Error type and frequency in children's reproductions of the Rey-Osterrieth complex figure as predictors of group membership.

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ERROR TYPE AND FREQUENCY IN CHILDREN'S REPRODUCTIONS
OF THE REY-OSTERRIETH COMPLEX FIGURE AS
PREDICTORS OF GROUP MEMBERSHIP

A Dissertation Presented
by
ROBERTO A. IRIZARRY

Submitted to the Graduate School of the
University of Massachusetts Amherst in partial fulfillment
of the requirements for the degree of
DOCTOR OF PHILOSOPHY
September 1996
School of Education
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Marla R. Brassard, Chair

John Carey, Member

Linda Vincent, Member

Jane Holmes Bernstein, Member

Bailey Jackson, Dean
School of Education
DEDICATION

To the loving memory of my father, Anibal Irizarry. He taught me that life was more than working in sugar cane fields and factories or dying in Viet Nam.

To my beautiful wife, Kim Gerould, and to our children, Diego and Yamila Irizarry-Gerould. With never ending love.
ACKNOWLEDGMENTS

I would like to express my deep gratitude to those individuals who offered encouragement and assistance throughout this project. To Dr. Yvonne Romero ("madrinita") who provided the initial materials that fueled my love affair with the R-OCF and who gave me so much encouragement and advice throughout my graduate school endeavors.

I am particularly grateful to Dr. Marla R. Brassard, my advisor and committee chair. Her support and encouragement for my work is deeply appreciated. Her clear and timely feedback and her uncanny problem-solving ability throughout the research process has been invaluable.

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I would like to acknowledge the assistance of Dr. John "Jay" Carey in matters of methodological design and
statistics. Also for grounding me in very practical ways at times when I felt stuck or lost in the process.

My thanks to Dr. Linda Vincent who offered thoughtful comments relevant to the conceptualization of the problem, particularly at the early stages of the project when I was muddling through theoretical and categorical issues.

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September 1996                                    R.A.I.
Abstract

Error type and frequency in children's reproductions of the Rey-Osterrieth Complex Figure as predictors of group membership

September 1996

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Error production in children's reproductions of the Rey-Osterrieth Complex Figure (R-OCF) was examined in this study. Subjects were a control group of normal children and two clinical groups—a language-based learning disorder group (LD) and a group of children with learning disorders secondary to tumors in the posterior fossa (infra-tentorial) region of the brain. The children were between the ages of 9 and 12 years.

The LD groups consisted of 7 subjects with learning disorders primarily referenced to left frontal systems (LD-LF) and 18 subjects with learning disorders primarily referenced to left hemisphere systems in general (LD-LH). The tumor group consisted of 13 subjects. Subjects in the clinical groups were matched for age, sex, and handedness with the control subjects. A scoring system was devised to evaluate the production of ten error types across copy,
immediate recall, and delayed recall administrations of the R-OCF. Statistical analyses were conducted to determine whether there were significant differences in error production between the control group and the two clinical groups across the copy and immediate recall conditions and between the two clinical groups across the copy, immediate recall, and delayed recall conditions.

Problems of statistical power and sample size resulted in the elimination of the LD-LF group from the analyses. Consequently, the question of differences in error production between the LD-LF and LD-LH groups could not be answered and awaits research with a larger sample. Overall, results indicate that error analysis can reliably differentiate normal children from children in clinical groups. Children in the LD-LH and tumor groups produced significantly higher frequencies of errors in reproductions of the figure than children in the control group under copy and immediate recall conditions. Data on specific error types differentiating the control and the clinical groups is presented.

The results also indicate that error analysis can reliably differentiate children in the LD-LH group from children in the tumor group. Data on specific error types differentiating the two clinical groups across the copy and immediate recall conditions is presented. No significant differences emerged between these two groups in error
production for the delayed recall condition. Suggestions for conducting further research on error production in children's reproductions of the R-OCF are discussed.
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CHAPTER 1
STATEMENT OF THE PROBLEM

Since its creation in 1941 by Andre Rey, the Rey-Osterrieth Complex Figure (R-OCF) (Figure 1, Appendix A) has gained popularity as a neuropsychological assessment and research instrument. A two-dimensional abstract geometric design belonging to the family of constructional tests, the Rey figure has been used to evaluate parameters relevant to neuropsychology, including the ability to organize complex visual information, motor planning and motor abilities, and visual memory.

A dramatic increase in the number of researchers using the Rey figure has taken place over the last 10 years, with the general trend being that of using the instrument to conduct research with adult populations. However, the 1990s have seen an increase in the use of it in research with child and adolescent populations. New scoring systems have been devised to address the need for gathering developmental data on children (Kirk & Willis, 1990; Waber & Holmes, 1985, 1986) and adolescents (Stern, Singer, Duke, & Singer, 1994).

The Rey figure has also been manipulated experimentally for studying cognition in children (Waber, Bernstein, & Merola, 1989; Waber et al., 1994) or used in
research protocols to evaluate various aspects of child
development, including visuospatial skills (Ardilla &
Rosselli, 1994) and executive function (Reader, Harris,
Schuerholz, & Denckla, 1994).

Error production in children's reproductions of the R-OCF has been studied only minimally and as part of studies addressing other aspects of children's reproductions of the figure. This is contrary to research with adults in which error analysis has been used to discriminate among clinical populations and make inferences about brain function and cognition. The question thus remains as to whether error production in children's reproductions of the Rey figure can be useful in discriminating among clinical groups and serve as an adjunct to existing scoring systems.

**Purpose of the Study**

This researcher will examine error production in reproductions of the R-OCF by three groups of children: a normal group (control), a language-based learning disorder group, and a clinical control group consisting of children with tumors in the posterior fossa (infratentorial) region of the brain. The groups have been selected to address the following questions of sensitivity and specificity:
1. Do error types/patterns on the R-OCF distinguish normal children from children with language-based learning disorders and children with learning disorders secondary to posterior fossa tumors?

2. Do error types/patterns on the R-OCF distinguish children with language-based learning disorders (presumed to reflect primarily cortically-mediated dysfunction) from children with learning disorders secondary to posterior fossa tumors (reflecting primarily subcortical disruption)?

3. Do error types/patterns on the R-OCF distinguish between language-based learning disorders that can be referenced to left frontal brain systems specifically and those referenced to left hemisphere brain systems in general?

Statistical analyses will be conducted to determine if type and/or frequency of error production can reliably differentiate these groups.

Significance and Rationale

This investigation is significant for a number of reasons. First, as was mentioned earlier, there are few studies in which the Rey figure was used with children and only a handful of these were designed to study the usefulness of the instrument itself. Moreover, there are no published studies of children addressing error production specifically and little data regarding normative trends...
relevant to this aspect of the reproduction of the figure. The information available from studies of adults, the scant data from studies of children, and observations gathered from clinical experience do indicate error analysis can be a productive line of research with this instrument.

Second, knowledge in the field of neuropsychology has evolved primarily from studies with adult populations (the mature brain/organism) and not from studies of children (the developing brain/organism). Studies of children are necessary for building a database for a developmental neuropsychological model capable of addressing issues relevant to the clinical evaluation of children and the study of cognition and brain-behavior relationships. The age groupings in this study allow for age comparisons and identification of trends relevant to developmental neuropsychology.

Third, children with language-based learning disorders comprise a large number of those referred for neuropsychological assessment. The identification of specific patterns of error production in this population can help in clinical decision making and in the study of cognitive systems and processes underlying language and language-related tasks. Although children with brain tumors are a much less frequent referral, they comprise a special clinical population because of the nature of their
condition and the challenges of their evaluation and management. The neuropsychological study of these children has focused primarily on issues of recovery and cognitive growth as measured by IQ (J. H. Bernstein, personal communication, 1995). Studying the performance of these children in a task such as the R-OCF can provide insights regarding specific aspects of their neurocognitive functioning.

Fourth, from the perspective of pediatric neuropsychology, the study allows for comparison of a population whose dysfunction is presumably mediated primarily by cortical structures (language-based learning disorder group), identified through neuropsychological examination, and a population whose dysfunction is presumably mediated primarily by subcortical structures (tumor group), identified through neurological examination. This is important insofar as neuropsychology has predominantly addressed cortical function and the lateral and anterior-posterior neuroanatomical axes versus the cortical-subcortical axis. As Kirk and Kertesz (1993) have pointed out, drawing impairment (reproduction of the R-OCF is a drawing task) "following subcortical lesions has not been systematically explored or compared with that following cortical damage" (p. 57).
CHAPTER 2

REVIEW OF THE LITERATURE

"Error is a place of dynamics everywhere."
Charles Stern, Painter

The Rey-Osterrieth Complex Figure was devised in 1941 by the Swiss neuropsychologist Andre Rey for the study of visual perceptual functions and visual memory in head-injured patients (Lezak, 1983, p. 395). Classified as a neuropsychological instrument belonging to the family of constructional tests, this complex two-dimensional abstract design is well suited for evaluating the ability to plan, organize, and assemble complex visual information (Waber & Holmes, 1985). Motor execution patterns and abilities can also be observed by using the figure. Because two memory/recall administrations (immediate and delayed recall) are routinely employed, the figure can provide useful information as to visual memory functions and transformations from short- to long-term memory.

In spite of the explosion in research with the R-OCF seen in the 1980s, research with child populations remains an area of need. Although advances in scoring systems have been made, aspects of production of the figure, including error production, call for additional study.
Definition of Error

Defining what constitutes an "error" in reproduction of the complex Rey-Osterrieth figure is part of the problem of studying its significance. This problem is reflected in the literature on the R-OCF from the perspective of scoring systems that define specific aspects of the figure to be scored (e.g., omission of a part) and ignore other aspects or have separate procedures for accounting for that which the scoring system does not encompass (e.g., error as an "independent" aspect of the reproduction). These scoring systems in turn have been applied to studies, both of children and adults, in which the purpose was to examine the usefulness of the R-OCF as an instrument by itself or as part of research protocols employing batteries of tests.

Employing a variety of procedures for evaluating the drawings, clinical researchers have also used the R-OCF to compare patterns of performance of various populations and clinical groups (e.g., younger adults vs. older adults, left hemisphere patients vs. right hemisphere patients). Within this context, norms assume less importance and the emphasis is more on the description of error as a pattern of performance or a stylistic/strategic variation, such as the production of perseverations in frontal lobe damage patients or spatially disordered protocols in right hemisphere damage patients.
Scoring Systems and Error Production

In the clinical assessment of children with the use of the R-OCF, knowledge of developmental trends is essential for establishing the diagnostic and developmental significance of the various aspects of the drawing production. Scoring systems provide a structured way of evaluating the drawings and estimating age-related changes. The relationship of age scores to neural change is not a linear one, given what Goldman Rakic has termed the "heterology of brain structure/function relationships in infants and adults" (Holmes, 1988, p. 138). This is the notion that different brain structures may mediate a behavioral function at different points in the maturation of the organism. Establishing a method of quantifying age changes has enhanced the utility of the R-OCF in the neuropsychological assessment of both children and adults.

