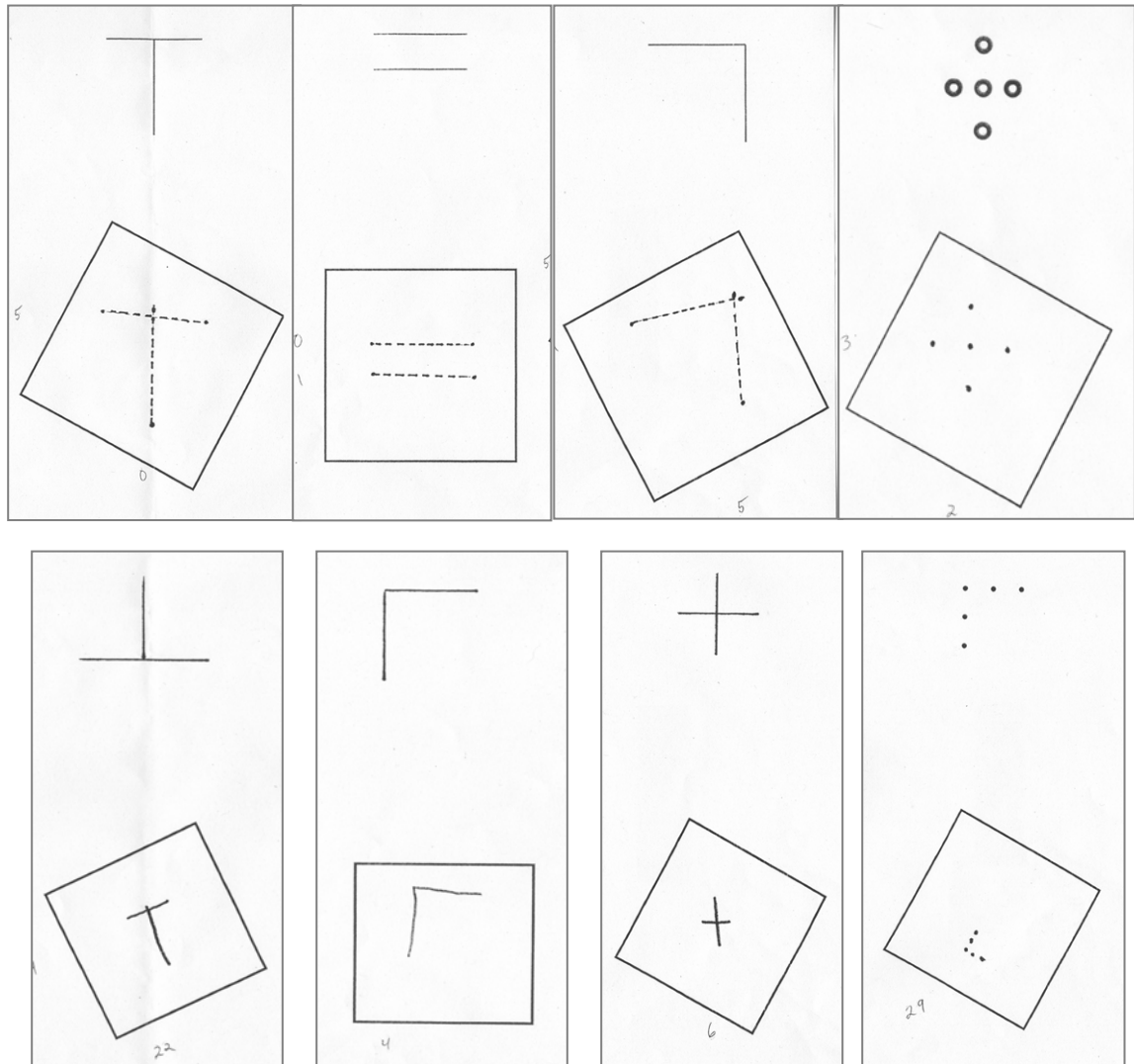


Figure 10. Responses made by a 9-3 year-old girl on Tilted-Frames. Placement tasks (dotted lines added) are on top and the drawing tasks on bottom.

