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The Effects of Unilateral Brain Damage on Analogical Reasoning by Stroke Patients

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This study examined the ability of individuals with unilateral left hemisphere damage (LHD) and right hemisphere damage (RHD) to complete multiple modality analogy tasks. Four groups, for a total of 46 subjects --12 LHD patients, 8 RHD patients, 20 child control subjects, and 6 adult control subjects--performed word, figure, and picture analogies. The combined non brain damaged control groups performed significantly better than the combined brain damaged experimental groups on the combined analogy tasks. No significant difference was found between the LHD and RHD groups on the combined analogy tasks. The modalities of analogical reasoning tasks did not differentially affect the performances of the LHD patients. However, RHD patients performed significantly better on the Word Set analogies than on the Figure Set analogies. The types of error responses made by the two experimental groups were also compared. LHD patients chose foils that were logically related to the correct answer significantly more frequently than they chose unrelated foils. However, RHD patients did not choose foils that were logically related to the correct answer significantly more frequently than they chose unrelated foils. In general, analogical reasoning abilities of LHD and RHD patients were poorer than the control subjects, but did not differ from each other.
ACKNOWLEDGEMENTS

I would like to dedicate this thesis to my family, those who are living and those who have passed away, for their love, support, and friendship which made this project a fulfilling experience.

I wish to acknowledge the support and guidance from the many individuals who facilitated my completing the thesis. Dr. Nickola Nelson's diligence, patience, and expertise has made this project possible and has taught me an appreciation for research and writing. The other members of my thesis committee who have given time, support and ideas are Mrs. Sandra Glista and Dr. Robert Erickson. I want to thank the staff at Southwestern Michigan Rehabilitation Hospital, especially Bill Locke, for aiding in the search for subjects. Also, special appreciation is given to Ms. Penninah Miller, Director of the Western Michigan Center for Statistical Services, for statistical advice, Mariam Asciutto for her artistic abilities, and my roommates, Alison, Deb, and Michele, for their humor and friendship throughout this project.

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Letitia Lynn Gillespie
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The effects of unilateral brain damage on analogical reasoning by stroke patients

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Western Michigan University, 1987
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CHAPTER I
INTRODUCTION

History of Cerebral Dominance

The idea of cerebral dominance has been of interest to clinical researchers at least since the publication of Broca's observation in the 1860s that the left hemisphere was dominant for language (Springer & Deutsch, 1981). Yet much of the information gathered in this area continues to be speculative.

Traditionally, the left hemisphere has been considered dominant for most linguistic, analytic, and complex mental functions. The right hemisphere has been considered to be the weaker side, dominant for visuospatial, emotional, and holistic operations (McDonald & Wales, 1986; Springer & Deutsch, 1981; and Wapner, Hamby, & Gardner, 1981). Research in the past few years, however, has shown less exclusivity in patterns than expected.

Research Relating to Verbal Processing in the Right Hemisphere

A study by Diggs and Basili (1987) showed patients who have experienced cerebrovascular accidents (CVAs) in the right hemisphere to have difficulty performing lexical-semantic verbal expression tasks. Other studies have shown right hemisphere damaged patients to have problems solving incongruent syllogisms (Caramazza, Gordon, Zurif, & DeLuca, 1976) and drawing proper inferences (Brownell, Potter, Bihrlle, & Gardner, 1986; McDonald & Wales, 1986; Wapner et al., 1981). These results suggest that the right hemisphere may play a greater role in language and
mental processing than earlier theorists had hypothesized.

Understanding Analogical Reasoning

Successful completion of analogy tasks has been used as an indicator of intellectual ability. Spearman (1927a) used analogical tasks to assess general intelligence, or the "g factor." Other theorists utilized analogies to assess specific factors of intelligence (Guilford, 1967; Thurstone, 1938). For example, Guilford (1967) used different types of analogies to measure specific cognitive factors, such as behavioral relations, symbolic relations, and semantic relations.

Analogies are of particular interest for studying the cognitive functioning of the two hemispheres because of the ability to present analogical reasoning stimuli in verbal or graphic form. If the left hemisphere is dominant for linguistic functions and the right hemisphere is dominant for visuospatial operations, then presenting a multiple modality analogies test to persons with unilateral brain damage might contribute to better understanding of hemispheric functioning.

Purpose of the Study

A study of analogical reasoning has implications for understanding the relationships of language and cognitive processing. If individuals with unilateral brain damage have relatively greater difficulty completing various types of analogical reasoning tasks than do non brain damaged individuals, it might indicate the involvement of cognitive processing impairments. Also, if left hemisphere damaged (LHD) or right hemisphere damaged (RHD) patients perform a specific set of analogical reasoning tasks better than another set of analogical reasoning tasks, then diagnosis and remediation techniques might be developed to provide a helpful initial pathway for beginning to improve patients' linguistic and cognitive abilities. Therefore the current study
was designed to assess the effects of unilateral brain damage on the complex operation of analogical reasoning when stimuli are presented in various modalities, as words, pictures, and geometric forms.

The following experimental questions were asked when designing this study:

1. Do brain damaged persons perform more poorly than do non brain damaged persons on analogical reasoning tasks?

2. Do left hemisphere damaged and right hemisphere damaged persons perform differently from each other on analogical reasoning tasks?

3. Do left hemisphere damaged persons perform better on non-linguistically based analogical reasoning tasks than on linguistically based analogical reasoning tasks?

4. Do right hemisphere damaged persons perform better on linguistically based analogical reasoning tasks than on non-linguistically based analogical reasoning tasks?
CHAPTER II

REVIEW OF THE LITERATURE

Evidence for Hemispheric Specialization

Researchers have compared the two cerebral hemispheres of the human brain in order to find physiological similarities and differences. Evidence of difference has been used to support theories of hemispheric specialization. Anatomical and functional asymmetries that have been identified in the left and right hemispheres are discussed below.

Anatomy of the Left and Right Hemispheres

The two cerebral hemispheres are not anatomically symmetrical. Each half has specific regions which are larger than the same regions on the opposite side. For example, Geschwind and Levitsky (1968) determined that the auditory association cortex (Wernicke's Area) and the planum temporale are both significantly larger on the left than on the right. It has also been demonstrated that the posterior part of the third frontal convolution of the left hemisphere, known as Broca's Area, is larger than the corresponding area on the right (Falzi, Perrone, & Vignolo, 1982). Conversely, specific sensory nuclei found in the parieto-occipital area are larger in the right hemisphere than the left (Eidelberg & Galaburda, 1982). Such anatomical asymmetries are consistent with the views that the left hemisphere of the brain is dominant for language, and the right hemisphere is primarily responsible for visuo-spatial processing abilities.
Methods of Measuring Hemispheric Functions

A number of procedures have been established for measuring hemispheric functions. Several are described in this section.

Cerebral Blood Flow to the Hemispheres

Studies using injection of Xenon 133 (a special radioactive isotope) into the cerebral arteries have shown differences in blood flow to the two hemispheres when specific functions are being performed. Gur and Reivich (1980) have shown that a person's performance on verbal tasks significantly increases the cerebral blood flow to the left hemisphere. "These findings ... suggest that the verbal task is more "hard-wired" in the left hemisphere, increasing the blood flow to the left relative to the right hemisphere in all but four of the subjects in this present study [36 right-handed undergraduate students] ..." (pp. 86-87). Conversely, Risberg, Halsey, Wilson, & Willis (1975) found that performance on nonverbal (spatial) tasks increased blood flow to the right hemisphere. These research findings suggest that when a person is required to perform a specific task (e.g., verbal versus spatial) an increase of blood will flow to the hemisphere (left or right) that is "dominant" for that task.

The Wada Amytal Test and the Hemispheres

The Wada test has been developed to determine functions of the cerebral hemispheres. The drug sodium amytal, a barbiturate, is injected into the carotid arteries to suppress temporarily the functions of the ipsilateral hemisphere. The Wada test has been used to show that the left hemisphere is dominant for language in over 90% of right-handers (Wada & Rasmussen, 1960).
Research Relating to Left Hemisphere Function

Much of the current knowledge relating to brain-language interactions has been derived from aphasialanguage disturbances (Brown & Perecman, 1986). Observations of stroke patients throughout the years have linked speech and language difficulties to left hemisphere damage (Springer & Deutsch, 1981). Frequently, these difficulties are classified and associated with the cerebral localization ofaphasia into fluent syndromes that are associated with lesions that occur posterior to the Rolandic Fissure and nonfluent syndromes that are associated with lesions that occur anterior to the Rolandic Fissure (e.g., Benson, 1979; Brookshire, 1986; Chapey, 1986a; and Goodglass & Kaplan, 1983). Broca's aphasia is the classic example of a nonfluent syndrome. The speech of patients with Broca's aphasia is often telegraphic. However,"comprehension of language is better than speech production or writing" (Brookshire, 1986, p. 32). Wernicke's aphasia is the classic example of a fluent syndrome. The speech of patients with Wernicke's aphasia is usually fluent, exhibiting different types of paraphasias. "Auditory comprehension of patients with Wernicke's aphasia is poor" (Brookshire, 1986, p. 33).

Research Relating to Right Hemisphere Function

Studies involving patients with RHD have recently demonstrated that the right hemisphere plays a greater role in language and mental processing than traditional theorists believed. Myers (1978) separated right hemisphere communicative disorders into four categories: (1) visual imagery (i.e., prosopagnosia and some forms of verbal reasoning problems), (2) figurative language, (3) affect, and (4) sense of humor. Difficulties noted in the language and humor areas are particularly pertinent to the current study.
Narrative and Humorous Processing

Wapner et al. (1981) devised a study to assess RHD patients' sensitivity to narrative and humorous material. Four types of stories were presented to 16 RHD patients. One type of story differed by the addition of elements that were categorized as spatial, emotional, or bizarre. The subjects were required to retell the stories and to answer questions about them. Another type of story was used to test the subjects' abilities to arrange a story in the order of events. A third type of story featured fable-like narrative structures, presented in linguistic and nonlinguistic forms. Again, the subjects were required to retell the stories and to answer questions about them. The last type of story featured jokes, for which the subjects were required to choose appropriate punchlines. Hypotheses regarding the types of tasks, such as straight linguistic processing, apprehension of, and integration within, narrative material, and humor, were tested. It was found that the RHD patients had no difficulty with ordinary language processing (i.e., subjects were able to use appropriate phonology and syntax) or with recalling the elementary facts. However, the RHD patients did have problems appreciating and integrating the narrative form of a story (e.g., RHD subjects were correct only 43% of the time when organizing a story into a logical sequence). These patients also had difficulty completing the humor task. They chose endings unrelated to the body of the joke (non sequitur endings) three times as often as normal controls [10 adults aged 45 to 65 and five adults aged 65 to 85]. It was concluded, "while their [RHD patients] ability to remember isolated details and wording is often preserved, they have clear difficulties in integrating specific information, in drawing proper inferences and morals, and in assessing the appropriateness of various facts, situations, and characterizations" (pp. 28-29).
Figurative Language Interpretation

Research by Winner and Gardner (1977) has also shown RHD patients to have difficulty understanding metaphors. The subjects in the Winner and Gardner study were to point to a picture which represented a given metaphoric sentence. Forty-three per cent of the initial responses given by the subjects were metaphoric compared to 73% metaphoric responses for the normal controls (10 subjects of comparable age, education, and socio-economic class). The RHD patients' difficulties were interpreted to indicate that the intact left hemisphere may not ensure comprehension of all linguistic messages.

Inferencing and Verbal Problem Solving Behavior

Brownell, Potter, Bihrlle, and Gardner (1986) tested RHD subjects' ability to draw inferences. It was concluded that RHD subjects had more difficulty drawing inferences than with retention and comprehension of factual information. These patients were able to understand isolated meanings and associations, but were unable to use additional information relevant to a story.

A study by McDonald and Wales (1986) also investigated RHD subjects' ability to make simple inferences. The presentation set for the test contained three items, two of which were premises and one of which was a filler item. After showing the presentation set, RHD subjects were to respond to four recognition tasks: (1) the true premise, (2) the true inference, (3) the false premise, and (4) the false inference. Right hemisphere damaged subjects were able to recognize true premises and inferences. However, they demonstrated significantly poorer performance when attempting to identify false premises and inferences. For example, in the stimulus pair, "Barbara became too bored to finish the history book. She had already spent five years writing
it," RHD subjects would accept the inappropriate inference, "Reading the history book bored Barbara," as the correct inference.

Caramazza et al. (1976) investigated RHD patients' ability to solve syllogisms. Syllogisms require individuals to store given information, make linguistic adjustments, and then logically deduce answers to the questions. For example, in the syllogism "A is taller than B; who is taller?," the individual must encode that "A is tall" more than "B is tall," distinguish the concepts of "more" and "most" (or in this case, "taller" and "tallest"), and then determine that "A" is taller than "B." Congruent and incongruent syllogism tasks were presented by Caramazza and associates to their RHD subjects. An example of a congruent syllogism is "John is taller than Bill, who is taller?" An example of an incongruent syllogism is "John is taller than Bill, who is shorter?" Caramazza et al. found that the RHD patients had a significant degree of difficulty solving the incongruent tasks (i.e., the premise and question having antonymic adjectives). "Our findings suggest, therefore, that verbal reasoning requires at some stage the formation of right-hemispherically based imagery--at either a visual or general cognitive level, and that in this fashion, the right hemisphere is often required for full elaboration of linguistic input" (p. 45).