The complexity of the figure is very well suited for assessing the cognitive growth of children as they progress through developmental stages. Children increase with age in their ability to deal with complex problems and to do so in more efficient ways (Inhelder & Piaget, 1958). The Rey figure poses a complex problem-solving situation for the child, being thus useful for evaluating the ability to plan, organize, and assemble complex information (Waber & Holmes, 1985).
The Osterrieth Scoring System

Paul Osterrieth (1944) created the first scoring system for the Rey figure and published a normative study based on the application of this system to a sample of 295 normal individuals of both sexes that included children from age 4 and adults (subjects 16 years of age and older constituted the adults). The children in the sample were taken from public and private schools in Geneva, Switzerland, in an attempt to obtain a representative sample of the current median. The adult group consisted of subjects willing to take the test. They represented the various socio-economic strata but most of them had a secondary school education.

Osterrieth evaluated the strategies employed by the subjects for reproducing the figure and identified seven procedural types:

(I) Subject begins by drawing the large central rectangle and details are added in relation to it. (II) Subject begins with a detail attached to the central rectangle and adds remaining details in relation to the rectangle. (III) Subject begins by drawing the overall contour of the figure without explicit differentiation of the central rectangle and then adds the internal details. (IV) Subject juxtaposes details one by one without an organizing structure. (V) Subject copies discrete parts of the drawing without any semblance of organization. (VI) Subject substitutes the drawing of a similar object, such as a boat or house. (VII) The drawing is an unrecognizable scrawl. (Lezak, 1983, pp. 395-397)

Osterrieth's typology is consistent with the concept of hierarchical levels of organization, a cornerstone of
cognitive developmental theory. As children increase in age (from age 13 onward in Osterrieth's sample), their constructional strategies are characterized by making use of the large central rectangle or subsections of it as organizing units, a process labeled by Van Sommers (1989) as "superordinate chunking" (p. 125).

According to Van Sommers (1989), all subjects chunk the figure, the critical difference being that of chunk dimensions ([Visser & Hermans, as cited in Van Sommers, 1989], with brain-impaired subjects (both children and adults) producing more fragmented versions and children with neurodevelopmental disorders (brain-impairment presumed) deviating from normal children in their chunking strategies. Figure 2 (see Appendix A) provides graphic examples of different strategies for chunking the R-OCF by subjects from the control, learning-disorder, and tumor groups of the present study.

Van Sommers (1989) also referred to chunking as a capacity and a process that is initiated to mobilize that capacity. For example, Pillon (as cited in Lezak, 1983) showed how frontal patients improve in the organization of the figure when given a program of action or set of steps to follow in constructing the figure versus parieto-occipital patients who do not benefit from such direction.

In research with children and the R-OCF, Waber et al. (1994) have addressed this problem of determining the
relationship between chunking as a capacity and a process by introducing experimental manipulations in the presentation of the figure in order to ascertain whether visuospatial reasoning difficulties have as their basis a spatial/visuoperceptual deficit or a metacognitive process deficit. Given its relevance to error analysis in clinical groups of children, their study will be discussed in another section of this work.

Osterrieth (1944) also devised a way of quantitatively scoring the figure (accuracy score) based on its division into 18 units. Each unit is appraised independently in terms of its presence/absence, adequate placement, and quality of depiction (see Appendix B), each of these parameters corresponding to errors of omission, misplacement, and distortion, respectively. It follows that, given the structural aspects of this scoring system, low scores will represent higher loadings of these error types.

A major criticism of this scoring system as it applies to developmental neuropsychological assessment is its equal treatment of all 18 units of the figure. Recent research on the figure (Waber & Holmes, 1985) has revealed that not all units have the same relevance within the structure of the figure and that the saliency of different structural attributes of the figure is mediated by neurodevelopmental change.
Loring, Martin, and Meador (1990) developed formal scoring criteria for the standard 18 elements of the Osterrieth scoring system and applied them to the reproductions of 87 healthy young adults. Two related findings of their study are relevant to error production: (a) Scores following a 30-minute delay recall were higher when immediate recall was given compared with scores for a 30-minute delay performance without immediate recall; (b) significantly fewer qualitative scoring errors (distortions) were present at the 30-minute delay if immediate memory was previously assessed. The study was the first to address the relationship between the copy, immediate recall, and delayed recall conditions and its impact on both the qualitative and quantitative aspects of the drawing productions. The amount of information retained or lost and the transformations occurring from copy to memory are of importance. From the developmental point of view, Waber and Holmes (1986) have indicated that "the process by which information is transformed from copy to memory is likely to be age related" (p. 564).

The normative study by Loring et al. (1990) presents some limitations. First, the scoring system assigns equal weight to different structural aspects of the figure, a limitation in its application to children discussed previously. Second, the use of a college sample for developing the norms limits their applicability to
children because an important aspect of research with children is that of evaluating changes in performance as a function of age/developmental status.

The Waber and Holmes Developmental Scoring System

Moved by the need to enhance the utility of the Rey figure as a neuropsychological instrument, Waber and Holmes (1985) conducted a large normative study with the goals of describing developmental changes in a number of aspects of children's productions and of creating a method of quantifying goodness of organization and style of production in a valid and reliable manner. The subjects consisted of 454 children from a middle to lower middle class school district in the United States, evenly divided by sex, ranging in ages from 5 to 14 years, with approximately 10% of the group being left-handed. Children in the sample were not screened for learning difficulties.

The investigators divided the figure into the smallest line segments, with each segment categorized as belonging to one of the four major components of the structure: base rectangle, main substructure (including verticals, horizontal, diagonals), outer configuration structures, and internal details (see Figure 3, Appendix A). The presence/absence of these line segments constituted the accuracy score. All possible intersections and
alignments (see Figure 3, Appendix A) were also scored as present/absent.

An organizational score was developed, resulting in five levels of organization with the identification of 24 features of the figure most salient for that parameter, the predictors being all variables representing alignment and intersection. Because different subsets of these features were discriminators for different pairs of organizational levels, the scoring system does not result in a linear index whose value increases with organization but is hierarchical in nature. This is consistent with cognitive-developmental theory as previously discussed. The criteria for the five levels of organization for copy productions is included in Appendix C. Figure 4 (Appendix A) provides a graphic example representative of each of the organizational levels.

The style parameter used color order (the figure is drawn with color markers) to identify the direction of execution of the drawing (whether left to right or right to left). Alignment variables were used to identify a set of 18 features relevant to the style categories (see Appendix D), resulting in drawings being classified as belonging to one of four categories: part-oriented, outer-configurational/inner part-oriented, outer part-oriented/inner configurational, and configurational.
The significant findings of the Waber and Holmes (1985) study in relation to copy production of the Rey figure are summarized as follows:

1. By age 9, children can reproduce reliably all parts of the design (nearly total accuracy is achieved), with changes thereafter reflecting more effective planning and organization.

2. When children are around age 8, the left side of the figure becomes clearly established as the anchoring point and a left-to-right copy direction emerges. At age 9 or older, children's directional preferences become diagnostically significant (not systematically related to handedness). Children who copy the design from right to left produce more part-oriented protocols.

3. Younger children organize their productions around the vertical axis, older children around both the horizontal and vertical axes; organization around diagonals appears last.

4. For the better organized productions (organizations levels four and five), the base rectangle is the salient organizational unit.

5. Level four becomes modal with children at age 13.

6. No effect of sex was found on the organization scores.
7. In every age group, right-handed children produced better organized designs; left-handed children produced more part-oriented protocols.

With developmental change, there is a shift in the perceptual saliency of different structures in the figure, with the main rectangle and main internal structures becoming predominant as organizational structures as children increase in age. As indicated by Waber and Holmes (1985), children begin to approach the figure in a logical rather than a figural manner. This shift is consistent with Piagetan theory, which describes the evolution in children from concrete to logical thought (Inhelder & Piaget, 1958). The productions of younger children are commonly executed in a part-oriented fashion, but the drawing becomes configurational as children increase in age. Whereas part-orientation at lower levels of organization results in the reproduction of isolated elements, at higher levels it occurs within the context of a structured whole and a logical approach.

The preceding observations are consistent with the previous discussion of "chunking" as a visual analysis capacity that develops progressively. From the neuro-psychological point of view, "error" can be conceptualized as differences in chunking or parsing different parts or components of the figure. These differences can provide clinically relevant data as to how children vary in
chunk(s) or unit(s) of analysis, in the topographic localization of the chunk of visual information in the two-dimensional representation, and the relation to age, sex, and neuroanatomical and neurobehavioral states.

Other age trends identified by Weber and Holmes (1986) include changes in accuracy in reproducing parts of the figure and directional preferences, which suggest that constitutional or neurodevelopmental (substrate) changes account for performance variables measured by the R-DCF. Given the complexity of attentional, organizational, and visual-perceptual processing, as well as the motor planning and execution demands imposed by the task, it seems likely that functional neural networks are deployed in a coordinated manner when a subject constructs the Rey figure.

Weber and Holmes (1986) also examined memory productions under two conditions: immediate and delayed (30-minute) recall. This was done during the data collection phase of their 1985 standardization study by dividing the subjects into two approximately equal groups and assigning each group randomly to the immediate or delayed recall condition.

For the memory productions, 18 criteria were identified for the five levels of the organization parameter (see Appendix F). Figure 5 (see Appendix A) provides a graphic example representative of each of the five levels. The style parameter was evaluated by
determining the continuity of lines of the four structural units critical for scoring organization: (a) the horizontal sides of the base rectangle; (b) the vertical sides of the base rectangle; (c) the diagonals; (d) the main horizontal and vertical. Within each organizational level, three categories reflecting style were obtained: part-oriented, intermediate, and configurational.

Of relevance to this work was the evaluation of errors in both the copy and memory productions. The errors evaluated were (a) conflations, or use of one line to represent more than one part; (b) rotation of part of the figure or of the whole figure; (c) perseveration; and (d) misplacement.

The significant findings of Waber and Holmes' (1986) study of memory reproductions of the Rey figure follow:

1. For the subjects of all ages, the main organizing structures were remembered better than details, with further loss of detail and a shift to a more configurational approach as the delay in memory increased.

2. Material on the left side of the figure was remembered better than that on the right by subjects until age 8, when both sides became equivalent in this respect.

3. Errors and distortions were more frequent on the memory than on the copy condition for the subjects of every age but were not affected by memory delay (immediate vs. delayed recall productions).
4. Except in younger children (ages 5-9), memory productions became increasingly more configural with age (predominance of gestalt vs. part-orientation in memory).

A number of points are significant for this researcher's study of error production in children:
(a) Part-orientation in memory productions is rare after a child reaches age 9 and is of diagnostic significance.
(b) Errors and distortions on copy productions are rare, although fairly common on memory productions. Errors in the copy condition and excessive number of errors on the memory condition are likely to indicate pathology (Waber & Holmes, 1986, p. 579). Waber and Holmes (1986) highlighted the importance of not relying only on the organization and style ratings but of also examining other parameters "such as accuracy (overall and of subcategories), errors, and asymmetries" (p. 579).

At present, the generalizability of Waber and Holmes' (1985, 1986) findings—given the selection of the sample for their large normative study from a relatively restricted regional, ethnic, and socio-economic pool—cannot be properly ascertained because of the scarcity of research on the performance of children and adults when reproducing the Rey figure and the relationship to demographic and cultural variables. In addition, the absence of the three administration conditions (copy,
immediate recall, and delayed recall), particularly with data available from adult studies suggesting that administering the copy condition followed by both memory conditions can have an impact on performance (Loring et al., 1990), represents a constraint on the findings of the study and their utility for future research.