Piaget (Piaget et al., 1960) noted that a developmental achievement in perceptual analysis is the ability to choose from among possible frames of references within a task to achieve a specific goal. It appears that this child did not have a sufficient ability to make appropriate choices and instead used the frame of reference that was most readily available for a particular item. Sometimes that frame of reference led to a very accurate

construction as seen in the “+” drawing item, but other times the choice was a poor one for the goal of the task. Lack of flexibility in choosing a reference may account for the inconsistency of performance. From a working memory perspective, if she had the capacity to hold in mind the goal of the task while considering various alternatives for organization, she may have been better able to make goal-appropriate responses.

Future Directions

The tasks designed for this study were shown to be potentially useful for investigating the influence of field effects and working memory on a construction task. However, analyses of the results indicate that some changes in the tasks could strengthen or clarify the theory under study.

An increase in the range of difficulty of the task items so that a ceiling performance can be found might lead to stronger correlations between the tasks and other developmental measures. Because the dot figures, particularly the dot placement item, were found to be sensitive measures in the Tilted-Frames, additional items plus a specific baseline item for dots would strengthen findings. The complexity of the figures could be increased by including more parts or that have an organization of the parts that is less predictable. The oblique figures were not found to be useful for the purpose of this study. However, if the concepts of a baseline and misleading contexts are reconsidered for these items, they may provide another measure of complex analysis. The baseline should be no frame at all because a square frame is already a misleading context, or the stimulus figure should have the same square frame so that the response and stimulus have the same references. Another possibility is to have one line of the figure perpendicular and the

other an oblique, this way requiring more effortful analysis than two perpendicular lines but including some available reference frame.

The Frame-Size Task may be more sensitive to figure complexity if the figures to be copied are not anchored to the bottom of the square. If they are centered within the square the judgment of size in the presence of misleading cues would be ongoing as the figure is completed and thus may show an effect of figure complexity.

The Corsi Block Tapping Test did not correlate with the tasks designed for this study. Because there is some other evidence that working memory capacity may be a factor in performance on the tasks, it may be useful to find another measure of visual-spatial working memory. Following the interactive model, an appropriate test would involve maintenance in the presence of interference. Such a test that is specifically visual is not known but may exist. In some research the memory span tasks are used but a delay with an interfering content is imposed prior to recall. These are not widely used or standardized but may be worth considering.

Finally, the structure of the study might be changed to focus on a small number of individual performances. The dynamics of the process could be studied more closely and possibly reveal task characteristics that would be useful for a larger scale study. The tasks could be manipulated to set up attractors through repetition of one format of the task and then have noise introduced in the form of interference or complexity. If a predictable level of performance could be established for a child and if that level is related to a working memory capacity measure, then the theory proposed in this study would be more strongly supported.

CONCLUSION

Visual motor skill development is an area of concern among teachers of elementary age children. Assessments used to evaluate these skills often include design copying (e.g., Beery & Beery, 2004), however the reasons for poor performance on such tests are not well understood (Salvia & Ysseldyke, 1995). One underlying component of performance may be the ability to overcome the misleading contextual influences inherent in a visual task in order to coordinate a response based on other frames of reference. Piaget (1969; Piaget & Inhelder, 1956) attributed this ability to onset of operational thinking, when children are no longer dominated by the immediate field effects of an image but can instead consider other references to construct a representation of an idea. Witkin (Witkin et al., 1971/2002) described very similar processes in terms of field dependence/independence.

This study is informed by two converging areas of psychological research, field dependence and visual-spatial working memory. Explanations of field dependence by both Piaget and Witkin imply a quantitative change in development: the ability to consider an increasing number of possibilities at one time in order to choose an appropriate frame of reference. The purpose of this study was to investigate the idea that performance on a field dependence task is related to working memory capacity, and together they can explain individual differences in ability on a copy task.