Expressive Language Abilities in the Right Hemisphere

Diggs and Basili (1987) directly investigated RHD patients' expressive language abilities. They presented convergent and divergent language tasks to both LHD and RHD subjects. Convergent tasks were picture naming, picture function, and picture description. For the first two tasks, a picture was shown and the subjects were to state its name and its function. For the picture description task, subjects viewed a picture scene and were to tell as much as possible about the picture. Divergent tasks also consisted of naming items and stating their functions. However, in this case, responses
were elicited by verbal commands to produce divergent responses in a category rather than to produce convergent responses to specific pictures. For example, naming of as many different animals as possible was selected as a task which matched the convergent task of picture naming. Stating uses for a brick was selected as a task which matched the convergent task of stating the function of a pictured item. The results of this study indicated that the verbal expression difficulties of RHD subjects were similar to the difficulties experienced by the LHD subjects in performing convergent naming and function tasks. Control subjects performed significantly better than the LHD subjects and the RHD subjects. However, no significant differences were found between the two brain-damaged groups. On the divergent tasks, control groups' performances were again superior to the LHD and RHD groups. However, the RHD group performed significantly better than the LHD group for flexibility and fluency during divergent naming and functions. Diggs & Basili (1987) concluded "Whatever the precipitating causes, whether they are cognitive, linguistic or both, right CVAs [cerebrovascular accident patients] have difficulty performing tasks that require verbal output" (p. 142).

**Analogical Reasoning as a Measure of Complex Cognitive Operation**

A cognitive operation is defined by Feuerstein (1982) as involving a set of rules whereby information is collected, organized, transformed, manipulated, and then used. In recent years cognitive operations, or processes, have been used to define intelligence.

Cognitive operations can be simple or complex. For example, syllogistic, analogical, and inferential thinking involve more complex processes than recognition or comparison thinking do (Feuerstein, 1982). Sternberg (1985a) classified complex
abilities into two types: inductive and deductive reasoning. Inductive reasoning is re­
quired for completion of such tasks as analogies, series completion, metaphors, and
inference problems. Deductive reasoning is required for performance of such tasks as
linear, categorical, and conditional syllogistic reasoning problems.

In the following sections, the relationship of analogical reasoning to broader the­
ories of inductive reasoning will be considered. Other topics include the use of ana­
logical reasoning in measuring general intelligence, the use of analogical reasoning in
measuring specific intelligence, the modalities which can be used for analogical pro­
blems, and the implications for testing analogical reasoning in left and right hemi-
sphere stroke patients.

**Analogical Reasoning and Theories of Inductive Reasoning**

An inductive reasoning task requires the selection of the single, logically certain
response which is currently absent from the problem (Sternberg, 1985a). To solve
analogies, one must use inductive reasoning. For example, in the analogy, "Day is to
night as light is to ... apple, lamp, or dark?;" the person being tested must select the
most appropriate, logical response to complete the parallel relationship. Theories have
been developed to explain how inductive reasoning problems are solved.

One such theory is Sternberg's componential theory of information processing in
inductive reasoning (Sternberg, 1985b). This theory proposes seven performance
components that are common to all inductive reasoning problems: (1) encoding, by
which the person perceives and accesses the information in long term memory in order
to interpret the stimuli (e.g., the person looks at each of the items in the analogy—
"day, night, light, apple, lamp, and dark" and stores the information); (2) inferencing,
by which the person determines a rule that relates the two items in the first half of the
problem (e.g., the person compares "day" to "night" and determines the relationship);
(3) mapping, by which the person discovers a high-order rule between the first half and second half of an inductive task (e.g., the person compares "day" to "light" in order to identify their relationship); (4) application, by which the person applies the rule discovered from the first half of the problem to complete the second half (e.g., the person identifies the relationship between "day" and "night" and applies it to "light"); (5) comparison, by which the person compares the high-order rule to the possible responses (i.e., the person mentally compares each response choice to test whether it fits the high-order rule); (6) justification, by which the person compares the preferred answer again to make sure that it is parallel with the first half of the analogy, given the high-order rule (i.e., the person determines which response is the most appropriate choice); and (7) response, by which the person actually chooses an answer and communicates the response in some way (e.g., the subject may write the answer, circle a number, or point to the response). The completion of analogical reasoning tasks is believed to require all of these performance components.

**Analogical Reasoning and General Intelligence**

Psychometric theory defines intelligence by a set of underlying abilities, such as verbal ability or reasoning ability (Sternberg, 1985a). Spearman (1927a) was one of the first theorists to discuss the idea of general intelligence. In his book, *The Nature of Intelligence and the Principles of Cognition*, Spearman observed that a person has the tendency to perform cognitive operations consistently even when they involve different forms and subject-matter. This consistency of performance is attributed to the hypothesis that beneath the level of consciousness there is a general factor in cognitive abilities of all kinds. Evidence gathered subsequently has supported this theory of general intelligence, or the existence of a "g factor" (Humphreys, 1979; McNemar, 1964). McNemar concluded, "it has been the thesis of this paper that the concept of
general intelligence, despite being ... disregarded or ignored by others, still has its
rightful place in the science of psychology and in the practical affairs of man" (p.
880).

Analogies have been found to provide a reliable task for measuring the "g factor."
Referring to analogical reasoning, Spearman (1927b) claimed "it is certain enough that
such tests...have correlations with all that are known to contain g" (p. 181). To test
the theory, Sternberg (1977) presented college students with what he called "people-
piece analogies." These are drawings of people varying in height, color, sex, and
girth, which are presented as analogical reasoning problems. Sternberg also used
verbal analogies and geometric analogies in his study. Results of the experiment
showed a consistent, systematic strategy for successfully completing analogies. The
use of this strategy was found to be one aspect that distinguished high-ability per­
formers from low-ability performers, regardless of testing format (i.e., the three types
of analogies).

McGrew (1986) also analyzed verbal analogical reasoning performance of normal
third, fifth, and twelfth graders in order to assess the ability of analogical reasoning
tasks to measure general intellectual ability. For this analysis, McGrew used vali-
dation study data from the Woodcock-Johnson Test of Cognitive Abilities (WJTCA)
(Woodcock, 1978) and data gathered by prior researchers using the WJTCA. Based
on his findings, McGrew concluded that the Analogies Subtest of the WJTCA is one
of the only good measures of the "g factor."

**Analogical Reasoning and Specific Cognitive Factors**

Individuals can express their intelligence in many ways. Gardner (1985) de-
scribed intelligence as involving multiple relatively autonomous competences. He
argued that these could be thought of as separate intelligences rather than as repre-
senting a unitary "g factor." Although theories of differential intelligence depart from Spearman's idea of general intelligence (1927a), most assume that intelligence can be understood and determined by individual "factors" (Sternberg, 1985a).

A number of theorists have proposed theories of intelligence that include multiple factors. Thurstone (1938) believed there are seven "primary mental abilities": (1) verbal comprehension, (2) verbal fluency, (3) number ability, (4) spatial visualization, (5) memory abilities, (6) reasoning ability, and (7) perceptual speed.

Another well-known theory was Guilford's "Structures of Intellect" model, originally published in 1967. In 1982 Guilford revised his theoretical model and proposed three main categories in the structure of intellect: (1) content categories, (2) operation categories, and (3) product categories. Within the operation category, are the subcategories: (a) cognitive abilities, (b) memory abilities, (c) divergent-production abilities, (d) convergent-production abilities, and (e) evaluative abilities. Guilford believed the content in tests of ability may be presented in five different modalities: (a) visual or figural, (b) auditory, (c) symbolic, (d) semantic, and (e) behavioral. Lastly, Guilford listed six types of products: (a) units of information, (b) classes, (c) relations, (d) systems, (e) transformations, and (f) implications.

The inductive reasoning task of analogical thinking has been used by both Thurstone (1938) and Guilford (1967) to provide evidence for their theories of intelligence. Thurstone (1938) used verbal and pattern analogies to affirm his hypothesis of primary mental abilities. Guilford (1967) used different types of analogies to support and measure the types of relations in his "Structures of Intellect" model. He presented cartoon analogies to measure behavioral relations, letter analogies to measure symbolic relations, and verbal analogies to measure semantic relations.
Analogies and Modalities of Cognitive Measurement

Individuals' intellectual abilities can be assessed in many ways. As noted, such theorists as Thurstone and Guilford have used different modalities to assess specific "factors" of intelligence. Another approach that is frequently used to assess cognitive abilities is one that includes tasks designed to assess both verbal and nonverbal intelligence.

Psychometric tests have been developed to investigate verbal versus nonverbal abilities. The verbal/performance dichotomy of the Wechsler Adult Intelligence Scale (WAIS) (Wechsler, 1955) and the Wechsler-Bellevue Scale (W-B) (Wechsler, 1944) are two test models that have been used to distinguish a person's different intelligence skills for processing verbal and visual-concrete stimuli (Kaufman, 1979). These two scales of intelligence have specific subtests which measure Verbal Intelligence Quotients (IQ) and Performance Intelligence Quotients (IQ). Both the WAIS and the W-B Scale contain eleven subtests, six of which are labelled as "verbal" and five which are labelled as "performance" subtests. The Verbal IQ group consists of the following six subtests: (1) information, (2) general comprehension, (3) memory span, (4) arithmetical reasoning, (5) similarities, and (6) vocabulary. The Performance IQ group consists of the additional five tests: (7) picture arrangement, (8) picture completion, (9) block design, (10) object assembly, and (11) digit symbol. Normative data from the WAIS show the mean differences between Verbal and Performance IQs to be approximately zero for the general population (Matarazzo, 1972). Therefore, the aspects of the verbal/performance dichotomy are considered to be represented equally in IQ across groups of normal persons. However, when assessing an individual's IQ, the chance of observing a difference between Verbal IQ and Performance IQ is increased. Matarazzo (1972) reported, given individual assessment, that one out of three persons
tested with the WAIS will show a difference of 10 points or more between the two scales.

Interpretations of results based on WJTCA normative data (McGrew, 1985) can also be made using a verbal versus nonverbal processing model. From his data analysis of the WJTCA subtest results, McGrew determined that the Antonyms-Synonyms, Verbal Analogies, and the Picture Vocabulary subtests all represented involvement of a common underlying verbal component. Visual Matching and Spatial Relations subtests yielded high factor loadings for visual perceptual/spatial stimuli.

Analogical reasoning is of particular interest for studying the verbal/nonverbal dichotomy because the stimuli for one cognitive task can be presented in both verbal and graphic form. The WAIS and the WJTCA both can be used to measure verbal and nonverbal aspects of processing. However, the WJTCA does not include figural analogies as measures of intelligence, and the WAIS does not use analogies of any type to distinguish Verbal/Performance IQ discrepancies.

Types of Analogies

Analogical reasoning problems can be presented in alternative modalities. Analogies using written words as stimuli provide a format that is clearly linguistic. Figural stimuli can be presented as geometric figures with no obvious linguistic representation. Alternatively, pictorial stimuli can be provided. Analogies using pictures could be easily represented linguistically in thought. Complex figure analogies might be less easily represented linguistically in thought. However, it could be possible to solve either figure or picture analogies without using verbal mediation.

Several types of analogical reasoning tasks have been used in test instruments. Some require different kinds of processing. Guilford (1967) addressed the issue of using verbal and figural analogies to measure specific factors of intelligence. He
concluded, "one of the best types of CFR [cognition of figural relations] tests is a figure-analogies form" (p. 68). Guilford went on to state, "we might expect a verbal-analogies test to be one of the best for factor CMR [cognition of semantic relations], and this seems to be the case" (p. 88).

Several other analogy subtests are currently available. The **Test of Nonverbal Intelligence** (TONI) (Brown, Sherbenou, & Johnsen, 1985) measures cognitive abilities without the addition of linguistic information for subjects ranging from 5-0 to 85-11 years. The test contains two forms, Form A and Form B, each of which includes 50 items of progressive difficulty. The objective of the TONI is to assess nonverbal problem solving. Figural analogies provide one of the five types of nonverbal problems tested. In order to complete each analogy on the TONI, subjects must determine the "high-order rule" or relationship of the first half of the analogy to apply it to the second. The relationships for the TONI analogy tasks vary in the following way: (a) matching (i.e., there is no difference between the two figures in the first half of the problem), (b) addition (i.e., figures change in the first half of the problem by adding attributes or figures), (c) subtraction (i.e., the figures change by subtracting one or more attributes), (d) alteration (i.e., figures or attributes are changed in some systematic way), (e) progressions (i.e., a continuous change appears among or between figures). Reliability studies with deviant populations were conducted in standardizing the TONI. The three reliability groups were 10 educable mentally retarded children, 30 hearing impaired children, and two groups of 11 and 16 learning disabled students. These studies showed that the TONI is internally consistent and stable when used with deviant populations.