Waber et al. (1989) used the developmental scoring system in conducting a developmental/neuropsychological study. The sample consisted of a group of 76 children ranging in ages from 10 to 13 years, fairly evenly distributed in terms of sex, predominantly right-handed, gathered from two 5th and two 8th grade classrooms in an upper-middle-class community in the northeastern United States. The 5th and 8th graders were assigned to two conditions: (a) copying the figure from the model (copy condition) followed by an immediate recall reproduction; (b) studying the figure only (copy condition not administered) followed by an immediate recall reproduction. Recall productions were evaluated in terms of accuracy, organization, and style.

The researchers found that 5th graders who did not copy the design remembered its organization better and reproduced it more configurationally than did those who copied it. Their performance was also equivalent to that of the 8th graders for whom there was no treatment group difference. The phenomenon was more pronounced among
boys. Waber et al. (1989) concluded that in preadolescent children the motor input (copy condition) apparently interferes with efficient encoding of visuospatial information and that elimination of this input enhanced the visual memory of the design.

The Kirk and Willis Scoring System

The Kirk and Willis (1990) scoring system is based on the notion that when copying simple geometric forms, and by extension also complex forms such as the Rey, children engage in rule-governed constructive activity. Departure from these rules appears to be related to the complexity of both the model and the movements necessary to carry out the rules. The scoring system is based on the hypothesis that these rules can be identified as starting and progression strategies and that these change with age. The changes in relation to age are attributed to changes in cognitive capacity in the child. Young children between the ages of 6 and 8 are reported as having more inconsistency and variability in the use of starting and progression strategies. Flexibility, however, defined as the ability to select alternate routes, seems to be characteristic of more skilled action and to be important in approaching complex forms (Kirk, 1981). The system provides guidelines for classifying starting and progression strategies as configurational, part-whole, or
piecemeal and for classifying starting and progression strategies according to the type of organization they reflect: structured or nonstructured.

Relevant to errors is the inclusion of a separate procedure for scoring "seven independent types of errors" (Kirk & Willis, 1990, p. 23), with prevalence of specific error types varying with age. These include omission of lines, duplication of lines, conflation, rotation, displacement of parts, overshooting and undershooting of lines. No theoretical or practical explanation for labeling these errors as independent or for including them in a procedure separate from their scoring system is provided. A possibility already discussed in this work is that error is seen as an event separate from that which is accounted for by a scoring system and as serving an adjunct purpose. The nature of this overlapping relationship between error and a given scoring system must be studied. Unfortunately, the data of the Kirk and Willis system has not been published and further discussion of theoretical and methodological aspects of this system awaits publication.
Neuropsychology of Error and the Rey-Osterrieth Complex Figure

Studies of Children

The body of research indicates that neuropsychological studies on error production with the Rey figure in different clinical groups are more advanced with adult subjects than with children. In spite of an increase in the number of studies in which the R-OCF was used with children, error production in children is not well documented. To the knowledge of this writer, there is no single study published that addresses error production specifically in children's reproduction of the R-OCF. The studies that have been published address different aspects of neuropsychological function among groups of children and use existing scoring systems.

A few researchers have evaluated different parameters relevant to neuropsychology in children and included data on error production with the Rey figure. Hagberg (1985) selected a group of 20 learning disabled children from the Learning Disabilities Clinic at the Children's Hospital in Boston, matched for age and sex with a group of 20 controls selected from the Waber and Holmes (1985) normative study. The groups were compared in terms of organization and style (using the Waber-Holmes scoring system), the direction and sequence of execution with an eye to identifying starting and progression strategies, the accuracy of the productions, and errors. The group
ages ranged from 9 to 12.8 years, with more than 50% of each group being girls and 90% being right-handed. Hagberg found the learning disabled group to have significantly more errors than the normal group in their copy productions, with incorrect proportions and missing elements as the types of errors that distinguished significantly between the two groups.

Hagberg (1985) also found subjects in the learning disabled group to have significantly lower organizational scores than those of controls and to produce significantly more outer-configurational/inner-part oriented style protocols than did controls. The learning disabled children displayed a piecemeal strategic approach to construction of the figure characterized by breaking main segments into pieces and proceeding haphazardly, whereas their normal counterparts had a part-whole approach characterized by breaking the figure into two or three major units and constructing the figure unit by unit.

Jaimes [1985] used the Waber and Holmes (1985) developmental scoring system to study the stylistic variations in copy productions of the R-OCF in two learning disabled groups and a group of normal controls. The subjects in the learning disabled groups were selected from a large pool of patients identified as having learning disabilities by a multidisciplinary team of the Learning Disabilities Clinic of the Children's Hospital.
Medical Center, Boston, Massachusetts. The two groups differed from each other in terms of lateralized motor findings. The sample included 24 males and 10 females between the ages of 8 and 15 years, with 22 males (92%) and 8 females (80%) being right-handed. The learning disabled subjects were matched for age, sex, and handedness with normal controls from the Waber and Holmes (1985) normative study. Jaimes found both learning disabled groups differed significantly from controls in their approach to the figure, with subjects in the learning disabled groups presenting a configurational approach to the figure (presumably mediated primarily by the right hemisphere) whereas the control group appeared "to have the flexibility to vary its approach" (p. 13).

Although the results of the studies by Hagberg (1985) and Jaimes (1985) are constrained in terms of generalizability, given the small size of the samples, the findings are consistent with those of other investigators reported in this work regarding the patterns of performance of learning disabled children on the R-OCF. Higher frequencies of error production and lower organizational scores relative to age than those of normal subjects as well as stylistic/strategic differences do seem to characterize the performance of learning disabled children when reproducing the R-OCF. The finding of a larger number of omissions in this group where left hemisphere
impairments are presumed is also consistent with the performance of left-brain-damaged adults.

Waber and Bernstein (1995) evaluated the performance on the R-OCF of 323 children between the ages of 7 and 14, with a group mean IQ of 103, range of 85 to 149, who had been referred for evaluation of learning disability and 353 non-learning-disabled controls. Referral to the Learning Disabilities Clinic of the Children's Hospital Medical Center, Boston, Massachusetts, associated with history of learning/academic difficulties was the main criteria for selection of subjects for the learning disabled (LD) group. The investigators did not use discrepancy-based criteria in their classification as the validity of this traditional approach to classifying LD children was questioned by them. The control subjects were drawn from the standardization study of their scoring system (Waber & Holmes, 1985, 1986). Waber and Bernstein employed the Waber-Holmes developmental scoring system (Waber & Holmes, 1985, 1986), which quantifies organization, style, accuracy (Organization Scheme components and Incidental-Feature components; see Figure 6, Appendix A), and errors. Errors scored included a tally of distorted parts, rotations, perseverations, misplacements, and conflations.

Waber and Bernstein (1995) found reliable group differences for all variables scored, with age-related
magnitudes. Children in the non-learning-disabled (N-LD) group showed marked improvement between the ages of 8 and 9 in organization, style (more configurational), and the number of organizational-structure components reproduced, with steady and more gradual improvement at older ages and decline in frequency of errors with age. No age-related effects for any variable were found for the children in the LD group, with their performance remaining at the 8-year level through age 14. Although under the copy condition, 7- and 8-year-olds in the N-LD group made more errors than 11- to 14-year-olds, and under the recall condition, 7-year-olds differed from 9-, 12-, 13-, and 14-year-olds, no age group differences were found for the LD group.

In their discussion of the study, Waber and Bernstein (1995) indicated that there were no group differences in remembering incidental feature components, which do not contribute to the organizational integrity of the figure, and that the "organization, style, and accuracy profiles constitute converging evidence that the LD group was less effective at spontaneously extracting and making use of the organizing scheme" (p. 18). They suggested that the R-OCF should not be conceptualized as a measure of visuo-spatial skill or perception, at least for LD children, and that it may be most sensitive to constitutionally-mediated metacognitive skills associated with the development of
frontal networks. These skills seem to enable the child to grasp the main structural components of a task, in this case the reproduction of a complex visual configuration.

The study just cited is consistent with the presumption of the present study and with the evidence so far accumulated, namely, that error incidence is higher in clinical groups of children with learning disorders where constitutional or neurodevelopmental factors are presumed. The specific neural systems and their relationship to error needs to be elucidated. How error itself is defined for study can have an impact on its power to discriminate groups. For example, is the part to be evaluated an organizing scheme component or an incidental feature component.

Waber et al. (1994) used the R-OCF in two studies to evaluate the metacognitive basis for visuoperceptual and spatial deficits in long-term survivors of childhood acute lymphoblastic leukemia. This group of children is at an increased risk for learning disorders, presumably as a result of central nervous system toxicity related to their successful treatment, which includes varying degrees of cranial irradiation therapy and chemotherapy.

The first study by Waber et al. (1994) was conducted to determine whether production of the Rey figure was related to gender of the child and/or intensity of the treatment and to describe group performance relative to
age norms. The sample, drawn from various medical facilities in the United States, included 51 children—22 girls and 29 boys—assigned to one of two intensity of treatment protocols: high risk and standard risk. The median time elapsed between diagnosis and testing was 77 months (range 47-112). The R-OCF was administered in standard fashion: copy, immediate recall, delayed recall (after approximately 20 minutes). The Waber and Holmes (1985, 1986) developmental scoring system was used to score the protocols and resulted in organization scores; style classification as part-oriented, intermediate, or configurational; accuracy scores based on a count of number of organizational-scheme (OS) and incidental-feature (IF) components (see Figure 6, Appendix A); and error scores consisting of a tally of distortions of parts, including rotations, perseverations, misplacements, and conflations. Error scores were transformed into proportions prior to analysis by dividing the total number of errors by the total accuracy score to correct for the greater opportunity of children who reproduced more parts to commit errors, an issue of particular concern in the memory conditions.

The results of this first study by Waber et al. (1994) indicated no gender and treatment group effects in organization scores, style scores, or accuracy scores. There were substantial main effects of gender and risk
group in error production. Girls in the high risk group committed more errors than those in the standard risk group, but there was no group difference for boys. This effect was more pronounced in the memory conditions. When compared with productions of normative controls, these children's productions were less well organized for all conditions, their memory productions were more part-oriented, and errors were more prevalent in the copy and recall conditions. An interesting pattern emerging on the accuracy score was that the children with acute lymphoblastic leukemia not only recalled fewer OS components than controls but recalled more IF components, suggesting that in their encoding of the figure they fail to extract and assign significance to the OS, treating all elements as if they were of equivalent organizational significance.

In their second study, Waber et al. (1994) tested the hypothesis that if the patterns of poor performance observed in the first study were due to metacognitive factors, the performance of the children with acute lymphoblastic leukemia should improve with structure. This study involved 20 girls and 17 boys tested between the ages of 7 and 16 years, with mean length of time elapsed since diagnosis being 45 months (range 18-67). Neuropsychological evaluation was divided in two sessions. The standard R-OCF administration was done during the first session; an experimental version was administered
during the second session, with children randomly assigned (prior to testing) to one of the two experimental conditions: configurational (CON), and linear (LIN) (see Figure 7, Appendix A).