The tasks designed for this study appeared to be a useful measure of field dependence because constructions within a misleading frame were significantly more deviant than those made in a facilitating frame. As predicted by the theoretical models, field dependence on these tasks decreased with the age of the participant and was more

pronounced with learning disabled children. This new approach to investigating field dependence may be a valuable contribution to this area of research which is dominated by the two tests used by Witkin, the Rod-and-Frame Test and Embedded Figures Test. By requiring a construction response to a perceptual analysis problem, the Misleading-Frames Tasks may be more ecologically relevant to school age performance questions, and they allow for manipulation of the complexity of the analysis. One important finding from this study is that the influence of field dependence is not a set characteristic of an individual but varies according to the demands of the task. Further evidence for the Misleading-Frames Tasks as measures of field dependence came from the significant correlation of performance on the tasks with scores on the Block Design Test.

The influence of working memory capacity on drawing made within a misleading context, specifically within tilted frames, was also demonstrated in this study. However, it was not the capacity for exact recall of a number of locations that was related, instead the interaction of working memory and inhibition best explained differences in performance. With increased demands on working memory in the form of a multi-part figure construction, ability to inhibit the influence of a misleading frame was compromised. The active inhibition required for accurate performance on the Tilted-Frames Tasks was ongoing throughout the construction. This may extend the interaction model proposed by Roberts and Pennington (1996) who focused on inhibition at the onset of a task response. For the purpose of understanding a child's performance on paper-and-pencil tasks the ongoing need for inhibition as the task progresses may be important.

REFERENCES

- Akshoomoff, N. A., & Stiles, J. (1995). Developmental trends in visuospatial analysis and planning: I. Copying a complex figure. *Neuropsychology*, 9, 364-377.
- Akshoomoff, N. A., & Stiles, J. (1996). The influence of pattern type on children's block design performance. *Journal of the International Neuropsychological Society*, 2, 392-402.
- Alevriadou, A., Hatzinikolaou, K., Tsakiridou, H., & Grouios, G. (2004). Field dependence-independence of normally developing and mentally retarded boys of low and upper/middle socioeconomic status. *Perceptual and Motor Skills*, 99, 913-923.
- Amador-Campos, J. A., & Kirchner-Nebot, T. (1997). Relations of scores on Children's Embedded Figures Test with age, item difficulty and internal consistency. *Perceptual and Motor Skills*, 85, 675-682.
- Amador-Campos, J. A., & Kirchner-Nebot, T. (1999). Correlations among scores on measures of field dependence-independence, cognitive style, cognitive ability, and sustained attention. *Perceptual and Motor Skills*, 88, 236-239.
- Baddeley, A. (2002). Is working memory still working? *European Psychologist*, 7(2), 85-97.
- Bagust, J. (2005). Assessment of verticality perception by a Rod-and-Frame Test: Preliminary observations on the use of a computer monitor and video eye glasses. *Archives of Physical Medicine and Rehabilitation*, 86, 1062-1064.
- Bayliss, D. M., Jarrold, C., Gunn, D. M., & Baddeley, A. (2003). The complexities of complex span: Explaining individual differences in working memory in children and adults. *Journal of Experimental Psychology: General*, 132(1), 71-92.
- Beery, K. E., & Beery, N. A. (2004). *The Beery-Buktenica Developmental Test of Visual-Motor Integration, Test Manual*. Minneapolis, MN: NCS Pearson.
- Berch, D. B., Kirkorian, R., & Huha, E. M. (1998). The Corsi block-tapping task: Methodological and theoretical considerations. *Brain and Cognition*, 38, 317-338.
- Boisvert, M., Standing, L., & Moller, L. (1999). Successful part-whole perception in young children using multiple-choice tests. *The Journal of Genetic Psychology*, 160, 167-180.
- Bouaziz, S., & Magnan, A. (2007). Contribution of the visual perception and graphic production systems to the copying of complex geometrical drawings: A developmental study. *Cognitive Development*, 22, 5-15.