**Raven's Progressive Matrices** (RPM) (Raven, 1960) serve as another nonverbal measure of general cognitive ability. This test includes visual pattern matching and analogy problems represented in nonlinguistic designs. The test has norms for ages

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eight to 65 years. Studies have shown the RPM to assess reasoning in the visuospatial modality. However, the test does not discriminate between differentiated groups of patients with right hemisphere or left hemisphere damage (Arrigoni & De Renzi, 1964).

The Lorge-Thorndike Intelligence Test (Lorge & Thorndike, 1957) includes a verbal analogy subtest as one of five Verbal Battery Subtests. A pictorial analogy subtest is also included as one of the three Nonverbal Battery Subtests. The test is designed for grades 3-13 (Vetter, 1972).

The California Test of Mental Maturity (CTMM) (Sullivan, Clark, & Tiegs, 1963) which was designed to parallel the Stanford-Binet Intelligence Scale (Terman & Merrill, 1973) uses analogies to assess logical reasoning as well. The test consists of two forms, a short form and a long form. The grade norms range from kindergarten to post-high school.

Similarly the Otis-Lennon Mental Ability Test (Otis & Lennon, 1970) has six levels of testing, ranging from kindergarten to the twelfth grade. All levels contain some form of analogies. However, verbal and figural analogies are assessed only in the upper three levels (Vetter, 1972).

Lastly, the Learning Potential Assessment Device (LPAD) was devised by Feuerstein (1982) in order to demonstrate the malleability of "intelligence." Feuerstein used figural and verbal analogies to analyze possible differential performances involving the same types of cognitive operations. He was also interested in investigating the level of difficulty in completing specific portions of mental acts (e.g., during the encoding, inferencing, or responding stages of completing analogies). Feuerstein's test was designed for a population of educationally and culturally retarded performers.
Measuring Cognitive Abilities in Unilateral Stroke Patients

Little is known about the specialization of the two cerebral hemispheres and the physiological mechanisms associated with the differences between them (Springer & Deutsch, 1981). To increase the difficulty of understanding the physiology of the two hemispheres, disturbance to the brain, such as a stroke, may change such abilities as speech, language, cognition, and perception (Chapey, 1986b).

When World War II brought increased attention to the need for understanding and remediating aphasia (Shewan, 1986), new assessment and therapy techniques were suddenly in demand. Intelligence tests were used as one technique to find patterns associated with brain damage (Matarazzo, 1972). Since that time, the Wechsler Adult Intelligence Scale (WAIS) and the Wechsler-Bellevue Scale (W-B) have continued to be used extensively to attempt to provide objective indices of brain damage (Matarazzo, 1972).

Anderson (1951) presented all of the Wechsler-Bellevue subtests to left and right unilateral stroke patients. Results of the testing indicated that LHD patients showed greater losses of verbal abilities than did RHD patients. Similar studies and literature reviews using the W-B Scale and the WAIS have affirmed the hypothesis that LHD patients show a lower mean Verbal IQ than RHD patients, and RHD patients show a lower mean Performance IQ than LHD patients (Matarazzo, 1980; Reitan, 1955).

Although the WAIS and the W-B Scale of Intelligence have been used to measure unilateral stroke patients' cognitive abilities, analogical reasoning tasks are not included in either of these measures. No studies have been located that report specifically on analogical reasoning abilities of patients with unilateral brain damage when presented multiple modality stimuli. Raven's Progressive Matrices (Raven, 1960), which utilize stimuli that assess figural analogical reasoning capabilities, have been
used to estimate intellectual abilities of aphasic patients; however, the test does not assess verbal analogical reasoning. A study comparing unilateral stroke patients' analogical reasoning abilities using multiple modalities might have implications for understanding the relationships of linguistic and cognitive abilities. Therefore, the current study was designed to determine the effects of unilateral brain damage on the complex operation of analogical reasoning when stimuli are presented using words, figures, and pictures.

Applications of Analogical Reasoning Tasks With Unilateral Stroke Patients

Little is still known about the hemispheres of the brain and the functions of each. Traditional theorists believed the left hemisphere to be dominant for language and analytic operations and the right hemisphere to be dominant for visual-spatial, emotional, and holistic operations. Research in recent years has shown the right hemisphere to play a more important role in linguistic and complex cognitive processes than originally thought.

Analogical reasoning tasks require inductive reasoning. To complete an analogy problem, a person must encode the information and go through a series of processes before choosing the correct answer. It has been determined that analogical reasoning is a good indicator of general intelligence (Spearman, 1927a; Sternberg, 1977) or an indicator of specific cognitive factors (Thurstone, 1938; Guilford, 1967; 1982).

The modalities of analogical reasoning tasks can be verbal or figural. This dichotomy, when used to design assessment tasks, can help determine a person's verbal and nonverbal cognitive skills. The use of a verbal/nonverbal dichotomy for analogical reasoning is particularly interesting for assessing unilateral stroke patients' cognitive abilities. If the traditional theorists are correct in their hypotheses regarding the
functional capabilities of the cerebral hemispheres, LHD patients should have greater
difficulty with verbal analogy problems, and RHD patients should have greater dif­

culty with analogy problems that might be solved without verbal strategies. These
outcomes would be consistent with the results of studies involving stroke patients'
performance on the Verbal Scale and Performance Scale of the Wechsler Adult Intel­
ligence Scale and the Wechsler-Bellevue Scale of Intelligence. Such studies have
shown LHD patients to have relatively more difficulty with the Verbal Subtests, and
RHD patients to have relatively more difficulty with the Performance Subtests, of such
instruments.

The current study also has implications for the assessment of language disorders
in unilateral stroke patients. Chapey (1986b) defines aphasia assessment as an evalu­
atation of a person's ability to demonstrate cognitive, linguistic, and communicative cap­
abilities. The cognitive components of assessment include recognition and under­
standing, memory, convergent thinking, divergent thinking, and evaluative thinking.
Analogical reasoning provides one type of high-level, convergent cognitive task that
might be used for assessing such individuals (Chapey, 1986b; Sternberg, 1985a).
Also, analogies can be performed using various types of stimuli, and the problems can
be solved using either verbal or nonverbal strategies depending on the types of stimuli
and strategies adopted by the individual. If the stimuli provided are verbal (e.g.,
written words), then linguistic components of language processing (i.e., content-
semantics and form-structure) would likely be needed to successfully complete the
task. If the stimuli provided are nonverbal, then the individual would likely need to
draw upon nonverbal cognitive strategies to solve the task. Multiple modality anal­
ogies might be used to assess different aspects of the cognitive and linguistic com­
ponents included in Chapey's (1986b) model.

Furthermore, it has been noted that analogical reasoning is a good indicator of
either general intelligence or specific factors of intelligence. If stroke patients are able to correctly complete analogies, either verbal or figural, it may imply that either general intelligence or a specific cognitive factor of intelligence is accessible to improve language comprehension and expression. Particularly, identifying the modality of best performance may provide insight into a pathway of intersystemic reorganization. Intersystemic reorganization is one of the mechanisms that Luria (1970) identified as an explanation for recovery in aphasia rehabilitation. It has been utilized by a number of clinicians (Sparks, Helm, & Albert, 1974; Helm-Estabrooks, Fitzpatrick, & Barresi, 1982; Rosenbeck, Collins, & Wertz, 1976), but intersystemic (i.e., cross-modality) use of analogies has not yet been reported in the literature.
CHAPTER III

METHODOLOGY

Subjects

Experimental Subjects

In this study, subjects in the experimental group were 20 adult, right-handed stroke patients who had experienced a single occurring cerebrovascular accident (CVA) at least three months, but no more than three years, prior to the study. These patients were divided into two groups on the basis of available computerized tomography (CT) scan results. The LHD group included 12 patients with left hemispheric lesions (seven males and five females), and the RHD group included eight patients with right hemispheric lesions (five males and three females). Patients were selected from those seen at the Southwestern Michigan Rehabilitation Hospital in Battle Creek, Michigan using procedures approved by the Human Subjects Institutional Review Board (see Appendix A).

A subject survey (see Appendix B) was used to gather the following information from potential subjects, or from family members if the patients were unable to provide the needed information:

1. Birthdate
2. Date of CVA
3. Handedness prior to CVA
4. Employment prior to CVA (or prior to retirement if appropriate)
5. Highest grade level completed
6. Native language
7. Current motor status (e.g., comments regarding ambulation and hemiplegia).

The criterion for age of subjects was set within the broad limits of 45 and 75 years in order to maximize the available number of potential subjects. The ceiling level of 75 years was established to reduce potential effects of physical or cognitive difficulties associated either with dementia or with decline in abilities due to normal aging. Schaie (1983) found that the period between the late 60s and the 70s is one in which many people seem to have significant psychometric difficulties. However evidence also shows that it is typically not until the age of 81 that the average person falls below the range of younger, normal adults (Schaie, 1983). The mean age for the LHD group in this study was 65 years, with a standard deviation of 8.65 years. The mean age for the RHD group was 62 years, with a standard deviation of 4.98 years.

The duration of the period between the patients' CVAs and the date of the study was controlled for this study to be between three months and three years post onset. The rationale for this decision was that bilateral effects from unilateral lesions are a possibility within the first three months post-onset (Rubens, 1977). Therefore, it was decided that testing analogical thinking before the first three months post-onset might not yield reliable results and might reflect suppression of function beyond that directly attributable to the primary lesion. However, when testing began, it was decided to test one RHD subject who suffered her stroke between two and three months prior to testing. This was done due to the lesser availability of RHD subjects. The results for this individual are discussed in Chapter IV. The upper limit of three years post-CVA was selected in order to maximize the number of subjects. Previously available medical history reports summarizing the patient's CT scan results were reviewed in order
to know which hemisphere was damaged (see Appendix C). The specific site of the lesion was not controlled except to be certain that it was unilateral within either hemisphere. Specific sites of lesion were noted where information was available.

The subjects in this study were all clearly right-handed before their strokes. It was demonstrated by Borod, Carper, Naeser, & Goodglass (1985), in a study with left-handed and right-handed aphasic individuals who had suffered left hemispheric lesions, that left-handed aphasics showed significantly poorer performance on tasks requiring visuo-spatial organization and construction. These results suggest the possibility that brain functions are organized differently for left-handed than for right-handed individuals. Borod et al. (1985) also found that, of the 323 subjects seen in a 10 year period, only 43 (i.e., 13%) were left-handed. Due to the possibility of mixed dominance in left-handed individuals, and to the small sample size available, patient handedness was controlled in this study by using only CVA patients who were right-handed prior to their strokes.

No formal measurement of experimental subjects' hearing acuity was conducted prior to this study. Only one of the three sets of experimental analogy tasks required any hearing ability. That is, the Word Analogy Set involved presentation of printed words, which were also read aloud by the examiner as the subject viewed them. This bimodality presentation was used to reduce the likelihood that a modality specific deficit might affect a subject's ability to perform the task. Two of the pretest recognition tasks also provided an informal screen of hearing acuity. That is, on the Word Pretest, subjects were required to point to printed words to match words spoken by the examiner, and on the Picture Pretest, subjects were required to point to pictures to match words spoken by the examiner. The ability to point correctly to a word or picture when given auditory stimuli in the pretest recognition task was considered an indication of adequate hearing for completing the experimental task. All of the subjects
were able to pass either the Word or Picture Pretest with at least 60% accuracy (3 of 5 correct items).

Although the socio-economic background of the subjects was not controlled for this study, information about employment prior to the CVA (or employment prior to retirement) was obtained (see Appendix D). This information was gathered to assist in analyzing possible variations between and within the subject groups.

All of the experimental subjects were retired. The types of employment LHD subjects held prior to their strokes were: (a) factory worker (n=2), (b) school teacher (n=2), (c) homemaker (n=2), (d) maintenance worker, (e) electrical technician, (f) purchasing agent, (g) plumber, (h) babysitter, and (j) restaurant owner. The types of employment RHD subjects held prior to their strokes were: (a) factory worker (n=5), (b) cook in a motel, (c) steel worker, and (d) bank teller.

The only criterion related to the educational backgrounds of the subjects was that each should have completed at least seventh grade. Of the 12 LHD subjects, one had completed 7th grade, one had completed eighth grade, one had finished eleventh grade, six had received a high school education, and three had achieved some level of higher education. Of the eight RHD subjects, one had finished tenth grade, three had finished eleventh grade, two had completed high school, and two had achieved some level of higher education. The analogical tasks were all designed to be within the capabilities of typical fifth graders in order to reduce the possible influence of educational differences on the study's outcomes.

Native language was controlled for the experimental group. All subjects had to speak English as their first and current language. The use of the English language was controlled to help ensure the understanding of verbal instructions and the words used in the verbal analogies.

Information regarding current motor status was gathered to help determine the
physical mobility capabilities of the experimental subjects. It also provided a check to confirm the hemispheric lesion site. That is, if subjects demonstrated weakness or paralysis on a specific side, then the contralateral hemisphere would be suspected as being the site of damage. All of the experimental subjects who experienced weakness or paralysis demonstrated symptoms that were contralateral to the lesion site noted in their history reports.