In the configurational presentation, the figure was decomposed into three sets of components: (a) organizational scheme components, (b) components appended to the exterior of the rectangle, and (c) details to the interior of the rectangle. A set of acetate overlays was used to present the figure components to the child in that order for the copy condition; then the copy was removed and the child asked to reproduce the figure from memory. In the linear presentation, the figure was also decomposed into three sets of components: (a) the whole left side of the rectangle, including external and internal details; (b) the right side of the rectangle also with internal and external detail; (c) the structures attached to the right side of the rectangle. Again a set of acetate overlays was used to present the components in this experimental condition in the order described. Following completion of the copy condition, the production was taken away and the child was instructed to reproduce the figure from memory. The protocols were evaluated for organization, style, accuracy, and error variables.

The results of the standard administration indicated the organization scores of both groups were within normal
limits for the copy condition, but the score for the CON group was below expectation on the recall condition. In the experimental administration, the CON group performed above normative expectation in both copy and recall conditions, whereas scores for the LIN group were within normal limits for both conditions. Consistent with previous research on the R-OCD (Waber & Holmes, 1986), less material (accuracy score) was produced in the recall condition than in the copy condition and structural components were more likely than incidental ones to be recalled.

Group by administration interactions emerged for organization, for errors, and to a lesser extent for accuracy. In the experimental administration the CON group obtained significantly higher scores in organization for both copy and recall conditions and also produced fewer errors (distortions) in these two conditions. Accuracy scores for the CON group were improved in both the copy and recall conditions but only for the OS components and not for the IF components. Children in the CON group produced more drawings in a configurational style for both copy and recall. Compared with productions during the standard administration, recall productions of the LIN group became less configurational whereas those of the CON group became more configurational.
The studies described document the existence of metacognitive factors involving deployment of attention and strategy development affecting the visuospatial performance of children treated for acute lymphoblastic leukemia (a finding also relevant to language-based learning-disabled children as seen in a study reviewed previously). These children seem unable to grasp and make use of the organizing framework inherent in the Rey figure as a guide for its construction. However, when provided with the main organizing scheme in a strategic fashion, the performance of these children equaled that of controls in organizational aspects and in frequency of error production. According to Waber et al. (1994), the prevalence of errors (typically involving distortion of elements) in the performance of children treated for acute lymphoblastic leukemia "and in other children with learning disabilities, may result not so much from disordered perceptual processes as from the absence of a meaningful framework to anchor the parts" (p. 365).

Studies of Adults

Loring, Lee, and Meador (1988) conducted the first study addressing directly the problem of error production in the reproduction of the Rey figure and its potential for discriminating among clinical populations in situations where the standard quantitative scoring system
does not. Using a sample of adult patients with complex partial seizures originating in the left or right temporal lobe (TLE), these authors found distinct qualitative differences in the memory productions of these patients that discriminated the two groups when the quantitative scoring system did not:

Distinct qualitative differences are present in the right TLE reproduction including significant distortion of the overall configuration, misplacement of the upper left cross which is not simply an extension of the figure, major mislocation, and incorporation of pieces into a larger element. (p. 244)

Goodglass and Kaplan (1979) described for the first time the performance of left-hemisphere damaged patients versus the performance of right-hemisphere damaged patients on drawing tasks such as the R-OCF. Left hemisphere damaged patients resemble normal people in their initial response to global configuration; elements usually maintain their spatial relations but drawings are simplified with omission of internal detail. Right hemisphere damaged patients cannot deal at once with the organizing configuration; they seek smaller units and attempt unsuccessfully to link them into a whole. Hemi-attentional problems (difficulties or deficits in the deployment of attention to a given quadrant of the visual field) are noted in both groups but are more severe in right hemisphere damaged patients. These lead to quantitative and qualitative differences in left-right
side productions of the figure. A larger number of omissions and distortions are present in the side of the figure affected by the hemi-attentional/neglect problem.

Levine, Warach, Benowitz, and Calvanio (1986) measured left spatial neglect in patients with right cerebral infarction by using a number of tasks, including the Rey figure. They quantified the severity of neglect (mild, moderate, severe) by establishing the percentage of right-most material copied from the figure. They found the Rey figure to be "a sensitive and reliable index of neglect" (p. 386).

Binder (1982) found that brain damaged groups differed both quantitatively and qualitatively from normal groups when reproducing the Rey figure. Normal people were able to make accurate reproductions and draw the main structural units as one unit. Binder used Grossman's term "chaining" (p. 152) to describe the tendency of left-brain damaged patients to break the configural segments into fragments that are then linked together into a closed figure, sometimes making an accurate reproduction. Binder found right-brain damaged patients to perform less accurately than left-brain damaged patients and their drawings to present with the grossest distortions. The left-brain damaged group displayed delayed lateral attention and asymmetries in their drawings, whereas the
right-brain damaged group neglected the side of the figure contralateral to the side of the lesion.

Messerli, Seron, and Tissot (as cited in Lezak, 1983) found that frontal-brain damaged patients rendered elements of the figure into familiar representations, omitted more parts, and repeated elements already copied (perseverations). Frontal-brain damage patients also displayed a disturbed program of execution that improved with a guide plan to copy the figure. Parieto-occipital patients showed significant spatial difficulties but their performance improved with spatial reference points (Pillon, as cited in Lezak, 1983).

These findings are consistent with those reported elsewhere in this paper, namely, that brain impaired individuals are deficient in (metacognitive) strategies to deal with complex visual forms and that when given such strategies, whether in the form of an execution plan or spatial reference points, their performance improves.

The R-OCF and Language Disorder

Given the limited research on children's reproductions of the R-OCF and specifically the limitations in the published literature addressing error production in their reproductions of the figure, it is important to include observations derived from clinical experience with the learning disordered population. In the case of this
author, clinical experience in the evaluation of children with learning disorders and in the use of the R-OCF has been accumulated over the course of approximately 8 years of work in a variety of settings. These settings included outpatient community clinics, one year of pre-doctoral training with a neuropsychology rotation in a hospital facility, and one year of work conducting psychological evaluations of children in an in-patient psychiatric situation. The following are errors possibly seen more frequently in populations with primarily language-based learning disorders where left-hemisphere involvement was presumed:

1. Significant omission of details of the figure, possibly occurring more frequently in memory than in copy productions, observed in the adult population with left-hemisphere damage (see Goodglass & Kaplan, 1979).

2. Rotation of the whole figure 90 degrees counterclockwise, seen in copy and memory productions, noted by Osterrieth (1944) and possibly involving a conscious decision to construct the figure that way.

3. Right-to-left direction of execution, diagnostically significant at age 9 (Waber & Holmes, 1985).

4. Incorrect proportions, including expansiveness of the whole figure.
5. Shifting of the whole figure to the left side of the horizontally-aligned paper, possibly seen more frequently in memory reproductions.

The R-OCF and Posterior Fossa Tumors

Improvements in the treatment of brain tumors in children have resulted in an increased emphasis on the quality of life for long-term survivors (Glauser & Packer, 1991, p. 2). The 1980s have seen a move from global descriptions of cognitive function to the use of neuropsychological tests to describe cognitive deficits in these children and the development of prospective studies (Glauser & Packer, 1991, p. 6).

Deficits in intellectual, emotional, and academic functioning have been documented for these children (Kun, Mulhern, & Crisco, 1983). Specific cognitive dysfunctions have also been described in children suffering from hemispheric tumors as similar to adult deficits following lesions to similar cortical areas (Ellenberg, McComb, Siegel, & Stowe, 1987, p. 642).

Factors identified as sources of risk for the development of neuropsychologic deficits include (a) young age at diagnosis, with children 6 years and younger having worst outcomes; (b) tumor location, with children with tumors in the supratentorium and the brain hemispheres developing greater cognitive deficits; (c) radiation
therapy, with children receiving entire cranial fields irradiation developing more global impairments depending on tumor size, location, and histology; (d) other factors, including the use of neurotoxic chemotherapy agents and remedial interventions (Duffner, Cohen, & Parker, 1988; Mulhern & Kun, 1985).

More recent clinical analysis of the performance of children with tumors in the posterior fossa (subcortical) has revealed significant deficits in executive function and in the processing of complex information (A. Helmus, personal communication, 1995). The R-OCF productions of these children are for the most part strikingly different from those of normal or language-based learning disabled children. Their organizational, stylistic stratégic approach, and error production patterns deviate significantly (J. H. Bernstein, personal communication, 1995). For this reason and given the fact that no data on the R-OCF productions of these children have been published, their inclusion in this study as a clinical group is of scientific import.
Subjects

Archival data from the Neuropsychology and Learning Disabilities Programs of the Children's Hospital, Boston, Massachusetts, were employed for this study. Subjects for the control group were obtained from the sample used for standardization of the Developmental Scoring System for the R-OCF by Waber and Holmes (1985, 1986). The sample included 454 children, evenly divided by sex and ranging in ages from 5 to 14 years, from a middle- to lower-middle-class school district in the United States. Approximately 10% of the children were left-handed. They were not screened for learning difficulties. All subjects in the Waber and Holmes' normative study between the ages of 9 years and 12 years, 11 months who were right-handed were identified. From this list, control subjects were randomly selected to match each of the subjects in the experimental group according to age, sex, and handedness.

Subjects for the experimental group were drawn from clinic records as being identified with language-based learning disorders following evaluation at the Learning Disabilities Clinic. Children referred to the clinic are routinely evaluated by a multidisciplinary team in the
areas of neurology, neuropsychology, language and speech, reading, and mathematics. Identification of a primary area of disorder is based on convergent findings.

The experimental group was further divided into two subgroups: (a) those with non-specific left hemisphere involvement (LD-LH, n = 18) and (b) those with specifically left frontal involvement (LD-LF, n = 7). The neuropsychologically-based classification is one of the diagnostic endpoints of the clinical evaluation and is routinely generated as one component of the patient registry database. Data entry requires the clinician to specify left frontal involvement (LF) where this is the case; left hemisphere involvement (LH) is specified when local LF findings are not present but left hemisphere mechanisms are implicated.

The theoretical and methodological underpinnings (including validity and reliability findings) of this neuropsychological approach are described in detail in Bernstein and Waber (1990) and in Waber, Bernstein, Kammerer, Tarbell, and Sallan (1992). In brief, the neuropsychological assessment process yields findings from areas of developmental history, scores from tests tapping a broad range of neurocognitive functions, and behavioral observations during the assessment. The data are analyzed for convergence of findings in order to identify diagnostic behavioral clusters, organized within a
heuristic model structured by the three primary neuroanatomical axes: anterior-posterior, left-right, cortical-subcortical (Waber et al., 1992, p. 5). Left frontal involvement is characterized primarily by findings of significant language output (including speech production parameters) and sequential processing difficulties; whereas left hemisphere involvement includes findings of global difficulties with language-related tasks, difficulties with language comprehension, difficulties in the processing of detail, both in language and visual processing tasks, and motor difficulties (J. H. Bernstein, personal communication, 1995).