- Case, R. (1999). Conceptual development in the child and in the field: A personal view of the Piagetian legacy. In E. Scholnick (Ed.), *Conceptual development: Piaget's legacy*. Mahwah, NJ: Erlbaum.
- Case, R., & Globerson, T. (1974). Field independence and central computing space. *Child Development*, 45, 772-778.
- Chen, S., & Levi, D. M. (1996). Angle judgment: Is the whole the sum of its parts? *Vision Research*, 36, 1721-1735.
- Chuah, Y. M. L., & Maybery, M. T. (1999). Verbal and spatial short-term memory: Common sources of developmental change? *Journal of Experimental Child Psychology*, 73, 7-44.
- Coté, C., & O'Donnell, A. (2007). Field dependence and stimulus complexity in a figure copying task. *Perceptual and Motor Skills*, 105, 1159-1170.
- Cowan, N., Elliott, E. M., Sauls, J. S., Morey, C. C., Mattox, S., Hismjatullina, A., et al. (2005). On the capacity of attention: its estimation and its role in working memory and cognitive aptitudes. *Cognitive Psychology*, 51, 42-100.
- Davis, A., DeBruyn, B., & Boyles, S. (2005). Angular figures constrain the perpendicular bias in children's line copying. *Cognitive Development*, 20, 422-426.
- de Ribaupierre, A., & Bailleux, C. (1994). Developmental change in spatial task of attentional capacity: An essay toward an integration of two working memory models. *International Journal of Behavioral Development*, 17(1), 5-35.
- de Ribaupierre, A., & Bailleux, C. (2000). The development of working memory: Further note on the comparability of two models of working memory. *Journal of Experimental Child Psychology*, 77, 110-127.
- DeLisi, R. (1983). Developmental and individual differences in children's representation of the horizontal coordinate. *Merrill-Palmer Quarterly*, 29, 179-196.
- Dempster, F. N. (1992). The rise and fall of the inhibitory mechanism: Toward a unified theory of cognitive development and aging. *Developmental Review*, 12, 45-75.
- Duffy, S., Huttenlocher, J., & Levine, S. (2005). It is all relative: How young children encode extent. *Journal of Cognition and Development*, 6, 51-63.
- Duffy, S., Toriyama, R., Itakura, S., & Kitayama, S. (2007). The development of culturally contingent strategies of attention in children. (*unpublished manuscript*).
- Elkind, D. (1975). Perceptual development in children. *American Scientist*, 63, 533-541.
- Elkind, D., & Scott, L. (1962). Studies in perceptual development: I. The decentering of perception. *Child Development*, 33, 619-630.

- Farkas, M., & Elkind, D. (1974). Effects of distance and stimulus position on perceptual comparison at five age levels. *Child Development*, 45, 184-188.
- Feeney, S. M., & Stiles, J. (1996). Spatial analysis: An examination of preschoolers' perception and construction of geometric patterns. *Developmental Psychology*, 32, 933-941.
- Flexner, B. K., & Roberge, J. J. (1980). IQ, field dependence-independence, and the development of formal operational thought. *The Journal of General Psychology*, 103, 191-201.
- Flexner, B. K., & Roberge, J. J. (1980). IQ, field dependence, and the development of formal operational thought. *The Journal of Genetic Psychology*, 105, 191-201.
- Gathercole, S. E., & Pickering, S. J. (2000). Working memory deficits in children with low achievements in the national curriculum at 7 years of age. *British Journal of Educational Psychology*, 70, 177-194.
- Gathercole, S. E., Pickering, S. J., Ambridge, B., & Wearing, H. (2004). The structure of working memory from 4 to 15 years of age. *Developmental Psychology*, 40(2), 177-190.
- Gruber, H. E., & Voneche, J. J. (Eds.). (1977). *The essential Piaget: An interpretive reference and guide*. New York: Basic Books.
- Hoffman, D. D. (1998). *Visual intelligence: How we create what we see*. New York: Norton.
- Huang, J., & Chao, L. (2000). Field dependence versus field independence of students with and without learning disabilities. *Perceptual and Motor Skills*, 90, 343-346.
- Kail, R. (2000). Speed of information processing: Developmental change and links to intelligence. *Journal of School Psychology*, 38(1), 51-61.
- Kandel, E. R., Schwartz, J. H., & Jessell, T. M. (1991). *Principles of neural science* (3rd ed.). New York: Elsevier.
- Kane, M. J., & Engle, R. W. (2003). Working-memory capacity and control of attention: The contributions of goal neglect, response competition and task set to stroop interference. *Journal of Experimental Psychology: General*, 132, 47-70.
- Kemps, E., de Rammeleare, S., & Desmet, T. (2000). The development of working memory: Exploring the complementarity of the two models. *Journal of Experimental Child Psychology*, 77, 89-109.
- Kovács, I. (2000). Human development of perceptual organization. *Vision Research*, 40, 1301-1310.