Control subjects

Two groups of control subjects participated in this study. Subjects in the first control group were 20 right-handed children (10 males and 10 females) between the ages of nine and 11, who had normal hearing acuity (as determined by school screening results), age-appropriate intelligence (as determined by educational history, with no grades repeated or skipped), and English as their native language (as determined by self or parental report). The subjects were selected from a southern Indiana elementary school. A subject survey (see Appendix B) was used to gather the following information from the child or parent:

1. Birthdate of child
2. Hand preference
3. Language spoken
   a. at home
   b. at school
4. Most recently completed or attended grade
5. Any grade skipped
6. Any grade repeated
7. Previous referral for speech, language, hearing or reading problems.

The nine to eleven year age range of the first control group was established based
on Feuerstein's (1982) research on analogical thinking using the Learning Potential Assessment Device (LPAD). Feuerstein found developmental characteristics for analogical reasoning, with the ceiling of the test being reached at, or above, the sixth grade level (i.e., 11 to 12 years old). Second grade level students (i.e., seven to eight years old) did not perform above the chance level. Feuerstein's assessment suggested that seven or eight year olds were not cognitively able to perform analogical reasoning tasks.

Handedness was controlled for the child control group in the same way it was controlled for the experimental groups. All subjects were right-handed. The rationale for controlling handedness was to be consistent with handedness expectations for the experimental groups and to increase the likelihood of predictable cerebral dominance patterns.

Spoken language was also controlled for the child control group. All subjects had to speak English at home and at school. Use of the English language was controlled to help ensure understanding of the words used in the verbal analogies.

To determine whether subjects in the control group had age-appropriate intelligence, an informal set of questions about academic performance was asked. The child and his or her parent were asked what grade the child had most recently completed and the grade of current enrollment. Information was also gathered to identify whether the child had ever been accelerated in placement past any grade or had ever been retained in any grade. Information as to whether the child had ever received speech, language, hearing, or reading remediation was also requested. Children with speech, language, hearing, or reading problems were not used for this study. Another criterion was that a child must be enrolled for the fourth or fifth grade for the upcoming or current school year, without having skipped or repeated a grade. Normal grade advancement and ability to succeed in the normal education curriculum were
used as informal screening measures to ensure that the school-aged children who served as subjects in the child control group did not have handicaps of visual perception, hearing acuity, general cognition, or written/auditory language processing that might have influenced their performance on the experimental tasks. Of the 20 children, 11 were either preparing to enter fourth grade or were presently attending fourth grade, and nine were either preparing to enter fifth grade or were presently attending fifth grade. Nine children were nine years old, eight children were 10 years old, and three children were 11 years old. The mean age for the child control groups was 10 years, with a standard deviation of .37 years.

The subjects of the second control group were six right-handed, English-speaking adults (three males and three females) between the ages of 45 and 75 years who reported themselves to have normal hearing acuity and who had denied ever being diagnosed as having experienced a CVA or any other type of neurological problem. As for the experimental subjects, the completion of the pretest tasks was also used as an informal screen of visual perception and hearing acuity. A subject survey (see Appendix B) was used to gather the following information from the subjects:

1. Birthdate
2. Hand preference
3. Language spoken
4. Employment (currently, or prior to retirement)
5. Highest grade level completed.

The age range of the second control group (the six adults) was set at 45 to 75 years of age to be consistent with the age range of the two experimental groups. The mean age for the adult control group was 60.78 years with a standard deviation of 8.42 years. The ranges, means, and standard deviations for both experimental groups and both control groups are summarized in Table 1.
Table 1
Age Ranges, Means, and Standard Deviations for the Control and Experimental Groups

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Range</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Child Controls</td>
<td>20</td>
<td>9 to 11 years</td>
<td>10.13</td>
<td>.37</td>
</tr>
<tr>
<td>Adult Controls</td>
<td>6</td>
<td>46 to 70 years</td>
<td>60.78</td>
<td>8.42</td>
</tr>
<tr>
<td>LHD Experimentals</td>
<td>12</td>
<td>45 to 75 years</td>
<td>64.81</td>
<td>8.65</td>
</tr>
<tr>
<td>RHD Experimentals</td>
<td>8</td>
<td>55 to 68 years</td>
<td>62.14</td>
<td>4.98</td>
</tr>
</tbody>
</table>

A one-way analysis of variance was used to determine if the adult control subjects' ages were significantly different from the ages of experimental subjects. It was concluded that ages of the adult control subjects were not significantly different ($F = .63; df = 2; p > .05$) from the ages of the LHD and RHD subjects (Statsoft, 1985).

Hand preference was controlled for the adult control group as it was for the other three groups. That is, all adult control subjects were clearly right-handed, as were all other experimental and control subjects in this study. As with the experimental and child control subjects, adult control subjects also were required to speak English.

Information about the employment and educational backgrounds of the adult control subjects was gathered as well. Two of the adult control subjects had received a high school education, three had earned Bachelor's Degrees, and one had earned a Master's Degree. All but one of the subjects were presently working. The types of employment were: (a) pastor, (b) corporate executive, (c) high school librarian, (d) insurance salesman, and (e) jeweler.
Stimuli

Experimental Stimuli

Three sets of analogy tasks were constructed, adapted from those constructed by Feuerstein (1982) and Nippold (1986). A Word Set was compiled to include 10 verbal analogies presented as written words. A Figure Set was designed to include 10 nonverbal analogies that could not be easily named. Finally, a Picture Set was designed to include 10 analogies that were presented nonverbally as drawings, but as drawings that could be easily named, so that the analogy could be solved using verbal skills if an individual chose to do so. Each set included three practice items and 10 test items. The word analogies and picture analogies were constructed using two each of the following five linguistic relationships: (1) synonyms, (2) antonyms, (3) locations, (4) whole-part, and (5) functions (Feuerstein, 1982). The figure analogies were constructed using the following spatial relationships: (a) addition—used in three items, (b) subtraction—used in two items, (c) reversal—used in three items, and (d) alteration—used in two items. Analogies constructed using addition involved changing one geometric figure by adding two or more geometric figures. Analogies constructed using subtraction involved changing the first geometric figure by subtracting attributes. Analogies constructed using reversals involved changing two geometric figures so that they switched places with each other. Lastly, analogies constructed using alteration involved changing the figures by moving them to a new position. Addition, subtraction, and alteration type analogies are used in the Test of Nonverbal Intelligence (TONI) (Brown, Sherbenou, & Johnsen, 1985).

All of the analogies were presented using a four-frame box-type arrangements (see examples representing each analogy set in Appendix E). A completed relationship
appeared in the upper two boxes, and a parallel stimulus word, picture, or figure appeared in the lower left-hand corner, with an empty box in the lower right-hand corner. This arrangement provided the analogical reasoning format of "A is to B, as C is to __." The response for insertion in the lower right-hand corner could be selected from three possible responses. These were numbered with the numerals "1," "2," or "3," which were printed above each of the response choices that appeared in boxes at the bottom of the page.

One of the response choices was not related to the analogy in any way; one was related to an item in either the completed or uncompleted portion but not in an analogical way; and one was the appropriate choice. For example, for the verbal analogy, "Green is to grass as blue is to ...red, sky, or daytime," the choice "sky" is the appropriate response, the choice "red" relates to "blue" and "green" in that all are colors (the related foil), and the choice "daytime" does not relate to "green", "grass", or "blue" (the unrelated foil). The arrangement of the three types of response choices was randomized so that the correct choice varied among the three answer positions.

**Pretest Stimuli**

All experimental and control subjects were given a pretest recognition task prior to the administration of the experimental task. The rationale for the pretest was to screen for possible visual perception, hearing acuity, cognitive, and written/auditory language processing problems that might influence performance on the experimental task.

The importance of identifying that individuals can recognize symbols as a prerequisite for having them perform analogical reasoning tasks using the same symbols was noted by Brownell et al. (1986). They stated, "Before one can address the issue of inferential capacity, it is necessary to establish whether or not a patient understands and remembers the actual content. If he does not, then making appropriate inferences..."
is presumably impossible" (p. 311).

Three sets of receptive recognition pretest tasks were constructed to be related to the three analogy tasks: (1) the verbal pretest included written words that had to be matched to spoken words, (2) the picture pretest included pictures that had to be matched to spoken words, and (3) the figure pretest included geometric figures that had to be matched to identically drawn figures. Each pretest included two sets of five stimulus items, all of which were items drawn from the experimental analogy tasks. All of the pretest items were printed or drawn with black ink in 3-by-2 inch outlined rectangle spaces to match the size of the response choices on the experimental tasks.

The first set of five items for each pretest was used to provide demonstration of the pretest task. Subjects were prompted until they could respond to two of the items. On the second set of items, subjects were required to respond to all five items by either pointing to a printed word or to a picture named by the examiner (on the Word and Picture Pretests) or by pointing to a geometric form to match each of five forms held by the examiner (on the Figure Pretest). Demonstration and correction were not provided during presentation of the second set of five pretest stimuli.

The five demonstration stimuli and five pretest stimuli for the Word and Picture Pretests were nouns and verbs randomly chosen from the response choices in the experimental analogy sets. The words were chosen to vary in syllable structure. They included two one-syllable words, two two-syllable words, and one three-syllable word (see Appendix F for lists of stimuli).

The five demonstration and five pretest stimulus items for the figure pretest were randomly chosen from the response choices in the experimental Figure Analogy Set. Two of them were geometric shapes that were shaded with parallel lines; two of them represented one geometric figure superimposed on another; and one was a picture of multiple geometric figures that were not overlapped (examples appear in Appendix F).
Procedures

Instructions for the Experimental Analogy Tasks

Before actual testing, three practice experimental analogy tasks were administered to the subjects of each group in counterbalanced order. Complete counterbalancing of the three tasks yielded six orders for the practice items (see Table 2).

Table 2
Counterbalanced Orders of the Three Analogy Sets

<table>
<thead>
<tr>
<th>Order</th>
<th>1st</th>
<th>2nd</th>
<th>3rd</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>W</td>
<td>P</td>
<td>F</td>
</tr>
<tr>
<td>2.</td>
<td>W</td>
<td>F</td>
<td>P</td>
</tr>
<tr>
<td>3.</td>
<td>P</td>
<td>W</td>
<td>F</td>
</tr>
<tr>
<td>4.</td>
<td>P</td>
<td>F</td>
<td>W</td>
</tr>
<tr>
<td>5.</td>
<td>F</td>
<td>W</td>
<td>P</td>
</tr>
<tr>
<td>6.</td>
<td>F</td>
<td>P</td>
<td>W</td>
</tr>
</tbody>
</table>

Note. W = Word Analogies  P = Picture Analogies  F = Figure Analogies

Thus, one to two subjects in each subgroup were tested in each of the six orders (see Appendix G). The order of the practice analogies was rotated as each subject was tested.

Once the three practice items for each analogy type were completed, the analogies from each set were individually presented in the following fixed order: the 10 analogies from the Word Set, followed by the 10 analogies from the Figure Set, and finally, the 10 analogies from the Picture Set. Both the control groups and experimental groups completed the experimental analogies in this order. The examples for each
Analogy Set were presented prior to the presentation of any of the analogy sets to reduce the likelihood that a learning effect might be a factor. The time required to complete all three experimental tasks (at most 30 minutes) was less than that usually expected to result in fatigue in stroke patients who are more than three months post-onset.

**Practice Procedures**

Control subjects and experimental subjects were each tested individually within a single session. They were given the following introductory instructions by the examiner:

"This is what I want you to do. Watch and listen carefully. Then look at each of the words or pictures and point to the best answer that fills the empty box."

The practice items for the analogies were presented without the addition of non-verbal cues for the Word Set, and without the addition of verbal cues for the Picture and Figure Sets.

The three practice items for the Word Set were administered individually in simultaneous oral and written form. For example, the experimenter said, "Bird is to fly as fish is to...[pause]... water, swim, or book?" while pointing to the written words. Spoken words were provided simultaneously with written words to help reduce the likelihood that reading problems might interfere with the ability to respond. A written example appears in Appendix E. As the word of each choice was spoken, an accompanying scanning hand movement was used from left to right beneath the three responses (taking three seconds to sweep across the words). This was done to encourage the subjects' scanning of the response choices. No other hand gesture was used by the examiner.
Subjects had to complete each analogy by pointing to one of the three response choices. If a subject responded correctly to each of the three practice analogies, the examiner proceeded to the next item. If a subject responded incorrectly, or did not respond at all, the examiner demonstrated the correct response for the subject. For example, she would say, "Bird is to fly as fish is to swim." Then testing would proceed to the next practice item. Even if the subject missed all three practice items, the experimental task was administered and scored.

The three practice items for the Picture and Figure Analogy Sets were administered without words. For these tasks, hand gestures only were used to demonstrate the items. The examiner placed her right index finger first on the upper left-hand box, then on the upper right-hand box. The examiner then touched the lower left-hand box, moved her index finger to the lower right-hand box, paused three seconds, and then moved her finger from left to right, beneath the three response choices (taking three seconds to sweep across choices). As the examiner's hand passed each response, the number of the choice was spoken (i.e., "one," "two," or "three"). Once the examiner's presentation was completed, the subject had to finish the analogy by pointing to response choice "1," "2," or "3," as done previously on the Word Analogy Set.