Intellectual quotient (IQ) was not controlled for in subjects in the language-based learning disorder groups (LD-LH, LD-LF) for two primary reasons:

1. Some selection is already operating in children referred to the Learning Disabilities Clinic of the Children's Hospital, Boston, MA. The primary reason for referral is learning disorder and associated academic difficulties. Children with psychiatric and/or neurological conditions and those suspected of having mental retardation are referred to other clinics within the facility.

2. The author subscribes to the discussion by Waber and Bernstein (1995) suggesting that the R-OCF taps metacognitive factors not identified by instruments.
designed to estimate general intellectual function and questioning discrepancy-based criteria for identifying learning disabilities. All subjects in the learning disorder groups were right-handed as a control measure for issues of laterality of language function.

A clinical control group consisting of a small sample of children with tumors (tumor group) in the posterior fossa region of the brain (infratentorial tumors) was identified from records of the Neuropsychology Program. Children with tumors are routinely referred from the Oncology Program for neuropsychological evaluation, and serial evaluations are administered to establish baselines of neurobehavioral function and to monitor progress following identification and treatment. The R-OCF protocols selected for this study from this tumor group were those from the initial neuropsychological evaluation following diagnosis of the condition.

The total number of subjects in this study was 75, with 51 subjects (68%) being male and 24 subjects (32%) being female. Two subjects in the clinical control group (a 10-year-old male with medulloblastoma and an 11-year-old male with a brainstem astrocytoma) were left-handed and all the other subjects were right-handed. This control was established in order to minimize issues of laterality and maximize the inferential power of the study in terms of functional neuroanatomical considerations.
The tumor group included 9 subjects with medulloblastomas, 2 subjects with brainstem astrocytomas, 1 subject with an exophitic brainstem tumor, and 1 subject with a pituitary astrocytoma.

Age groupings included children between the ages of 9 years and 12 years, 11 months, with 21.3% of the children in the sample in the 9-year-old group, 30.7% in the 10-year-old group, 40% in the 11-year-old group, and 8% in the 12-year-old group. Subjects in the study are described in Table 1.

Table 1

| Description of Subjects in the Control, Learning Disorder-Left Hemisphere (LD-LH), Learning Disorder-Left Frontal (LD-LF), and Tumor Groups |
|---|---|---|---|---|
| Age Groups | Control n = 37 | LD-LH n = 18 | LD-LF n = 7 | Tumor n = 13 |
| 9-year olds | 8 | 5 | 1 | 2 |
| 10-year olds | 12 | 6 | 2 | 4 |
| 11-year-olds | 14 | 6 | 2 | 7 |
| 12-year-olds | 3 | 1 | 2 | 0 |

| Sex | | | | |
| --- | --- | --- | --- |
| Female | 12 | 5 | 2 | 5 |
| Male | 25 | 13 | 5 | 8 |
The groups were selected to address questions of sensitivity and specificity:

1. Do error types/patterns elicited by the R-OCF distinguish normal children from children with language-based learning disorders and children with learning disorders secondary to posterior fossa tumors?

2. Do error types/patterns elicited by the R-OCF distinguish children with language-based learning disorders (presumed to reflect primarily cortically-mediated dysfunction) from children with learning disorders secondary to posterior fossa tumors (reflecting primarily subcortical disruption)?

3. Do error types/patterns elicited by the R-OCF distinguish between language-based learning disorders that can be referenced to left frontal brain systems specifically and those referenced to left hemisphere brain systems in general?

**Procedures**

The R-OCF protocols for each of the subjects selected for the study were obtained from clinic records. Routine administration of this test yields three protocols for each subject corresponding to the following conditions: (a) a copy reproduction with the stimulus in front of the subject; (b) an immediate recall/memory reproduction with the stimulus removed from the subject's visual field; and
(c) approximately 20 minutes after the copy reproduction, a delayed recall/memory reproduction, also with the stimulus removed from the subject's visual field.

Subjects in the control group were further selected from those in the normative sample who had been administered the copy and immediate recall conditions, given that in the Waber and Holmes (1985, 1986) standardization study no subject was administered the three conditions. For subjects in the LD-LH, LD-LF, and tumor groups, all three conditions were available.

Each protocol was evaluated for the presence/absence of 10 independent error types—-including 3 error types involving the whole figure (Rotation, Displacement, and Disproportion)—-and 7 error types involving parts of the figure (Omission, Incompletion, Distortion, Misplacement Rotation, Conflation, and Perseveration). The figure was broken into 18 parts according to the procedure devised by Osterrieth (1944). Each part was evaluated for the presence/absence of the 10 independent error types. A diagram depicting the parts listed by Osterrieth, the definitions of the 10 independent error types, and the instructions for their scoring is included in Appendix F.

The error types were selected from the literature reviewed on error production with the Rey figure by both children and adults and from clinical experience. For example, some of the errors included, such as omissions
and rotation of the whole figure, were expected to be seen more frequently in the language-based learning disorder populations, whereas others, such as distortion, were expected--following clinical observation--to be more frequent in the tumor group. Because there was no specific literature on error analysis that would help in making the decision as to which errors should be included or left out, this author chose to survey the various error types and quantify their frequency in the groups included in the study. In addition, scoring criteria for the various error types was also limited in the literature. For this reason, this author devised his own system of scoring by specifying criteria for each of the 10 error types.

Interrater reliability was insured by the author's teaching an independent rater for the study the error scoring system devised. Each error type was reviewed independently with the rater, with examples of scoring of each error type demonstrated by the author for the rater. Protocols selected randomly from a pool of protocols of normal, learning disorder, and tumor children (who were not included in the study) for copy, immediate recall, and delayed recall conditions were consecutively rated by both the author and the independent rater and errors reviewed and discussed until inter-rater agreement reached percentages of 90 and above on each protocol.


Statistics
The protocols were evaluated for error production by an independent rater blind to administration condition and group membership. Twenty percent of all protocols were randomly selected and rated by the author for the computation of interrater reliability. Interrater reliability, established with the Pearson product-moment correlation formula, yielded acceptable coefficients with the exception of coefficients for displacement of the whole figure, incompletion of parts, and rotation of parts, which were moderately low. Difficulties establishing acceptable reliability for these error types may have stemmed from ambiguity in the scoring criteria and limitations in the process of teaching the scoring system so that it possibly did not reflect the range of error phenomena present in the rating situation. Percentages of interrater agreement based on reliability coefficients for the 10 error types are shown in Table 2 (p. 49).

Frequencies, means, and standard deviations for each error type, for all groups, and across administration conditions were computed. A repeated measures analysis of variance (ANOVA) was used to determine group by error type interactions. Schaffe contrasts were conducted for all groups and across all administration conditions. Post-hoc analysis for age and sex effects was possible for trend indications only.
<table>
<thead>
<tr>
<th>Error type</th>
<th>Percent agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole Figure Rotation</td>
<td>100</td>
</tr>
<tr>
<td>Whole Figure Displacement</td>
<td>72</td>
</tr>
<tr>
<td>Whole Figure Disproportion</td>
<td>94</td>
</tr>
<tr>
<td>Omission</td>
<td>97</td>
</tr>
<tr>
<td>Incompletion</td>
<td>73</td>
</tr>
<tr>
<td>Distortion</td>
<td>88</td>
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<tr>
<td>Misplacement</td>
<td>88</td>
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<tr>
<td>Rotation-Part</td>
<td>69</td>
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<tr>
<td>Conflation</td>
<td>79</td>
</tr>
<tr>
<td>Perseveration</td>
<td>91</td>
</tr>
</tbody>
</table>
Initial comparison of scores for the learning disorder-left hemisphere (LD-LH) group and the learning disorder-left frontal (LD-LF) group through a two-tailed t test indicated the means of these groups for frequency of error types in reproductions of the R-OCF under the copy condition, the recall condition, and the delayed recall condition were for the most part not significantly different from each other. The following exceptions were noted: (a) For Displacement of the whole figure under the copy condition, a significantly higher percentage of subjects in the LD-LH group (66%) than in the LD-LF group (14%) produced this error type, $t(23, 25) = 2.56, p < .01$. (b) For Displacement of the whole figure under the delayed recall condition, a significantly higher percentage of subjects in the LD-LH group (55%) than in the LD-LF group (0%) produced this error type, $t(23, 25) = 2.184, p < .009$.

The difference between group means for Omission of parts under the immediate recall condition approached significance; the LD-LH group had a higher frequency of this error type ($M = 6.44, SD = 2.83$) than the LD-LF group ($M = 4.28, SD = 1.49$), $t(23, 25) = 1.90, p < .07$. 

50
The literature reviewed in this study (Bernstein & Waber, 1990; Waber et al., 1992) supports the notion that the LD-LH and LD-LF groups are different in their performance patterns when reproducing visual material such as the R-OCF. In addition, the results of this study strongly indicate the possibility that these two groups are different in their error production patterns, a possibility that can only be ascertained by conducting a study with a larger sample. For this reason, the productions of the LD-LF group (n = 7) were dropped from further analysis.

Results of a one-way ANOVA for total number of errors in reproductions of the R-OCF under the copy condition indicated significant differences among means, \( F(2, 68) = 8.77, p < .0004 \), for the control group (\( M = 11.70, SD = 5.07 \)), the LD-LH group (\( M = 18.00, SD = 10.64 \)), and the tumor group (\( M = 21.15, SD = 9.39 \)). Schaffe contrasts showed no significant difference between the LD-LH and tumor groups for total number of errors under the copy condition; however, both the LD-LH and tumor groups produced a significantly higher number of errors than the control group under this condition.

The one-way ANOVA for total number of errors in reproductions of the R-OCF under the immediate recall condition also indicated significant differences among means, \( F(2, 68) = 8.03, p < .0008 \), for the control group
(M = 19.94, SD = 6.37), the LD-LH group (M = 23.05, SD = 6.05), and the tumor group (M = 25.46, SD = 6.52). Schaffe contrasts showed that the difference between the LD-LH and tumor groups in mean number of errors under the immediate recall condition approached significance at the .11 level and that both the LD-LH and tumor groups produced a significantly higher number of errors than the control group under this condition.

A two-tailed t test for total number of errors in reproductions of the R-OCF under the delayed recall condition indicated no significant difference between means, t(29, 31) = 1.21, p < .23, for the LD-LH group (M = 66.27, SD = 21.90) and the tumor group (M = 71.84, SD = 19.93).

The post-hoc analysis revealed no significant differences in sex by age interactions for mean scores of the LD-LH, tumor, and control groups on reproductions of the R-OCF, \( \chi^2(3, N = 75) = 5.92, p < .12 \). There were no significant age by group effects.

Percentages of subjects in the LD-LH, tumor, and control groups producing whole figure errors (Rotation, Displacement, and Disproportion) in reproductions of the R-OCF under the copy, immediate recall, and delayed recall conditions are included in Table 3 (p. 53). Means and standard deviations from the ANOVA and Schaffe contrasts for frequency of errors (Omission, Incompletion,
Table 3

Percentages of Subjects in the Learning Disorder-Left Hemisphere (LD-LH), Tumor, and Control Groups Producing Whole Figure Errors Across Copy, Immediate Recall (IR), and Delayed Recall (DR) Conditions

<table>
<thead>
<tr>
<th>Error type</th>
<th>LD-LH (n = 18)</th>
<th>Tumor (n = 13)</th>
<th>Control (n = 37)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Copy</td>
<td>IR</td>
<td>DR</td>
</tr>
<tr>
<td>Rotation</td>
<td>22</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>Displacement</td>
<td>67</td>
<td>72</td>
<td>56</td>
</tr>
<tr>
<td>Disproportion</td>
<td>55</td>
<td>72</td>
<td>72</td>
</tr>
</tbody>
</table>
Distortion, Misplacement, Rotation, Conflation, Perseveration) involving parts of the R-OCF in reproductions by the LD-LH, tumor, and control groups across the copy, immediate recall, and delayed recall conditions are included in Table 4 (pp. 55-58).