- Lezak, M. D., Howieson, D. B., & Loring, D. W. (2004). *Neuropsychological assessment*. New York: Oxford University Press.
- Logie, R. H., & Pearson, D. G. (1997). The inner eye and the inner scribe of visuo-spatial working memory: Evidence from developmental fractionation. *European Journal of Cognitive Psychology*, 9(3), 241-257.
- McKenna, F. P. (1984). Measures of field dependence: Cognitive style or cognitive ability? *Journal of Personality and Social Psychology*, 47, 593-603.
- Miles, C., Morgan, M. J., Milne, A. B., & Morris, E. D. M. (1996). Developmental and individual differences in visual memory span. *Current Psychology*, 15(1), 53-67.
- Miyake, A., Witzki, A. H., & Emerson, M. J. (2001). Field dependence-independence from a working memory perspective: A dual-task investigation of the Hidden Figures Test. *Memory*, 9, 445-457.
- Morra, S. (1994). Issues in working memory measurement: Testing for M capacity. *International Journal of Behavioral Development*, 17, 143-159.
- Morra, S. (2002). On the relationship between partial occlusion drawing, M capacity and field independence. *British Journal of Developmental Psychology*, 20, 421-438.
- Morra, S. (2005). Cognitive aspects of change in drawings: A neo-Piagetian theoretical account. *British Journal of Developmental Psychology*, 23, 317-341.
- Morra, S., Angi, A., & Tomat, L. (1996). Planning, encoding and overcoming conflict in partial occlusion drawing: a neo-Piagetian model and an experimental analysis. *Journal of Experimental Child Psychology*, 61, 276-301.
- Newcombe, N. (1991). New direction for research on cognitive style? *Contemporary Psychology: A Journal of Reviews*, 36(6), 502.
- Nolan, L., Grigorenko, A., & Thorstensson, A. (2005). Balance control: Sex and age differences in 9- to 16-year-olds. *Developmental Medicine & Child Neurology*, 47, 449-454.
- Pagulayan, K. F., Busch, R. M., Medina, K. L., Bartok, J. A., & Krikorian, R. (2006). Developmental normative data for the Corsi Block-Tapping task. *Journal of Clinical and Experimental Neuropsychology*, 28, 1043-1052.
- Pascual-Leone, J. (1987). Organismic processes for neo-Piagetian theories: A dialectical causal account of cognitive development. *International Journal of Psychology*, 22, 531-570.
- Pascual-Leone, J., & Baillargeon, R. (1994). Developmental measurement of mental attention. *International Journal of Behavioral Development*, 17, 161-200.

- Piaget, J. (1969). *The mechanisms of perception*. New York: Basic Books.
- Piaget, J., & Inhelder, B. (1956). *The child's conception of space*. New York: Norton.
- Piaget, J., Inhelder, B., & Szeminska, A. (1960). *The child's conception of geometry*. New York: Basic Books.
- Pickering, S. J. (2001). The development of visuo-spatial working memory. *Memory*, 9, 423-432.
- Pickering, S. J., Gathercole, S. E., Hall, M., & Lloyd, S. A. (2001). Development of memory for pattern and path: Further evidence for the fractionation of visuo-spatial memory. *The Quarterly Journal of Experimental Psychology*, 54A(2), 397-420.
- Prevor, M. B., & Diamond, A. (2005). Color-object interference in young children: A Stroop effect in children 3 1/2 - 6 1/2 years old. *Cognitive Development*, 20, 256-278.
- Pulos, S. (1997). Divergent validity and the measurement of processing capacity. *International Journal of Behavioral Development*, 20, 731-734.
- Roberts, R. J., & Pennington, B. F. (1996). An interactive framework for examining prefrontal cognitive processes. *Developmental Neuropsychology*, 12, 105-126.
- Salvia, J., & Ysseldyke, J. E. (1995). *Assessment* (6th ed.). Boston: Houghton Mifflin Company.
- Smith, L. B. (2005). Cognition as a dynamic system: Principles from embodiment. *Developmental Review*, 25, 278-298.
- Stiles, J., Delis, D. C., & Tada, W. L. (1991). Global-local processing in preschool children. *Child Development*, 62, 1258-1275.
- Tada, W. L., & Stiles, J. (1996). Developmental change in children's analysis of spatial patterns. *Developmental Psychology*, 32, 951-970.
- Thelen, E., & Smith, L. B. (1994). *A dynamic systems approach to the development of cognition and action*. Cambridge, MA: MIT Press.
- Tinajero, C., Paramo, M. F., Quiroga, M. A., & Rodriguez-Gonzalez, J. (2000). Comparative analysis of different correction methods for measuring Rod-and-Frame test performance. *Perceptual and Motor Skills*, 90, 93-101.
- van Geert, P., & Steenbeek, H. (2005). Explaining after by before: Basic aspects of a dynamic systems approach to the study of development. *Developmental Review*, 25, 408-442.