As on the other analogy practice tests, if the subject answered the first of the three practice items correctly, the examiner proceeded to the next analogy. If the subject's response was incorrect, or if the subject did not respond at all, the examiner showed the subject the correct response. For example, she would say, "This [while pointing to the top left-hand box] is to this [while point to the top right-hand box], as this [while pointing to the lower left-hand box] is to this [while pointing to the correct response choice]." Then the second practice item was presented. Even if the subject missed all three practice items, the experimental task was administered and scored.

One LHD subject and one RHD subject missed all three of the practice items on
one of the three Analogy Sets. The LHD subject missed all three practice items on the Figure Set. However, the subject was able to correctly choose two of the three practice items for the Word Set and all three of the practice items for the Picture Set. The RHD subject missed all of the practice analogies on the Picture Set. That same individual also missed two of the three practice items on the Word and Figure Sets.

Test Procedures

The 10 analogies each from the Word, Figure, and Picture Sets were administered in that order after the practice items of all three types had been administered in one of the randomized orders (see Table 2). Stimuli for each analogy were presented in the same manner as they were presented for the practice items. Subjects completed the analogies by pointing to one of the three responses. However, unlike the practice sets, no feedback was given in response to the subjects' choices.

A time limit of 30 seconds was allowed after the examiner completed her presentation of verbal or gestural stimuli for each analogy item. The examiner repeated the stimuli once if a subject requested a repetition within the 30 seconds. At the end of the time limit, if the subject had pointed to one of the response choices (whether correct or incorrect), the examiner recorded the numeral on a score sheet. However, if the subject had not pointed to a response choice within the 30 second limit, the examiner repeated the stimulus. The score sheet included a blank area to the right of each response in order to record information regarding subjects' verbal or gestural behaviors observed while they were completing the analogies (see Appendix H). For example, notes would be made if, while trying to complete an analogy from the Picture Set, a subject pointed to each of the pictures before choosing an answer and then named the picture he or she believed to be the correct choice. A space was also included for recording if and when a repetition was given, either within the first 30 seconds (if a
subject requested it) or at the end of the first 30 seconds (if no response was selected within that time limit). Once the response was recorded, or if no response was made within 60 seconds, the next analogy in the set was presented. In all instances, responses were made within the 60 second time limit.

A short break from testing, lasting one to three minutes, was used to separate presentation of the three sets of analogies. This short break was used to facilitate subjects' reorientation to slightly different tasks.

In scoring the results, each answer was assigned a value of zero, two, or three. A score of three was awarded if a correct answer was given within the first 30 seconds without a stimulus repetition. A score of two was awarded if a correct answer was given within the first 30 seconds following a requested stimulus repetition or within the second 30 seconds following an unrequested stimulus repetition. A score of zero was given for an incorrect answer that was chosen at any time during the analogy's presentation.

Raw data that were gathered using this scoring system appear in Appendix I. Results of the experiment are presented in Chapter IV.

Pretest Procedures

The three pretest tasks were administered using identical procedures for both experimental and control subjects. The three sets of pretest items were presented in the following order: (1) the Word Pretest, (2) the Picture Pretest, and (3) the Figure Pretest. The pretest tasks were given within a single session within the same day, but prior to, the experimental task.

Instructions for the Pretest

For the Word Pretest, the following instructions were given both to the control
and experimental groups by the examiner:

"This is what I want you to do. Listen to the word I say and point to the
written word that goes with what I say."

For the Picture Pretest, the following instructions were given both to the control and
eperimental groups by the examiner:

"This is what I want you to do. Listen to the word I say and point to the
picture that goes with the word."

For the Figure Pretest, the following instructions were given both to the control and
experimental groups by the examiner:

"This is what I want you to do. I am going to show you a picture. Point to
the picture in front of you that looks exactly like the one I am holding."

Following each set of instructions, the two practice items for that particular pretest
were administered by placing five demonstration cards, with either words, pictures, or
geometric figures printed on them, horizontally across the table, one inch apart, in
front of the subject. Once the cards were in place, the examiner paused 10 seconds for
the subject to scan the cards visually. Scanning was not prompted in any way. For
the Word and Picture Pretests, the examiner then spoke one of the words, which
represented a written word or picture on one of the five cards in front of the subject.
For the Figure Pretest, the examiner held the card in her right hand at the client's eye
level, approximately one and one-half feet away, for the subject to match to one of theive cards in front of the subject.

To pass a screening practice item, the subject had to point to the correct card
within 15 seconds. If the subject's response was correct, the examiner presented the
next practice item. However, if the subject chose an incorrect response, or did not re-
spend within 15 seconds, the examiner produced the word again or showed the figure
again and asked the subject to "Look and try again." If the subject missed the first
practice item two times, the examiner proceeded to the second practice item. The same procedure was used for the second stimulus word or figure. If the subject missed both practice words twice, the pretest was discontinued, and the subject was not administered the experimental task. However, if the subject correctly answered one of the example practice items on either trial, the examiner proceeded to the five pretest items for that subtest.

In this study, all of the subjects were able to respond correctly to at least one of the two practice items for all three of the pretests within the 15 second time limit. Therefore, the sets of five test stimulus cards for the pretests were presented to all experimental subjects.

On each pretest, the second set of five pretest stimulus words, pictures, or figures were presented in similar fashion to the practice items. The cards were placed in the same arrangement and the examiner paused 10 seconds for visual scanning time, without prompts of any type. Then she named the first stimulus word or picture or showed the first stimulus figure. The subject had to point to the corresponding word, picture, or figure within 15 seconds. The stimulus word was repeated once if the subject requested it. The response was marked correct if the correct response was chosen within the 15 second response period (one repeat allowed). The response was marked incorrect if the patient's answer was incorrect or was not chosen within the 15 second time limit.

All of the subjects passed the pretest items and proceeded to the experimental analogy tasks. Perfect performance was not required for all five items on the three pretest tasks. This decision was made in order to avoid eliminating too many potential subjects whose brain injuries might limit their abilities to perform these types of tasks. However, subjects whose pretest performance for any or all of the subtests was below 60% accuracy (i.e., fewer than three out of five correct) were noted in order to con-
sider whether their difficulties might have been the result of basic reading, hearing, and/or perceptual deficits.

Pretest performances were below 60% accuracy for one of the three subtests for three experimental subjects. Two of these subjects were LHD and one subject was RHD. The first LHD subject who scored below 60%, responded correctly to only one of the five items on the Word Pretest (i.e., 20% accuracy), but was able to choose correctly all five of the items on the Picture Pretest and all five items on the Figure Pretest. The other LHD subject who scored below 60%, responded correctly to only two of the five Picture Pretest items (i.e., 40% accuracy). However, this individual was able to correctly choose all five of the Word Pretest items and all five of the Figure Pretest items. The RHD subject who scored below criterion on a pretest answered only one of the five Picture Pretest items correctly (i.e., 20% accuracy). However, he was able to correctly point to all five of the Word Pretest items and three of the Figure Pretest items (i.e., 60% accuracy).

Considering these results, it is possible that the LHD subject who had difficulty with the Word Pretest might have had a basic reading impairment. However, during the experimental analogy tasks, words were read to subjects while they were looking at the printed stimulus words. Therefore, a basic reading impairment would not, by itself, be sufficient to prevent a person from completing the Word Analogies task. For the other LHD subject and the RHD subject, a basic visual perceptual problem or a word recognition problem might have been possible. However, both subjects were able to point to the Figure Pretest items and the Word Pretest items with at least 60% accuracy. Therefore, perceptual problems or word recognition problems could not have been the exclusive cause of their difficulties. A summary of subjects' performance on the pretest tasks is found in Table 3.
Table 3
Summary of Experimental Subjects' Performances in Percentages on the Three Pretest Tasks

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Word Pretest</th>
<th>Picture Pretest</th>
<th>Figure Pretest</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. **</td>
<td>20%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>2.</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>3. **</td>
<td>100%</td>
<td>40%</td>
<td>100%</td>
</tr>
<tr>
<td>4.</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>5.</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>6.</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>7.</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>8.</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>9.</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>10.</td>
<td>60%</td>
<td>80%</td>
<td>100%</td>
</tr>
<tr>
<td>11.</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>12.</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>13. **</td>
<td>100%</td>
<td>20%</td>
<td>60%</td>
</tr>
<tr>
<td>14.</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>15.</td>
<td>100%</td>
<td>80%</td>
<td>100%</td>
</tr>
<tr>
<td>16.</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>17.</td>
<td>100%</td>
<td>100%</td>
<td>80%</td>
</tr>
<tr>
<td>18.</td>
<td>100%</td>
<td>80%</td>
<td>100%</td>
</tr>
<tr>
<td>19.</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>20.</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Note. ** = Subjects who completed a Pretest Set with less than 60% accuracy.
CHAPTER IV

RESULTS

In this study, analogical reasoning was measured by having subjects complete 10 analogy problems each in the three modalities, words, figures, and pictures. Each response was awarded a value of zero, two, or three (see Chapter III for an explanation of rating criteria), with a maximum score of 30 points for each set. The summary of mean raw scores and standard deviations for all groups, including the child control group, adult control group, LHD group, and RHD group, are shown in Table 4. Raw data for individual subjects are reported in Appendix I.

The data collected from this study were analyzed using the following procedures: (a) repeated measures analysis of variance (ANOVA) for the four groups by three analogy tasks, (b) post hoc analysis comparing performance differences between the two combined control groups and two combined experimental groups on the three analogy sets (c) post hoc analysis between LHD and RHD groups on the three analogy sets, (d) post hoc analysis of the performance differences within the LHD and within the RHD group on the three analogy sets, (e) post hoc analysis of performance differences within the adult control group on the three analogy sets, and (f) Chi-square analysis comparing error response differences within the LHD group and the RHD group.
Table 4  
Group Mean Scores and Standard Deviations  
for the Three Analogical Reasoning Tasks  

<table>
<thead>
<tr>
<th>Group</th>
<th>Group Means</th>
<th>Group SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Child Control Group</td>
<td>W = 26.4</td>
<td>W = 3.02</td>
</tr>
<tr>
<td>(N = 20)</td>
<td>F = 24.7</td>
<td>F = 3.51</td>
</tr>
<tr>
<td></td>
<td>P = 22.35</td>
<td>P = 4.51</td>
</tr>
<tr>
<td>Adult Control Group</td>
<td>W = 27.5</td>
<td>W = 2.26</td>
</tr>
<tr>
<td>(N = 6)</td>
<td>F = 26.5</td>
<td>F = 1.22</td>
</tr>
<tr>
<td></td>
<td>P = 25.0</td>
<td>P = 2.45</td>
</tr>
<tr>
<td>LHD Group</td>
<td>W = 16.17</td>
<td>W = 6.41</td>
</tr>
<tr>
<td>(N = 12)</td>
<td>F = 15.42</td>
<td>F = 5.73</td>
</tr>
<tr>
<td></td>
<td>P = 12.17</td>
<td>P = 5.51</td>
</tr>
<tr>
<td>RHD Group</td>
<td>W = 21.38</td>
<td>W = 6.89</td>
</tr>
<tr>
<td>(N = 8)</td>
<td>F = 11.63</td>
<td>F = 6.30</td>
</tr>
<tr>
<td></td>
<td>P = 15.25</td>
<td>F = 6.25</td>
</tr>
</tbody>
</table>

Note. W = Word Set. F = Figure Set. P = Picture Set.

Repeated Measures Analysis of Variance  
for the Four Groups

A repeated measures analysis of variance (ANOVA) for the three analogical reasoning tasks by the four groups is summarized in Table 5. The ANOVA calculated three effects: (1) main effect for group, (2) main effect for repeated measures (i.e., analogy tasks), and (3) interaction effect for group-by-repeated measures.
Table 5

Analysis of Variance For the Four Groups by Three Repeated Measures

<table>
<thead>
<tr>
<th>EFFECT</th>
<th>SS</th>
<th>DF</th>
<th>MS</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
<td>3288.4</td>
<td>3</td>
<td>1096.13</td>
<td>25.99</td>
<td>.000</td>
</tr>
<tr>
<td>Error 1</td>
<td>1771.57</td>
<td>42</td>
<td>42.18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Repeated Measures</td>
<td>364.21</td>
<td>2</td>
<td>182.11</td>
<td>13.73</td>
<td>.000</td>
</tr>
<tr>
<td>Group x Repeated Measures</td>
<td>263.15</td>
<td>6</td>
<td>43.86</td>
<td>3.31</td>
<td>.006</td>
</tr>
<tr>
<td>Error 2</td>
<td>1114.48</td>
<td>84</td>
<td>13.27</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The main effect for group was found to be significant \((F = 25.99; \text{df} = 3, 42; \text{p} < 0.001)\), indicating significant differences among the four groups of subjects. The main effect for repeated measures was also found to be significant \((F = 13.73; \text{df} = 2, 84; \text{p} < .001)\) indicating significant differences among the three analogy tasks. Lastly, the group-by-repeated measures interaction effect was found to be significant \((F = 3.31; \text{df} = 6, 128; \text{p} < 0.01)\), indicating that the relative task difficulty was experienced differentially by the four subject groups. The finding of significance for the group effect, the repeated measures effect, and the interaction effect makes it appropriate to use post hoc comparisons to determine specific areas of significant difference.