Schaffe contrasts indicated that under the copy condition, subjects in the LD-LH group were the only ones to produce Rotation of the whole figure errors, \( f(2, 68) = 6.83, p < .002 \). For the immediate recall condition, there was no significant difference between the LD-LH and tumor groups in percentage of subjects producing this error type, but a significantly higher percentage of subjects in those groups than in the control group produced Rotation of the whole figure errors, \( f(2), 68) = 6.51, p < .002 \). For the delayed recall condition, again there was no significant difference between the LD-LH and tumor groups, \( f(1, 31) = .03, p < .43 \), in percentage of subjects producing this error type.

Schaffe contrasts revealed no significant differences between the LD-LH and tumor groups in percentage of subjects producing errors of Displacement of the whole figure under the copy and immediate recall conditions. However, a significantly higher percentage of subjects in the LD-LH and tumor groups than in the control group produced Displacement of the whole figure errors under the copy condition, \( f(2, 68) = 3.09, p < .05 \), and immediate
Table 4

Means, Standard Deviations, and Schafffe Contrasts for Errors Involving Parts of the Figure Produced by the Learning Disorder-Left Hemisphere (LD-LH), Tumor, and Control Groups Across Conditions

<table>
<thead>
<tr>
<th>Condition</th>
<th>LD-LH (n = 18)</th>
<th>Tumor (n = 13)</th>
<th>Control (n = 37)</th>
<th>f</th>
<th>Contrasts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Omission</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Copy</td>
<td>1.44(1.69)</td>
<td>1.54(1.20)</td>
<td>0.59(1.19)</td>
<td>3.73*</td>
<td>1=2, 1&gt;3, 2&gt;3</td>
</tr>
<tr>
<td>Immediate recall</td>
<td>6.44(2.83)</td>
<td>5.77(2.90)</td>
<td>4.32(2.78)</td>
<td>3.81*</td>
<td>1=2, 1&gt;3, 2&gt;3</td>
</tr>
<tr>
<td>Delayed recall</td>
<td>5.44(2.55)</td>
<td>6.08(2.19)</td>
<td></td>
<td>0.50</td>
<td>2=3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incompletion</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Copy</td>
<td>1.67(1.33)</td>
<td>1.46(1.13)</td>
<td>1.30(1.24)</td>
<td>0.54</td>
<td>1=2, 1=3, 2=3</td>
</tr>
<tr>
<td>Immediate recall</td>
<td>2.50(1.25)</td>
<td>2.92(1.89)</td>
<td>2.43(1.32)</td>
<td>0.58</td>
<td>1=2, 1=3, 2=3</td>
</tr>
<tr>
<td>Delayed recall</td>
<td>2.39(1.09)</td>
<td>2.67(1.56)</td>
<td></td>
<td>0.33</td>
<td>2=3</td>
</tr>
</tbody>
</table>

Continued, next page
<table>
<thead>
<tr>
<th>Condition</th>
<th>LD-LH (n = 18)</th>
<th>Tumor (n = 13)</th>
<th>Control (n = 37)</th>
<th>f</th>
<th>Contrasts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distortion</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Copy</td>
<td>6.72(3.43)</td>
<td>9.23(3.44)</td>
<td>5.24(2.39)</td>
<td>9.24**</td>
<td>1&lt;2, 1&gt;3, 2&gt;3</td>
</tr>
<tr>
<td>Immediate recall</td>
<td>6.06(2.10)</td>
<td>7.54(2.76)</td>
<td>6.24(2.06)</td>
<td>2.04</td>
<td>1&lt;2, 1=3, 2&gt;3</td>
</tr>
<tr>
<td>Delayed recall</td>
<td>7.72(2.40)</td>
<td>7.92(1.78)</td>
<td></td>
<td>0.06</td>
<td>2=3</td>
</tr>
<tr>
<td>Misplacement</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Copy</td>
<td>2.56(2.28)</td>
<td>3.00(2.27)</td>
<td>1.57(1.44)</td>
<td>3.56*</td>
<td>1=2, 1&gt;3, 2&gt;3</td>
</tr>
<tr>
<td>Immediate recall</td>
<td>3.50(2.09)</td>
<td>4.46(2.11)</td>
<td>2.81(1.88)</td>
<td>3.44*</td>
<td>1=2, 1=3, 2&gt;3</td>
</tr>
<tr>
<td>Delayed recall</td>
<td>4.11(1.88)</td>
<td>4.67(2.64)</td>
<td></td>
<td>0.45</td>
<td>2=3</td>
</tr>
</tbody>
</table>
Table 4 (continued)

<table>
<thead>
<tr>
<th>Condition</th>
<th>LD-LH (n = 18)</th>
<th>Tumor (n = 13)</th>
<th>Control (n = 37)</th>
<th>f</th>
<th>Contrasts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rotation of parts</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Copy</td>
<td>1.22(1.48)</td>
<td>1.08(1.32)</td>
<td>0.54(0.99)</td>
<td>2.32</td>
<td>1=2, 1&gt;3, 2=3</td>
</tr>
<tr>
<td>Immediate recall</td>
<td>0.83(1.10)</td>
<td>1.08(1.12)</td>
<td>0.84(0.90)</td>
<td>0.31</td>
<td>1=2, 1=3, 2=3</td>
</tr>
<tr>
<td>Delayed recall</td>
<td>1.72(1.41)</td>
<td>1.50(1.51)</td>
<td></td>
<td>0.17</td>
<td>2=3</td>
</tr>
<tr>
<td>Conflation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Copy</td>
<td>0.33(0.77)</td>
<td>0.85(0.90)</td>
<td>0.32(0.58)</td>
<td>2.89</td>
<td>1&lt;2, 1=3, 2&gt;3</td>
</tr>
<tr>
<td>Immediate recall</td>
<td>0.61(0.70)</td>
<td>1.15(0.90)</td>
<td>0.65(1.09)</td>
<td>1.52</td>
<td>1=2, 1=3, 2&gt;3</td>
</tr>
<tr>
<td>Delayed recall</td>
<td>0.72(1.18)</td>
<td>1.08(0.90)</td>
<td></td>
<td>0.80</td>
<td>2=3</td>
</tr>
</tbody>
</table>

Continued, next page
Table 4 (continued)

<table>
<thead>
<tr>
<th>Condition</th>
<th>LD-LH (n = 18)</th>
<th>Tumor (n = 13)</th>
<th>Control (n = 37)</th>
<th>f</th>
<th>Contrasts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perseveration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Copy</td>
<td>2.61(2.23)</td>
<td>2.92(2.43)</td>
<td>1.41(1.30)</td>
<td>4.64*</td>
<td>1=2, 1&gt;3, 2&gt;3</td>
</tr>
<tr>
<td>Immediate recall</td>
<td>1.44(1.58)</td>
<td>1.38(1.39)</td>
<td>1.86(1.36)</td>
<td>0.83</td>
<td>1=2, 1=3, 2=3</td>
</tr>
<tr>
<td>Delayed recall</td>
<td>1.61(2.09)</td>
<td>1.92(1.38)</td>
<td></td>
<td>0.20</td>
<td>2=3</td>
</tr>
</tbody>
</table>

*p < .05. **p < .01.
recall condition, $f(2, 68) = 9.21, p < .0003$. There was a tendency for the percentage of subjects in the LD-LH and tumor groups producing Displacement of the whole figure errors to increase relative to control subjects under the immediate recall condition. There was no significant difference between the LD-LH and tumor groups for this error type under the delayed recall condition, $f(1, 31) = .02, p < .88$.

Schaffe contrasts showed no significant differences between the LD-LH, tumor, and control groups in percentage of subjects producing Disproportion of the whole figure errors under the copy condition, $f(2, 68) = .77, p < .46$. Under the immediate recall condition, a significantly higher percentage of subjects in the LD-LH group than in the tumor group produced Disproportion of the whole figure errors, $f(2, 68) = 4.05, p < .02$, but there was no significant difference between the LD-LH group and the control group in this respect. There was a tendency for the percentage of subjects in the LD-LH group producing Disproportion of the whole figure errors to increase relative to controls under the immediate recall condition. There was no significant difference between the LD-LH and tumor groups for this error type under the delayed recall condition, $f(1, 31) = .10, p < .75$.

Schaffe contrasts indicated there was no significant difference between the LD-LH and tumor groups in
frequency of errors of Omission of parts for either the copy or immediate recall condition, but both these groups produced significantly higher frequencies of this error type than the control group under the copy and immediate recall conditions. The data indicate this trend increased significantly in the LD-LH group relative to the control group under the immediate recall condition as compared with the copy condition. There was no significant difference between the LD-LH and tumor groups in frequency of Omission of parts under the delayed recall condition.

Schaffe contrasts indicated no significant differences in frequency of errors involving Incompletion of parts among the LD-LH, tumor, and control groups across the three administration conditions.

Schaffe contrasts revealed the tumor group produced a significantly higher frequency of errors of Distortion of parts than the LD-LH or control group under the copy condition. In addition, the LD-LH group produced a significantly higher frequency of this error type than the control group under the copy condition. Under the immediate recall condition, the LD-LH, tumor, and control groups did not produce frequencies of errors of Distortion of parts significantly different from the population mean. However, the tumor group produced a significantly higher frequency of Distortion of parts than the LD-LH or control group under the immediate recall condition, but there was
no significant difference in this respect between the LD-LH and control groups. There was no significant difference between the LD-LH and tumor groups in frequency of Distortion of parts under the delayed recall condition.

Schaffe contrasts showed there was no significant difference between the LD-LH and tumor groups in frequency of errors of Misplacement of parts under the copy condition; however, these two groups produced significantly higher frequencies of this error type than the control group under this condition, with the tendency being more pronounced for the tumor group. For the immediate recall condition, no significant difference was noted between the LD-LH and tumor groups or between the LD-LH and control groups in frequency of errors of Misplacement of parts. On the other hand, the tumor group produced a significantly higher frequency of this type of error than the control group under the immediate recall condition.

Although no significant differences were found between the means of the LD-LH, tumor, and control groups and the population means for frequency of errors of Rotation of parts across the three administration conditions, Schaffe contrasts indicated the LD-LH group produced a significantly higher frequency of this type of error than the control group under the copy condition. Although the tumor group did not produce frequencies of
of this type of error under the three conditions that were significantly different from those of the control group, the differences approached significance, with the tumor group showing a trend of producing more of this type of error than the control group under the copy condition.