- Van Leijenhorst, L., Crone, E. A., & Van der Molen, M. W. (2007). Developmental trends for object and spatial working memory: A psychophysiological analysis. *Child Development*, 78, 987-1000.
- Vandierendonck, A., Kemps, E., Fastame, M. C., & Szmalec, A. (2004). Working memory components of the Corsi blocks task. *British Journal of Psychology*, 95, 57-79.
- Wechsler, D. (1991). *Wechsler Intelligence Scale for Children* (3rd ed.). San Antonio, TX: Psychological Corporation.
- Witkin, H. A., & Asch, S. E. (1948). Studies in space orientation: IV. Further experiments on perception of the upright with displaced visual fields. *Journal of Experimental Psychology*, 38, 762-782.
- Witkin, H. A., Oltman, P. A., Raskin, E., & Karp, S. A. (1971/2002). *Group Embedded Figures Test manual*. Menlo Park, CA: Mind Garden, Inc.
- Zhang, L. (2004). Field-dependence/independence: cognitive style or perceptual ability? - validating against thinking styles and academic achievement. *Personality and Individual Differences*, 37, 1295-1311.
- Zigler, E. (1963). A measure in search of a theory? *Contemporary Psychology: A Journal of Reviews*, 8, 133-135.

CURRICULUM VITA

Carol A. Coté

Academic Background

Ph.D., Educational Psychology, 2008, Rutgers University,
Graduate School of Education, New Brunswick, NJ
M.A., Learning Disabilities, 1994, Montclair State University, Upper
Montclair, NJ
B.S., Occupational Therapy, 1981, Kean University, Union, NJ

Teaching Experience

Rutgers University, Department of Educational Psychology, Teaching
Assistant/Instructor, 2006
Montclair State College, Department of Communication Sciences and
Disorders, Adjunct Instructor, 1995 – 1996
Union County College, Occupational Therapy Assistant Program, Adjunct
Instructor, 1983 – 1984

Positions Held

OT Ideas, Inc., Randolph, NJ, Private Practice Occupational Therapist
1988 – Present
Harding Township Public School, New Vernon, NJ, Occupational
Therapist, 1995 – 2001
Saint Barnabas Medical Center, Livingston, NJ, Staff Occupational
Therapist, 1981 – 1984

Publications

Coté, C. A. and Golbeck, S. (2007). Pre-schoolers' feature placement on
own and others' person drawings. *International Journal of Early
Years Education*, 15, 231-243.
Coté, C. A. and O'Donnell, A. M. (2007). Field dependence and stimulus
complexity in a figure copying task. *Perceptual and Motor Skills*,
105, 1159-1170.
Coté-Loikith, C. (2005). Development of Visual Attention. In M. Gentile,
(Ed.), *Vision issues in pediatrics: A guide for therapists*, Rockville,
MD, AOTA.
Coté-Loikith, C. (1997). Visual perception: Development, assessment and
intervention. In M. Gentile (Ed.), *Functional visual behavior: A
therapist's guide to evaluation and treatment options*, Rockville,
MD, AOTA.