The Bonferroni method for post hoc analysis (Neter, Wasserman, & Kutner, 1985), with adaptation for unequal group size (Stoline, 1981), was used to specify areas in which statistically significant differences occurred between individual means. The post hoc analyses were used to test the individual experimental hypotheses. An
alpha Type I error level of .05 was established for all post hoc analyses.

**Differences Between Control Groups and Experimental Groups**

The main effect for group was significant, indicating that the four groups were not all alike. Post hoc analysis was used to discover if the two experimental groups demonstrated significantly poorer performance than the two control groups on the three analogy sets.

Examination of the data showed that the combined experimental groups' means for the three analogy sets to be: (1) 18.25 for the Word Set, (2) 13.9 for the Figure Set, and (3) 13.4 for the Picture Set. The means (based on a possible 30 points in each case) reflected a low degree of accuracy by the two experimental groups for all three analogy sets, especially the Figure and Picture Sets. Individual raw scores for the total experimental task ranged from 18 to 71 of a possible 90 points. Individual mean scores for the total experimental task ranged from 6 to 23.67 of a possible 30 points, with an across task mean score for the two experimental groups of 15.02 points.

The LHD groups' mean scores for the three analogy sets were (1) 16.17 for the Word Set, (2) 15.42 for the Figure Set, and (3) 12.17 for the Picture Set. Individual raw scores for the LHD subjects on the total experimental task ranged from 18 to 64 of a possible 90 points. Individual LHD mean scores for total experimental task ranged from 6 to 21.33 of a possible 30 points.

The RHD groups' mean scores for the three analogy sets were (1) 21.38 for the Word Set, (2) 11.63 for the Figure Set, and (3) 15.25 for the Picture Set. Individual raw scores for the RHD subjects on the total experimental task ranged from 27 to 71 of a possible 90 points. Individual RHD mean scores for the total experimental task
ranged from 9 to 23.67 of a possible 30 points.

The RHD subject whose CVA occurred between two and three months prior to testing received a total mean score for the experimental task of 32 out of a possible 90 points (i.e., based on a possible 30 points for each Analogy Set). The separate Analogy Set scores were: (a) 9 points for the Word Set, (b) 5 points for the Figure Set, and (c) 18 points for the Picture Set. This same RHD subject scored 14 out of a possible 15 points for the combined pretest recognition tasks. Although these scores from the female subject, who was between two and three months post onset, appear low, one other RHD subject, who was 11 months post CVA onset, obtained a score of 32 as well, and another RHD subject, who was 6 months post CVA onset received a score of 27.

Examination of the data showed that the combined control groups' mean scores for the three analogy sets were (1) 26.65 for the Word Set, (2) 25.12 for the Figure Set, and (3) 22.96 for the Picture Set. These scores (of a possible 30 points) reflect the relatively high degree of accuracy by the two control groups. Individual control subjects' raw scores show that one subject achieved a perfect score of 90 (i.e., 30 points for each of the analogy sets), one subject made only one error on the Word Set, and one subject made only one error on the Figure Set and one error on the Picture Set. The largest number of errors made by a subject in the control groups was 14 [made by a child control subject]; four errors occurred on the Word Set, three on the Figure Set, and seven errors on the Picture Set. The across task mean score for the two control groups (adult and child) was 24.87.

The mean scores for the three analogy sets of the child control group were: (1) 26.4 for the Word Set, (2) 24.7 for the Figure Set, and (3) 22.3 for the Picture Set. The adult control group's mean scores for the three analogy sets were: (1) 27.5 for the Word Set, (2) 26.5 for the Figure Set, and (3) 25.0 for the Picture Set.
A comparison of the combined means for the two groups averaged across all tasks showed that the control groups performed 10.05 points (combined group mean = 25.4; SD = 2.83) better than the experimental groups (combined group mean = 15.33; SD = 6.18). Post hoc analysis resulted in a confidence interval of 10.05 ± 5.5 (i.e., between 4.6 to 15.6 points). According to Neter et al. (1985), if the interval range does not contain zero, significance can be attributed to the difference between means. Therefore, given the interval range of 4.6 to 15.4 points, it can be concluded at the .05 level of confidence that the control groups performed better than the experimental groups.

Differences Between the LHD Subjects and RHD Subjects on the Three Analogy Sets

The significant interaction effect made it appropriate to analyze further the varied difficulty of the three analogy sets for the two experimental groups. The hypotheses for differences between LHD subjects and RHD subjects on the three analogy sets were as follows: (1) LHD and RHD subjects were expected to perform significantly differently from each other on the Figure Set (on which it was expected that the LHD subjects would perform better) and on the Word Set (on which it was expected that the RHD subjects would perform better) and (2) LHD and RHD subjects were expected not to perform significantly differently from each other on the Picture Set. A t-test using Bonferroni's method of analysis (Neter et al., 1985) was used to compare the LHD and RHD subjects' performance on the three sets. As noted previously, Bonferroni's method of post hoc analysis is based on the principle that, if the calculated interval does not contain zero, significance can be concluded.

When comparing the LHD and RHD mean scores for the Figure Set, the LHD group's performance (mean = 15.42; SD = 5.73) was 3.6 points better than the RHD
group's performance (mean = 11.63; SD = 6.3). Using a one-sided t-test and Bonferroni's method, an interval of 3.6 ± 5.3 was found. Because the interval contains zero (i.e., -1.7 to 8.9 points), it cannot be concluded at the .05 level that LHD subjects' performance on the Figure Set was significantly better than the RHD subjects' performance on this task (see Appendix J).

Performance on the Word Set showed the RHD group (mean = 21.38; SD = 6.89) to perform 5.2 points higher than LHD subjects (mean = 16.17; SD = 6.41). Using a one-sided t-test the interval was calculated as 5.2 ± 5.53. Therefore, at the .05 level, the RHD group did not complete the Word Analogy Set significantly better than the LHD group (see Appendix J).

A two-tailed t-test was used to compare LHD and RHD subjects' performance on the Picture Set analogies. RHD subjects successfully completed the Picture Set analogies (mean = 15.25; SD = 6.25) with a mean score of 3.08 points better than the mean score (mean = 12.17; SD = 5.51) earned by LHD subjects. The interval was 3.08 ± 6.08. Because the interval (i.e., -3.00 to 9.16) contains zero, no significant difference between the LHD and RHD subjects' performance on the Picture Set could be concluded (see Appendix J).

Differences Within the Experimental Groups on the Three Analogy Sets

**Left Hemisphere Damaged Group Performance**

The experimental hypotheses for expected modality differences within the LHD group were that the LHD subjects would perform significantly better on the Figure Set than on the Word Set and would perform better on the Picture than on the Word Set. When comparing LHD subjects' performance on the Figure and Word Sets, the Figure Set mean score (mean = 15.42; SD = 5.73) was actually 0.75 points lower than the
Word Set mean score (mean = 16.17; SD = 6.41). In testing the original hypothesis, the interval was between -.75 ± 3.78 (i.e., between -4.53 to 3.03 points). Because the interval contains zero, it cannot be concluded that the LHD subjects performed significantly better on the Figure Set than the Word Set at the .05 level.

When comparing LHD performance on the Picture and Word Sets, the mean score for the Picture Set (mean = 12.17; SD = 5.51) was 4.0 points lower than the mean score for the Word Set (mean = 16.17; SD = 6.41). The interval was -4.0 ± 1.49 (i.e., between -7.8 to 0.2 points). Therefore, at the .05 level, it cannot be concluded that the performance of LHD subjects on the Picture Set was significantly better than their performance on the Word Set.

**Right Hemisphere Damaged Group Performance**

The experimental hypotheses for expected modality differences within the RHD group was that the RHD subjects would perform significantly better on the Word Set than on the Figure and would perform significantly better on the Picture than on the Figure Set.

Right hemisphere damaged subjects' mean scores for the three analogy sets were: (1) 21.38 for the Word Set, (2) 11.63 for the Figure Set, and (3) 15.25 for the Picture Set. Individual total raw scores for the three sets ranged from 27 points to 71 points. The 27 points were earned by a subject who received 15 points on the Word Set, 3 points on the Figure Set, and 9 points on the Picture Set. The 71 points were earned by a subject who received 27 points on the Word Set, 20 points on the Figure Set, and 24 points on the Picture Set.

RHD subjects' performance on the Word Set and the Figure Set were compared. The mean score obtained on the Word Set (mean = 21.38; SD = 6.89) was 9.75 points better than the mean score obtained on the Figure Set (mean = 11.63; SD = 6.30). The
interval was 9.75 ± 4.64 (i.e., between 5.11 and 14.39 points). Because the interval
does not contain zero, it may be concluded that RHD subjects performed significantly
better on the Word Set than on the Figure Set at the .05 level.

RHD subjects' performance on the Picture Set and the Figure Set were also
compared. The mean score on the Picture Set (mean=15.25; SD = 6.25) was 3.62
points better than the mean score for the Word Set (mean = 11.63; SD = 6.30). The
interval was 3.62 ± 4.64. Because the interval contains zero, it cannot be concluded at
the .05 level that the RHD subjects performed significantly better on the Picture Set
than on the Figure Set.

Differences Within the Control Groups
on the Three Analogy Sets

To compare the performance of the child control group (i.e., fourth or fifth
graders) on the three analogy sets, the Bonferonni method was again used. The mean
score on the Word Set (mean = 26.4; SD = 3.02) was 1.7 points better than the mean
score for the Figure Set (mean = 24.7; SD = 3.51). The interval was 1.7 ± 2.93. Be­
cause the interval contains zero, it cannot be determined at the .05 level that the child
control group's performance on the Word Set was significantly higher than the
group's performance on the Figure Set.

The performance by the child control group on the Word and Picture Sets was
also compared to discover whether differences between the two sets were significant.
The mean score for the Word Set (mean = 26.4; SD = 3.02) was 4.05 points higher
than the mean score for the Picture Set (mean = 22.35; SD = 4.51). The interval was
4.05 ± 2.93. Given this range, it can be concluded, at the .05 level, that the student
control group completed the Word Set analogies at a significantly higher level than
they completed the analogies in the Picture Set.
Performances by the adult control group on the Word and Figure Sets and on the Word and Picture Sets were also compared. The mean score on the Word Set (mean = 27.5; SD = 2.26) was 1.0 point higher than the mean score on the Figure Set (mean = 26.5; SD = 1.22). The interval was 1.0 ± 5.36; therefore, it cannot be concluded that the adult control group performed significantly differently on the analogies from the Word Set and the Figure Set.

The mean score earned by the adult control group on the Word Set (mean = 27.5; SD = 2.26) was 2.5 points higher than their mean score on the Picture Set (mean = 25.0; SD = 2.45). The computed confidence interval of 2.5 ± 5.36, led to the finding of no significant difference between the performance of the adult control group on the Word Set and the Picture Set.

Types of Errors by the Experimental Groups

Analysis of types of errors according to analogy set and response choice was examined to determine whether foils related to the critical feature within analogy problems were chosen more frequently than the unrelated foils were chosen (see Chapter II for an explanation of each type of error). The Chi-square test was used to calculate differences within the LHD group for types of errors observed in the combined analogies task (see Table 6). LHD subjects chose related foils significantly more frequently ($X^2 = 27.1; df = 2; p < .0001$) than unrelated foils on the total analogy task (i.e., results on the three sets were combined for this analysis). Differences within the RHD group according to the combined experimental task and the type of errors were also examined. It was concluded that related foils were not chosen significantly more frequently ($X^2 = 1.97; df = 2; p > .05$) than unrelated foils on the three combined experimental tasks by the RHD group (see Table 7).
Table 6  
Results of Chi-Square Analysis of LHD Subjects' Foil Choices

<table>
<thead>
<tr>
<th>Set</th>
<th>Frequencies</th>
<th>(f₀ - fₑ)</th>
<th>(f₀ - fₑ)²</th>
<th>(\frac{(f₀ - fₑ)^2}{fₑ})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Word Related</td>
<td>44</td>
<td>39.68</td>
<td>4.32</td>
<td>18.56</td>
</tr>
<tr>
<td>Picture Related</td>
<td>27</td>
<td>41.15</td>
<td>-14.15</td>
<td>199.22</td>
</tr>
<tr>
<td>Figure Related</td>
<td>62</td>
<td>52.17</td>
<td>9.83</td>
<td>96.61</td>
</tr>
<tr>
<td>Word Unrelated</td>
<td>10</td>
<td>14.32</td>
<td>-4.32</td>
<td>18.56</td>
</tr>
<tr>
<td>Figure Unrelated</td>
<td>29</td>
<td>14.85</td>
<td>14.15</td>
<td>199.22</td>
</tr>
<tr>
<td>Picture Unrelated</td>
<td>9</td>
<td>18.83</td>
<td>-9.83</td>
<td>96.61</td>
</tr>
<tr>
<td>Totals</td>
<td>181</td>
<td>181</td>
<td>0.00</td>
<td>27.1</td>
</tr>
</tbody>
</table>

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Table 7

Results of Chi-Square Analysis of RHD Subjects' Foil Choices

<table>
<thead>
<tr>
<th>Set</th>
<th>Frequencies</th>
<th>(f₀ - fₑ)</th>
<th>(f₀ - fₑ)²</th>
<th>(f₀ - fₑ)² / fₑ²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Word Related</td>
<td>14</td>
<td>13.42</td>
<td>.58</td>
<td>.34</td>
</tr>
<tr>
<td>Figure Related</td>
<td>24</td>
<td>27.42</td>
<td>-3.42</td>
<td>11.70</td>
</tr>
<tr>
<td>Picture Related</td>
<td>25</td>
<td>22.17</td>
<td>2.83</td>
<td>8.01</td>
</tr>
<tr>
<td>Word Unrelated</td>
<td>9</td>
<td>9.58</td>
<td>-.58</td>
<td>.34</td>
</tr>
<tr>
<td>Figure Unrelated</td>
<td>23</td>
<td>19.58</td>
<td>3.42</td>
<td>11.70</td>
</tr>
<tr>
<td>Picture Unrelated</td>
<td>13</td>
<td>15.83</td>
<td>-2.83</td>
<td>8.01</td>
</tr>
<tr>
<td>Totals</td>
<td>108</td>
<td>108</td>
<td>0.00</td>
<td>1.97</td>
</tr>
</tbody>
</table>

Summary

To summarize the results of this study, significant differences were found for the main effect for group, main effect for repeated measures, and the interaction effect for group-by-repeated measures. Bonferroni's method of post hoc analysis was used to compare means in order to identify specific areas of significant difference.