Schaffe contrasts revealed no significant difference between the LD-LH and tumor groups in frequency of errors of Perseveration of parts under the copy condition, but both groups produced significantly higher frequencies of this type of error than the control group, with the level of significance being larger for the tumor group and control group contrast. There were no significant differences among the LD-LH, tumor, and control groups in frequency of errors of Perseveration of parts under the immediate recall condition. Likewise, there was no significant difference in this respect between the LD-LH and tumor groups for the delayed recall condition.
CHAPTER 5
DISCUSSION

There were two purposes for this study. The first was to determine whether error production types/patterns in children's reproductions of the Rey-Osterrieth Complex Figure (R-OCF) could be used to distinguish normal control subjects from children with language-based learning disorders (LD-LH group) and children with learning disorders secondary to posterior fossa tumors (tumor group).

The findings of this study provide strong evidence that error analysis can distinguish normal children from children in clinical groups. Both the LD-LH group and the tumor group produced significantly higher frequencies of errors than the control group in copy and immediate recall reproductions of the R-OCF.

The error types that discriminated both the LD-LH group and tumor group from the control group in the copy condition included Displacement of the whole figure, Omission, Distortion, Misplacement, and Perseveration. Rotation of the whole figure and Rotation of parts were error types that also discriminated the LD-LH group, but not the tumor group, from the control group in the copy condition. (It is important to note than no subject in
the control or tumor groups produced a Rotation of the whole figure under the copy condition and that inspection of the protocols revealed that all instances of this error type by LD-LH subjects involved a 90 degree counterclockwise rotation of the figure. Conflation errors discriminated the tumor group, but not the LD-LH group, from the control group in the copy condition.

Rotation of the whole figure, Displacement of the whole figure, and Omission errors discriminated both the LD-LH group and the tumor group from the control group in the immediate recall condition. Distortion, Misplacement, and Conflation errors also discriminated the tumor group, but not the LD-LH group, from the control group in the immediate recall condition. Unexpectedly, lower frequencies of errors of Disproportion of the whole figure discriminated the tumor group from the control group in the immediate recall condition, whereas no significant difference was found between the LD-LH group and the control group for this error type.

These results are consistent with findings of Hagberg (1985), Jaimes (1985), Waber et al. (1994), and Waber and Bernstein (1995) of higher incidence of error production in reproductions of the R-OCF in children with learning disorders when compared with reproductions of normal children. The data indicate that a higher incidence of error production (e.g., Omission of parts) or the
production of specific error types (e.g., Rotation of the whole figure) across copy and immediate recall conditions has diagnostic significance in differentiating normal and clinical groups.

The data lend evidence to the assumption that the statistically significant differences in error production between normal and clinical groups observed in this study reflect disruptions in the neural systems mediating performance on a complex visual-constructional task such as the R-OCF. In the case of the LD-LH group, primarily left hemisphere cortical structures are presumed to be involved, with disruption of neurodevelopmental growth associated with neurodevelopmental disorder. For the tumor group, subcortical structures are presumed to be primarily involved with disruption to normal neurodevelopmental growth associated with a neurological event (a tumor).

The second purpose of this study was to determine (a) if error production types/patterns in children's reproductions of the R-OCF could distinguish children with language-based learning disorders (presumed to reflect primarily cortically-mediated dysfunction) from children with learning disorders secondary to posterior fossa tumors (presumed to reflect primarily subcortically-mediated disruption) and (b) if error production types/patterns in children's reproductions of the R-OCF could
distinguish children with language-based learning disorders that can be referenced to left frontal brain systems specifically (LD-LF group) from children with language-based learning disorders that can be referenced to left hemisphere brain systems in general (LD-LH group).

The second purpose of the study was achieved in part. An initial comparison of the LD-LF and LD-LH groups suggested they were not significantly different from each other in error production on reproductions of the R-OCF. Given the low number of subjects in the LD-LF group, it could not be reasonably assumed that there were no significant differences between this group and the LD-LH group or the control group. Consequently, the data collected for the LD-LF group were not included in the analysis.

However, results of the two-tailed t test conducted for the mean scores of these two groups do suggest some differences in error production between them. The LD-LH group produced more Displacement of the whole figure errors in the copy and immediate recall reproductions of the R-OCF and more Omission of parts errors in the immediate recall reproductions than did the LD-LF group. These findings, although constrained by a small sample size, raises the possibility that neuropsychologically, the mechanisms involved in the production of these (clinically significant) errors in the reproduction of
complex geometric configurations by language-based learning disorder children are differentially distributed within the left hemisphere.

Clinical experience suggests that children with left hemisphere impairments may have different visual field preferences than those of normal children. A preference for drawing the figure on the left side of the horizontally-aligned paper (the left side of visual space, ipsilateral to the side of presumed hemispheric lesion and mediated presumably by the nonimpaired hemisphere—-the right) is often observed in these children's reproductions of the R-OCF. In addition, omission of details in copy and especially in memory reproductions of the figure has been associated with left hemisphere impairment as well.

The findings presented concerning the LD-LH group point to the possibility of differentiating the mechanisms within the left hemisphere mediating these performance characteristics. This issue of relevance to error production on the R-OCF and developmental neuropsychological assessment awaits exploration through a research protocol with a larger sample size.

Although there were no significant differences in frequencies of errors between the LD-LH and tumor groups under the copy and immediate recall conditions, the data suggest a trend for error frequency to increase in the tumor group as compared with the LD-LH group under the
immediate recall condition. Also, the level of statistical significance in the contrasts between groups increased substantially for the tumor and control group versus the LD-LH and control groups in both the copy and immediate recall conditions. One possibility is that these statistical findings reflect a higher level of central nervous system disruption in the systems mediating a complex visual-constructional task such as the R-OCF in subjects in the tumor group as compared with subjects in the LD-LH group.

Rotation of the whole figure was the error type that discriminated the LD-LH group from the tumor group in the copy condition, with no subjects in the tumor group producing this type of error. Distortion and Conflation errors also discriminated the LD-LH group from the tumor group in the copy condition with the tumor group producing significantly higher frequencies of these error types.

Disproportion of the whole figure and Distortion were the error types that discriminated the LD-LH and tumor groups in the immediate recall condition, with the LD-LH group producing a higher frequency of Disproportion of the whole figure and the tumor group producing a higher frequency of Distortion errors. No significant differences emerged between the LD-LH and tumor groups in frequency of errors or in contrasts for each of the error types in the delayed recall condition.
The differences in error production in reproductions of the R-OCF between the clinical groups in this study and the control group were striking across copy and immediate recall conditions. Frequency of error production across a variety of error types reliably differentiated control children from those in the clinical groups.

Specific error types involving the whole figure were drastically different between the clinical groups and the control group. For example, no subject in the control group produced a Rotation of the whole figure in copy or immediate recall reproductions; subjects in the control group produced few Displacement of the whole figure errors in comparison with subjects in the clinical groups.

The question is raised as to the cognitive processes underlying these differences. It is possible that these error types reflect neuropsychologically relevant differences in the integration of visual fields expressed in the reproduction of a complex visual array by children in clinical groups. The following are recommendations to improve the scoring of errors involving the whole figure and to increase their discriminant power:

1. For Rotation of the whole figure, establish a metric for measuring the degree of rotation of the figure and its direction (clockwise or counterclockwise).
2. For Displacement of the whole figure, establish a metric for measuring the direction of the displacement along the vertical and horizontal axes.

3. For Disproportion of the whole figure, establish a metric for measuring the magnitude of the disproportion and its direction along the vertical and horizontal axes.

Regarding errors involving parts of the figure, although the results of this study clearly identified error types and patterns of error production that differentiated control subjects from subjects in the LD-LH and tumor groups and subjects in the LD-LH group from those in the tumor group, further specification of the scoring system is required to increase its discriminant power and to elucidate the neuropsychological significance of the various error types in relation to normal and clinical group membership. For example, the significance of Incompletion versus Distortion errors is not altogether evident when R-OCF productions of tumor group subjects are being evaluated, given the high level of fragmentation (distortion) observed in the protocols used in this study.

Also, the relationship between error production and part cannot be evaluated with the scoring system used in this study. This is particularly relevant, given research cited in this study as to the differential saliency of different structural components of the figure for different groups. Children with learning disorders (and
adults with brain damage, as well) fail to grasp the main structural components of the R-OCF and consequently they have a deficient or fragmented framework on which to hang, so to speak, the details and incidental components of the figure. This neuropsychological process, labeled "superordinate chunking" by Van Sommers (1989, p. 125) and described as "metacognitive factors" mediating visuo-spatial performance by Waber et al. (1994), may be a significant source of variance differentiating normal subjects from clinical subjects and subjects within clinical groups, as well as account for differences between copy and memory productions.

A system that isolates the organizing scheme components of the figure (base rectangle and main substructures) and its incidental feature components (appended structures and details; Waber et al., 1989) and evaluates error separately for each of these components/features may yield a broader range of statistical as well as qualitative differences between these groups with regard to error production. Also, providing an accuracy score for counting error over total number of parts reproduced will provide a more exact measure of error in each of these groups and across administration conditions. Finally, establishing correlations between the various error types and with the organization and style parameters of the Waber and Holmes (1985, 1986) developmental scoring
system may yield relevant information as to the utility of error analysis as an adjunct to a formal scoring system constructed specifically to evaluate children.

A significant strength of this research has been the use of a fairly large database that included normal control subjects matched to subjects from two clinical groups according to age, sex, and handedness. Given the scarcity of research with children and the R-OCF, the use of two groups of children with learning disorders is an important contribution. The inclusion of a posterior fossa tumor group has special significance for clinical child neuropsychology given the particular characteristics of this population. A limitation of this research is the sample size, which precluded the comparison between the LD-LH and LD-LF groups and created problems of statistical power. This results of this research provide conclusive evidence of the utility of error analysis of children's reproductions of the R-OCF in discriminating normal and clinical groups.
APPENDIX A

ILLUSTRATIONS OF THE REY-OSTERRIETH COMPLEX FIGURE
Figure 1

The Rey-Osterrieth Complex Figure
Figure 2

Illustration of the process of chunking

The figure upper left is the copy production of an 11-year-old normal subject. Inspection of the color code reveals a strategy of reproduction consisting of constructing the main rectangle and main internal structures of the figure as a single unit (blue) and proceeding to append internal and external structures and details to the main configuration (purple, brown, green). The figure upper right is the copy production of an 11-year-old subject from the language-based learning disorder group. The color code reveals a strategy of reproduction by which the main rectangle and main internal structures are reproduced in a fragmented manner (blue, green, black) without clear differentiation among the components of the figure. The figure at the bottom is that of an 11-year-old subject from the tumor group. Notice the increase in fragmentation revealed by the color code (blue, green, black, orange).
Figure 3

Structural components and intersections and alignments for the R-OCF

Figure 4

Representative examples of copy productions of each of the five levels of organization of the Rey-Osterrieth Complex Figure

Figure 5

Representative examples of memory productions of each of the five levels of organization of the Rey-Osterrieth Complex Figure

Figure 6

Organizing scheme components (top) and incidental feature components (bottom) for the Rey-Osterrieth Complex Figure

Note. From "Metacognitive Factors in the Visuospatial Skills of Long-Term Survivors of Acute Lymphoblastic Leukemia: An Experimental Approach to the Rey-Osterrieth Complex Figure Test," by D. P. Waber, P. K. Isquith, C. M. Kahn, I. Romero, S. E. Sallan, & N. J. Tarbell, 1994, Developmental Neuropsychology, 10, 349-367.
Figure 7