The combined experimental groups' means for the three analogy sets were lower than the means for the three analogy sets earned by the combined control groups. Post
hoc analysis of the results for the control groups and the experimental groups showed the control groups to perform significantly better on the combined analogical tasks than the experimental groups did. Examination of the LHD and RHD groups' performance on the combined experimental tasks showed no significant difference between the two groups on the total analogies task. LHD subjects did not perform significantly better on the Figure Set than on the Word Set or better on the Picture Set than on the Word Set. RHD subjects did perform significantly better on the Word Set than on the Figure Set but did not perform significantly better on the Word Set than on the Picture Set.

Child control subjects did not perform significantly better on the Word Set than on the Figure Set but did perform significantly better on the Word Set than on the Picture Set. Adult control subjects did not perform significantly better on the Word Set than on the Figure Set or better on the Word Set than on the Picture Set.

The LHD subjects chose foils related to the correct choice in a logical way more frequently than foils unrelated to the correct choice in a logical way on the total analogy task. However, RHD subjects did not choose foils related to the correct choice in a logical way significantly more frequently than they chose unrelated foils.
CHAPTER V

DISCUSSION

The results of this study showed the experimental groups to perform significantly differently from the control groups on the analogical reasoning tasks. Significant differences were found for the total group effect, the repeated measures effect, and the group-by-repeated measures interaction effect. The significance for the group effect indicates significant differences among the four groups on the experimental task. Significance for the repeated measures indicates differences among the three sets of analogies. The significant group-by-repeated measures interaction indicates that difficulty of the three tasks was experienced differentially by the four subject groups. Although significance was found for the group performance and the three analogy sets, specific interactions could not be determined without post hoc analyses.

Differences Between the Experimental Groups

In answer to the primary experimental question, it was found that the two experimental groups (i.e., LHD and RHD groups) performed significantly differently than the two control groups (i.e., the child control group and the adult control group) on the analogy tasks. The mean scores of the experimental groups were significantly lower than mean scores of the control groups. It was noted that only four individuals from the experimental groups demonstrated scores of 20 points or more for the each of the analogical tasks (out of 30 possible points) compared to all but one individual from the control groups obtaining 20 points or more. These results were expected. They indicate that experimental subjects' brain damage hindered their reasoning abilities.
Further analysis comparing the LHD subjects and RHD subjects on the three analogy sets showed no significant differences between the two groups on any of the individual analogy sets. These results are consistent with the findings of Brownell et al. (1986), Caramazzo et al. (1976), and McDonald and Wales (1986), who found RHD subjects to have difficulty performing complex linguistic and cognitive functions. They suggest that there is a need for both hemispheres to function in order to comprehend fully and to complete complex analytical operations, such as analogical reasoning.

One consideration for further investigation based on these findings is related to the fact that specific sites and extents of lesion for the experimental subjects were not controlled. Comparing LHD and RHD subjects who experienced damage in similar areas of the brain (e.g., the frontal or parietal lobes of each hemisphere) might yield different results. Comparing individuals who experienced more extensive or less extensive lesions also might yield different results. Another consideration for future investigation based on these findings is that participation in speech-language remediation for the experimental group was not controlled. Stroke patients who received speech therapy might have regained some linguistic and cognitive functioning that patients who suffered similar strokes (i.e., same site of lesion, same extent of lesion, and same post onset time) but did not receive the same amount of therapy would not have.

Differences Within Experimental Groups

In addition to differences between the experimental groups on the varied analogy tasks, differences were also assessed on the three types of analogies within groups. The LHD subjects' performances on the three analogy sets were compared. It was concluded that LHD subjects did not perform significantly differently on the three
analogy tasks. It had been hypothesized that LHD subjects would perform significantly better on the Figure Set than on the Word Set, and that they would perform significantly better on the Picture Set than on the Word Set. The means did not vary in the expected direction.

One consideration for no significant difference between the analogy tasks is that the three analogy sets might not have been equal in their measurement of cognitive functions. The Word Set might have been easier to complete than the Picture Set. Supporting this possibility, the child control group performed significantly better on the Word Set than on the Picture Set. If test difficulty were confounded with group differences, a result might have been acceptance of the null hypothesis that the difficulty of the Word Set is no different than difficulty of the other sets for the LHD subjects, even if such a relationship does exist. Alternatively, the drawings for the Picture Set might not have represented clearly the intended relationships. If this were true, the Picture set might have been more difficult to complete than the Word Set. Also, if specific sites and sizes of lesion had been controlled, different sites and sizes of damage to the left hemisphere might have been associated with significant differences in the successful completion of the three analogical reasoning tasks for them. For example, LHD patients who experienced an anterior lesion might not have had as much difficulty completing the tasks as LHD patients who experienced a posterior lesion. LHD patients who experienced a small posterior lesion might not have had as much difficulty completing the tasks as LHD patients who experienced a large posterior lesion. Sarno (1981) noted that patients with large dominant hemisphere lesions, either one large or many small ones, fare poorly on many tasks, whereas those with lesser lesions do better. This suggests that extent of lesion may be an important variable to control in future studies. Lastly, participation in speech-language therapy was not controlled. LHD subjects who received remediation might have performed signifi-
cantly better than LHD subjects who did not receive speech-language therapy, but such relationships were not tested in this study.

The RHD subjects' performances on the three analogy sets were also compared. It was found that the RHD subjects' performance on the Word Set was significantly better than on the Figure Set. However, the RHD subjects did not perform significantly differently on the Picture and Word Sets. It had been expected that RHD subjects would perform significantly better on the Word Set than on the Figure Set and perform significantly better on the Picture Set than on the Figure Set.

The same considerations discussed for the LHD subjects' results might be applied to the RHD subjects' results. Significant difference between the Word Set and Figure Set might reflect differences in the testing material itself that could have masked differences in subjects' performance. Also, the specific sites and sizes of lesion for the RHD patients were not controlled in this study. Significant differences in performance of tasks using the Word and Figure Sets might be associated with size and site differences within the right hemisphere. Right hemisphere damaged patients with posterior lesions might have performed significantly better on the Word Set than right hemisphere damaged patients with anterior lesions. RHD patients with large posterior lesions might have performed significantly better on the Word Set than RHD patients with lesser posterior lesions. Lastly, participation in speech-language therapy was not controlled. RHD subjects who received remediation might have performed significantly better than RHD subjects who did not receive speech-language therapy.

Results from the three analogy sets by the control groups showed that the children's performances on the Word and Figure Sets were not significantly different. However, it was determined that the child control subjects performed significantly better on the Word Set than on the Picture Set. This result would support the idea that the Word analogies were easier to complete than the Picture analogies.
Performance on the Word and Figure Sets and on the Word and Picture Sets by the adult control subjects was also compared. No significant differences were found for the Word and Figure Sets or for the Word and Picture Sets for the adult controls. These results indicate that for the normal adult group, the three analogy sets are equally balanced in their measurement of linguistic and cognitive functions. It is noted, however, that the adult group consisted of only six subjects. Also, a majority of the subjects in the adult control group presently held white collar jobs and had received at least a partial college education. The higher education and socio-economic level of this group in relation to the child control group and the experimental groups might have been another factor that resulted in equal performance on the three sets for the adult control group. It should be noted, however, that declined cognitive abilities resulting from increased age did not appear to be in evidence. In fact, the adult control group received the highest scores for each of the three analogy sets. These results suggest that the experimental subjects' analogical reasoning deficits were related to their unilateral brain damage and not to such factors as decline in abilities due to normal aging. A consideration for future investigation is that adult control subjects of various socio-economic and educational levels might be tested to help develop analogy tasks that better measure similar levels of cognitive abilities in different modalities.

Analysis of types of errors according to analogy set and response choice was conducted to determine whether foils related to a critical factor within analogy problems were chosen more frequently than foils that had no clear relationship to the target response. A Chi-square analysis was used to examine the LHD subjects' foil choices for the entire experimental task and the RHD subjects' foil choices for the entire experimental task.

LHD subjects chose analogy foils that were related to the correct choice in a logical way significantly more frequently than they chose the unrelated foils on the total
analogy task. One reason for this significant difference might be that the LHD subjects' intact right hemisphere enabled them to use holistic operations to encode and infer relationships within the analogy problem to some degree. However, the damaged left hemisphere might have prevented them from using the encoded information to complete the analogy with full detailed accuracy.

Right hemisphere damaged subjects did not choose logically related foils significantly more frequently than unrelated foils. These subjects, because of the damage to the right hemisphere, might not have been able to look at the general aspects of the problem in order to encode the needed information. Therefore, the high-order relationships (Sternberg, 1985a) might not have been understood, and, as a result, responses might have been randomly chosen. Future investigations examining unilateral brain damaged patients' response choices should be performed before conclusions can be drawn in this area.

Clinical Implications

Analogical reasoning abilities do appear to be difficult for both the LHD and the RHD patients. All of the subjects (except three) were able to recognize all or most of the words and pictures when given auditory or visual cues in the pretest conditions; however, completing the steps of the inductive reasoning tasks in order to make the correct response choices was difficult.

RHD patients did not perform significantly better than LHD patients on the total experimental task. These results indicate that although basic perceptual and receptive language processing might have been intact, RHD patients had difficulty completing analogical reasoning tasks.

LHD subjects did not complete the Picture Set significantly better than the Word Set. In fact, the mean score for performance on the Word Set by the LHD subjects
was higher than their mean score for performance on the Picture Set was (although not significantly different). RHD subjects performed significantly better on the Word Set than on the Figure Set, but no significant difference was found between performance by the RHD subjects on the Word and Picture Sets.

The process of analogical reasoning contains sequential components that must be completed successfully in order to solve analogy problems correctly (Sternberg, 1985a; 1985b). It has been determined that analogical reasoning is a good indicator of general intelligence (Spearman, 1927a; Sternberg, 1977) or an indicator of cognitive factors within other psychometric theories of intelligence (Thurstone, 1938; Guilford, 1967; 1982). If this is true, practice performing analogical reasoning tasks might help stroke patients improve their ability to meet day-to-day challenges which require the general intelligence that has been developed throughout their years. Feuerstein (1982) devised the Learning Potential Assessment Device (LPAD) to investigate the possibility of influencing the cognitive development of retarded performers. Results of pre- and post-testing indicated that a significant number of children were able to modify and improve their current abilities after therapy utilizing analogical reasoning tasks. Therefore, it may be possible also to modify and improve linguistic and cognitive abilities of unilateral stroke patients using analogical reasoning tasks.

Analogies might also be used to measure aspects of the LHD and RHD patients' verbal and cognitive abilities during diagnostic procedures. "The purposes of assessment are to describe language behaviors, to identify existing problems, to determine the goals of intervention, and to define factors which facilitate the retrieval of language" (Chapey, 1986b, p. 82). Assessment of analogy tasks could fulfill each purpose. Results of this study showed LHD and RHD groups to perform significantly more poorly than the normal control groups on the combined analogy tasks. This information might help to describe the language behaviors of LHD and RHD stroke...
patients. Also, the three types of stimuli could help to identify the subjects' verbal and nonverbal cognitive deficits. Factors which facilitate problem solving could be identified based on the patients' level of performance on each analogy set. For example, if a RHD or LHD patient had difficulty completing figure and picture analogies, but was relatively able to complete the word analogies, a clinician might use verbal analogies to facilitate reasoning for processing for nonverbal analogies. Often, picture cards are used as stimulus materials with linguistically impaired adults without a clear rationale. If a patient performs better on printed word analogies or figure analogies, such types of stimuli might provide a better initial pathway for beginning to improve the patient's linguistic and cognitive abilities than picture stimuli would.