Configurational and linear presentations of the Rey-Osterrieth Complex Figure

Note. From "Metacognitive Factors in the Visuospatial Skills of Long-Term Survivors of Acute Lymphoblastic Leukemia: An Experimental Approach to the Rey-Osterrieth Complex Figure Test," by D. P. Waber, P. K. Isquith, C. M. Kahn, I. Romero, S. E. Sallan, & N. J. Tarbell, 1994, Developmental Neuropsychology, 10, 349-367.
APPENDIX B

OSTERRIETH'S SCORING SYSTEM FOR THE REY-OSTERRIETH COMPLEX FIGURE

<table>
<thead>
<tr>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Cross upper left corner, outside of rectangle</td>
</tr>
<tr>
<td>2. Large rectangle</td>
</tr>
<tr>
<td>3. Diagonal cross</td>
</tr>
<tr>
<td>4. Horizontal midline of 2</td>
</tr>
<tr>
<td>5. Vertical midline</td>
</tr>
<tr>
<td>6. Small rectangle, within 2 of the left</td>
</tr>
<tr>
<td>7. Small segment above 6</td>
</tr>
<tr>
<td>8. Four parallel lines within 2, upper left</td>
</tr>
<tr>
<td>9. Triangle above 2 upper right</td>
</tr>
<tr>
<td>10. Small vertical line within 2, below 9</td>
</tr>
<tr>
<td>11. Circle with three dots within 2</td>
</tr>
<tr>
<td>12. Five parallel lines within 2 crossing 3, lower right</td>
</tr>
<tr>
<td>13. Sides of triangle attached to 2 on right</td>
</tr>
<tr>
<td>14. Diamond attached to 13</td>
</tr>
<tr>
<td>15. Vertical line within triangle 13 parallel to right vertical of 2</td>
</tr>
<tr>
<td>16. Horizontal line within 13, continuing 4 to right</td>
</tr>
<tr>
<td>17. Cross attached to 5 below 2</td>
</tr>
<tr>
<td>18. Square attached to 2, lower left</td>
</tr>
</tbody>
</table>

Scoring
Consider each of the 18 units separately. Appraise accuracy of each unit and relative position within the whole of the design. For each unit count as follows:

<table>
<thead>
<tr>
<th>Correct</th>
<th>placed properly</th>
<th>2 points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distorted or incomplete but</td>
<td>placed properly</td>
<td>1 point</td>
</tr>
<tr>
<td>recognizable</td>
<td>placed poorly</td>
<td>1/2 point</td>
</tr>
<tr>
<td>Absent or not recognizable</td>
<td></td>
<td>0 points</td>
</tr>
<tr>
<td>Maximum</td>
<td></td>
<td>36 points</td>
</tr>
</tbody>
</table>

APPENDIX C

CRITERIA OF THE WABER AND HOLMES DEVELOPMENTAL SCORING SYSTEM FOR THE FIVE LEVELS OF ORGANIZATION FOR COPY PRODUCTIONS OF THE REY-OSTERRIETH COMPLEX

FIGURE

Level I: Any production that does not satisfy criteria for Level II.

Level II: (1) Upper left corner of base rectangle and one other corner.

(2) Left vertical of base rectangle aligned.

(3) Middle vertical of base rectangle aligned.

(4) Three of 6 of the following aligned: Upper horizontal of base rectangle; middle vertical of base rectangle aligned with upper right cross; middle horizontal of base rectangle aligned with horizontal of external right triangle; right vertical of base rectangle aligned; lower horizontal aligned at middle of base rectangle.

Level III: (1) Both corners on left side of base rectangle and one on the right.

(2) Two of three sides of base rectangle (excluding left side).

(3) One of three outer configuration structures aligned with main horizontal and vertical.

(4) Diagonals of left interior box intersect.

(5) Upper right triangle intersects right corner appropriately.

Level IV: (1) All four corners of base rectangle.

(2) All sides of base rectangle aligned.

(3) Two of three outer configuration structures aligned with main horizontal and vertical.
(4) Main diagonals of horizontal and vertical intersect.
(5) Two left corners and one right of left interior box touch base rectangle and main diagonal appropriately.

Level V:  
(1) All three outer configuration structures aligned with main horizontal and vertical.
(2) Diagonals and horizontal and vertical all intersect.
(3) All four corners of left interior box touch appropriately.

APPENDIX D

CRITERIA OF THE WABER AND HOLMES DEVELOPMENTAL
SCORING SYSTEM FOR THE STYLE PARAMETER
FOR COPY PRODUCTIONS OF THE
REY-OSTERRIETH COMPLEX
FIGURE

The variable is scored if the adjacent segments are
produced in the same color and are properly aligned: the
whole line is judged as drawn continuously. There are 18
criterial style features belonging to 5 general categories:

I: (3) The central intersection (diagonals and main
vertical).

II: (3) The main horizontal.

III: (4) The four corners of the base rectangle.

IV: (4) The four sides of the base rectangle.

V: (4) The four major points where the outer
configurational structures join the base
rectangle.

Note. From The Rey-Osterrieth Complex Figure: Two studies
on children with learning disability, by I. C. Hagberg,
1985, unpublished doctoral dissertation, Neurologischen
Universitätsklinik, Zurich, Switzerland.
APPENDIX E

CRITERIA OF THE WABER AND HOLMES DEVELOPMENTAL SCORING SYSTEM FOR THE FIVE LEVELS OF ORGANIZATION FOR MEMORY PRODUCTIONS OF THE REY-OSTERRIETH COMPLEX FIGURE

Level I: Any design that does not satisfy criteria for Level II.

Level II: (1) Upper and lower left corner of base rectangle.

(2) Left side of base rectangle aligned.

(3) Lower horizontal of base rectangle aligned at the middle.

(4) Lower horizontal aligned at lower left box or middle horizontal aligned at left center box or upper horizontal aligned.

Level III: (1) Upper and lower left corner of base rectangle.

(2) Lower right corner of base rectangle.

(3) Four sides of base rectangle aligned.

(4) Middle vertical aligned at center or middle horizontal aligned at left center box or main horizontal and vertical intersect or main diagonals intersect.

Level IV: (1) Upper and lower left corner of base rectangle.

(2) Lower right corner of base rectangle.

(3) Four sides of base rectangle aligned.

(4) Diagonals of base rectangle intersect.

(5) Main horizontal and vertical intersect or middle vertical aligned at center or middle horizontal aligned at left center box.
Level V: (1) Four corners of base rectangle aligned.
(2) Four sides of base rectangle aligned.
(3) Main horizontal and vertical aligned.
(4) Diagonals aligned.
(5) Horizontal, vertical, and diagonals intersect.

APPENDIX F

SYSTEM FOR SCORING ERROR PRODUCTION IN THE REY-OSTERRIETH COMPLEX FIGURE

The error scoring system presented here provides the rater with a set of rules for scoring 11 independent types of errors on the Rey-Osterrieth Complex Figure. Because the analysis of error is considered as an adjunct (vs. a substitute) to existing scoring systems, it is not exhaustive; that is, it does not consider every possible type of error in constructing the complicated Rey figure. The system is exclusive, and this is achieved by applying a set of rules to scoring each error and ignoring exceptions.

The rater must follow scoring rules strictly. Deviations from scoring rules are not to be scored.

Shown below is a model of the Complex Figure as created by Andre Rey in 1941. The dimensions and orientation are that of the original figure as used for the purposes of this project and for clinical evaluation and research. Marked with a dotted line is an extra part attached to item #18 of the listing of parts according to Osterrieth (1944), namely, the square attached to the lower left part of the base rectangle. The rater will find this extra part reproduced in some of the protocols in this research. This extra part is to be ignored and not scored or considered in any way by the rater.
Below is a listing of the parts of the figure as devised by Osterrieth (1944) and a diagram of the figure with the numerated parts. There are 18 items/parts listed with their corresponding abbreviations as they appear on the Scoring Sheet. THE RATER MUST SCORE EACH PART INDEPENDENTLY FOR ERROR.

1. Cross upper left corner (CUL), outside of rectangle.
2. Base rectangle (BR)
3. Diagonal cross (DC)
4. Horizontal midline (HM) of base rectangle
5. Vertical midline (VM) of base rectangle
6. Small rectangle (SR) within base rectangle, left side
7. Small segment above #6 (SS)
8. Four parallel lines (PL) within base rectangle, upper left
9. Triangle (T) above base rectangle, upper right
10. Small vertical (SV) line within base rectangle, upper right
11. Circle (C) with three dots
12. Five parallel lines (FPL) crossing lower right diagonal
13. Sides of triangle (ST) attached to right side of base rectangle
14. Diamond (D) attached to side triangle
15. Vertical line (VL) within right triangle
16. Horizontal line (HL) within right triangle
17. Cross (LCC) attached to low center
18. Square (SQ) attached to base rectangle, lower left
Following is a list of error types to be used in this research project, with their definitions or set of rules for scoring and visual examples of each type of error.

Each error type is to be scored on the Scoring Sheet as "1" if present, and "0" if not present. WHEN IN DOUBT AS WHETHER TO SCORE AN ERROR AS PRESENT ALWAYS SCORE IT "0."

ERROR TYPE 1: Rotation of the whole figure--the whole figure is rotated from its horizontal presentation, usually 90 degrees counterclockwise, but rotation of more than 10 degrees in any direction is scored.

Paper aligned horizontally

90 degree rotation

30 degree rotation
ERROR TYPE 2: Displacement of the whole figure—the whole figure is shifted from its normally central position, up, down, left, right, or any combination thereof.
ERROR TYPE 3: Disproportion of the whole figure—using the transparent template placed over the reproduction, it is evident from visual inspection that the figure is significantly smaller/larger than the model. DO NOT SCORE IF IN DOUBT. Example below of small figure. Example on following page of large figure.
ERROR TYPE 4: Omission—any of the 18 parts listed is omitted in its totality; PARTIAL OMISSIONS ARE NOT SCORED.
ERROR TYPE 5: Incompletion of a part--the part is present and clearly identifiable but not complete; one or more line segments that form the part are missing.
ERROR TYPE 6: Distortion of a part—the shape of the part is altered in a significant way; the issue of form distinguishes it from Incompletion; when the part is significantly larger/smaller than other parts (an alteration of proportions) Distortion is also scored.
ERROR TYPE 7: Misplacement of a part—a part of the figure is not properly placed; the issue is one of location.
ERROR TYPE 8: Rotation of a part—part of the figure is rotated any number of degrees; a rotation of a part can occur within a figure that is rotated as a whole.

Example 1: Rotation of a part
Example 2: Rotation of a part
ERROR TYPE 9: Conflation of a part--an outer detail is blended with a segment of the base rectangle or outer contour.
ERROR TYPE 10: Perseveration--a part is repeated in its totality (accuracy in reproduction of the part is not necessary for scoring) or extra lines or redrawing of lines is present.
R-OCF SCORING SHEET:  

Whole Figure Error: (score 1=present, 0=not present)  
Type 1. Rotation  
Type 2. Displacement  
Type 3. Disproportion  

Error in parts: (score 1=present, 0=not present)  

Additional Scoring Example
REFERENCES