"Studies have shown that the aphasic person, in spite of intensive ongoing therapy, may not regain his premorbid potential in linguistic skills" (Mills, 1986, p. 349). If an individual's linguistic and cognitive abilities are severely impaired, verbal communication might be impossible. It has been determined that analogical reasoning is a good measure of intelligence (Guilford, 1967; Sternberg, 1985a; Thurstone, 1938). It might be possible to use a multiple modality analogies test to assess a stroke patient's ability to use augmentative communication successfully. A person must be able to understand a set of high-order rules and to express intentions in order to communicate with high level augmentative communication systems. In such cases a picture or symbol must become the referent for an actual action, object, or request. A similar process is needed to complete analogy problems. The individual must look at the stimuli, relate them to other actions or objects, and select the appropriate symbols to represent the desired meaning. Analogies might help to assess stroke patients' nonverbal intelligence and to decide whether augmentative communication is a possible remediation tool.

Finally, it should be noted that diagnosis and remediation using analogical rea-
soning tasks with unilateral stroke patients might not result in the same outcomes as found in this study. Research significance does not necessarily relate to clinical significance. When assessing unilateral stroke patients, individual differences should be considered. From the group experiment, however, it does appear that the different types of analogies might detect generalized cognitive deficits and differentiate them from deficits that are more strictly linguistic or spatial in nature. Also, given the previous literature pertaining to the contribution that practice in performing analogies can make on modification of intelligence (Feuerstein, 1982), modification of present levels of performance in brain injured adults might be possible.

Recommendations for Future Research

Problems in the design of the current study might be addressed by using larger subject groups and better constructed analogies for determining normal performance across all three sets. Results of such investigations could determine further the differences between LHD and RHD patients and among the three types of analogy sets.

Additional studies are also needed to extend the investigation of the relationship between analogical reasoning abilities and linguistic or cognitive deficits. For example, studies of the relationship between sites and extent of lesion of unilateral stroke patients and the types of analogical reasoning tasks might also determine hemispheric abilities in relation to a task's stimuli. Comparing analogical reasoning in normal aging adults and dementia patients might help to better understand the cognitive abilities of older adults. A study examining unilateral stroke patients' abilities to improve analogical reasoning may determine if using analogical reasoning problems can improve stroke patients' present linguistic and cognitive abilities. In addition, a direct study comparing analogical abilities of other linguistically impaired individuals (e.g., hearing impaired children or patients with traumatic brain injuries) using a multiple modalities
Conclusions

This study was designed to investigate the effects of unilateral brain damage on analogical reasoning abilities of LHD and RHD stroke patients. The conclusions that can be drawn from the study are as follows:

1. People who have brain damage have more difficulty with the cognitive task of analogical reasoning than do people without brain damage.

2. Apparently both hemispheres make contributions to the processing of analogies. The fact that the RHD subjects in this study had less difficulty on the Word analogies than the Figure analogies leads to the conclusion that the right hemisphere probably plays a lesser role in the processing of verbal analogies than the left hemisphere does. The fact that the LHD subjects had similar difficulties on the three types of analogies leads to the conclusion that the left hemisphere probably plays a role in multiple aspects of analogical processing.

3. The results shown by the LHD subjects would tend to support a conclusion that there is a general intelligence factor that is affected negatively by brain injury; whereas the results with the RHD subjects provide greater support for the conclusion that intelligence represents a group of somewhat independent factors, that may be differentially affected when brain injury affects the right hemisphere only.
APPENDIX A

CONFIRMATION LETTER FROM HSIRB STATING
APPROVAL OF RESEARCH PROTOCOL
TO: Letitia Gillespie  
Nicola Nelson  

FROM: Ellen Page-Robin, Chair  

RE: Research Protocol  

DATE: July 8, 1987  

This letter will serve as confirmation that your research protocol, "The Effects of Unilateral brain damage on analogical thinking abilities of left and right hemisphere damaged patients" has been approved by the HSIRB with the following provisions:

1. Your revised forms meeting the criteria set by the HSIRB.  

2. The consent form is amended to avoid responsibility to persons who do not wish to participate and a revision of such be sent to the Board.

If you have any further questions, please contact me at 383-4917.

P.S. Please send copies of the change in consent form to the HSIRB.
APPENDIX B

SUBJECT QUESTIONNAIRES
CHILD CONTROL SUBJECTS’ QUESTIONNAIRE

Name: _______________________________________________________

Birthdate: ___________________________________________________

Sex:________________________________________ Grade completed__________

Which hand does your child prefer to use? When writing:___________
When playing sports or doing hobbies:___________________________

What language does your child speak? At home:____________________
In school:___________ Was this the first language he/she learned?_____

Has your child skipped a grade?____ Has your child repeated a grade?_____

Has your child ever been referred for a speech, language, hearing, or reading
evaluation?_______ If so, please describe__________________________

__________________________________________________________________

__________________________________________________________________
ADULT CONTROL SUBJECTS' QUESTIONNAIRE

Name:_____________________________________________________

Birthdate:__________________________________________________

Sex:________________________________________________________

Which hand do you prefer to use when writing?____________________
When playing sports or doing hobbies?_____________________________

How is your present health?____________________________________

What is your native language?____________________________________
Do you speak any other language fluently?__________________________
If so, which ones?____________________________________________

Are you presently working?_______ Where?__________________________
If you are retired, where did you work before you retired?____________

What is the highest grade level completed or highest degree obtained?

______________________________________________________________
EXPERIMENTAL SUBJECTS' QUESTIONNAIRE

Name:_________________________________________________________

Birthdate:______________________________________________________

Sex:___________________________________________________________

Date of cerebrovascular accident (stroke): ____________________________

How was your health prior to your stroke?_______________________________

How is your health now?___________________________________________

Where do you presently live? At home?____ With family members?______
   In a nursing home?____________________

Before the stroke, which hand did you prefer to use? When writing:_______

When playing sports or doing hobbies:________________________________

What was the last job you held before the stroke?_______________________

If you were retired prior to the stroke, what was the job you held before you retired?____

What was the highest grade level completed or highest degree obtained?____

What is your native language?__________________ If other than English, at what age did you begin to use English?_____________________ Do you speak any other languages fluently?____________________ If so, which ones?____________________________

Do you presently use a wheelchair or walking aid?_______________________

Is there paralysis or weakness on either side?____ If so, which side?_______

Are any of the following parts of your body paralyzed or weakened?
   mouth______ arm______ leg_____

Did you receive speech-language therapy in the hospital?_____ If so, how long did you receive speech-language therapy in the hospital?_____ When you left the hospital, did you continue to receive speech-language therapy?_____ If so, for how long?_____ Who provided therapy for you?____

Approximately how many hours of speech-language therapy have you received?____

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APPENDIX C

SUMMARY OF EXPERIMENTAL SUBJECTS' CT SCAN RESULTS
### SUMMARY OF EXPERIMENTAL SUBJECTS' CT SCANS

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Sex</th>
<th>CVA Post-Onset</th>
<th>Site of Lesion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Male</td>
<td>16 mos.</td>
<td>Left Hemisphere</td>
</tr>
<tr>
<td>2.</td>
<td>Male</td>
<td>8 mos.</td>
<td>Left Hemisphere</td>
</tr>
<tr>
<td>3.</td>
<td>Male</td>
<td>8 mos.</td>
<td>Left Hemisphere</td>
</tr>
<tr>
<td>4.</td>
<td>Female</td>
<td>5 mos.</td>
<td>Left Hemisphere</td>
</tr>
<tr>
<td>5.</td>
<td>Female</td>
<td>10 mos.</td>
<td>Left Middle Cerebral Artery</td>
</tr>
<tr>
<td>6.</td>
<td>Female</td>
<td>4 mos.</td>
<td>Left Posterior Parietal Lobe</td>
</tr>
<tr>
<td>7.</td>
<td>Male</td>
<td>4 mos.</td>
<td>Left Hemisphere</td>
</tr>
<tr>
<td>8.</td>
<td>Female</td>
<td>9 mos.</td>
<td>Left Hemisphere</td>
</tr>
<tr>
<td>9.</td>
<td>Male</td>
<td>14 mos.</td>
<td>Left Middle Cerebral Artery</td>
</tr>
<tr>
<td>10.</td>
<td>Female</td>
<td>15 mos.</td>
<td>Left Hemisphere</td>
</tr>
<tr>
<td>11.</td>
<td>Male</td>
<td>33 mos.</td>
<td>Left Anterior &amp; Middle Cerebral Arteries</td>
</tr>
<tr>
<td>12.</td>
<td>Male</td>
<td>20 mos.</td>
<td>Left Hemisphere</td>
</tr>
<tr>
<td>13.</td>
<td>Female</td>
<td>3 mos.</td>
<td>Right Parietal-Frontal Area</td>
</tr>
<tr>
<td>14.</td>
<td>Male</td>
<td>6 mos.</td>
<td>Right Parietal Lobe</td>
</tr>
<tr>
<td>15.</td>
<td>Male</td>
<td>21 mos.</td>
<td>Right Hemisphere-large area</td>
</tr>
<tr>
<td>16.</td>
<td>Female</td>
<td>11 mos.</td>
<td>No CT; Physician's Diagnosis</td>
</tr>
<tr>
<td>17.</td>
<td>Male</td>
<td>3 mos.</td>
<td>Right Hemisphere</td>
</tr>
<tr>
<td>*18.</td>
<td>Female</td>
<td>2 mos.</td>
<td>Right Middle Cerebral Artery</td>
</tr>
<tr>
<td>19.</td>
<td>Male</td>
<td>20 mos.</td>
<td>Right Hemisphere</td>
</tr>
<tr>
<td>20.</td>
<td>Male</td>
<td>16 mos.</td>
<td>Right Frontal-Temporal Area</td>
</tr>
</tbody>
</table>

**Note.** * = RHD subject who suffered CVA fewer than 3 months prior to testing.
APPENDIX D

SUMMARY OF EXPERIMENTAL SUBJECTS' EMPLOYMENT,
EDUCATION, AND MOTOR SYSTEM INVOLVEMENT
### SUMMARY OF EXPERIMENTAL SUBJECTS' EMPLOYMENT AND EDUCATIONAL INFORMATION

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Employment</th>
<th>Education</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Maintenance Worker</td>
<td>12th Grade</td>
</tr>
<tr>
<td>2.</td>
<td>Electrical Technician</td>
<td>12th Grade</td>
</tr>
<tr>
<td>3.</td>
<td>Restaurant Owner</td>
<td>12th Grade</td>
</tr>
<tr>
<td>4.</td>
<td>Homemaker</td>
<td>11th Grade</td>
</tr>
<tr>
<td>5.</td>
<td>Babysitter</td>
<td>12th Grade</td>
</tr>
<tr>
<td>6.</td>
<td>Purchasing Agent</td>
<td>2 yrs. of college</td>
</tr>
<tr>
<td>7.</td>
<td>Plumber</td>
<td>1 yr. of college</td>
</tr>
<tr>
<td>8.</td>
<td>Teacher</td>
<td>4 yrs. of college</td>
</tr>
<tr>
<td>9.</td>
<td>Factory Worker</td>
<td>8th Grade</td>
</tr>
<tr>
<td>10.</td>
<td>Homemaker</td>
<td>7th Grade</td>
</tr>
<tr>
<td>11.</td>
<td>Teacher</td>
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</tr>
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<tr>
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<td>2 yrs. of college</td>
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<td>12th Grade</td>
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**Note.** Subjects one through 12 are LHD. Subjects 13 through 20 are RHD.
### SUMMARY OF EXPERIMENTAL SUBJECTS' HEALTH AND MOTOR SYSTEM INVOLVEMENT

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<td>Diabetes; Blocked Arteries</td>
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<td>High Blood Pressure; Diabetes</td>
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<td>High Blood Pressure</td>
<td>Rt. Side Paralysis</td>
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<tr>
<td>6.</td>
<td>Diabetes; Infections</td>
<td>Rt. Side Weakness</td>
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<tr>
<td>7.</td>
<td>High Blood Pressure; Diabetes</td>
<td>Rt. Side Paralysis</td>
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<td>Heart Problems</td>
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<td>Heart Problems</td>
<td>Rt. Side Weakness</td>
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<td>Rt. Side Paralysis</td>
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<td>12.</td>
<td>Fluctuating Blood Pressure</td>
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<td>High Blood Pressure; Arthritis</td>
<td>Lt. Side Paralysis</td>
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<tr>
<td>14.</td>
<td>Diabetes</td>
<td>Lt. Side Paralysis</td>
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<td>15.</td>
<td>Sugar Control Problems</td>
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<td>High Blood Pressure</td>
<td>Lt. Side Paralysis</td>
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<td>High Blood Pressure</td>
<td>Lt. Side Paralysis</td>
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<td>19.</td>
<td>High Blood Pressure; Diabetes; Heart Attack</td>
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</tr>
<tr>
<td>20.</td>
<td>High Blood Pressure</td>
<td>Lt. Side Paralysis</td>
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**Note.** Subjects one through 12 are LHD. Subjects 13 through 20 are RHD.
APPENDIX E

EXAMPLES OF THE THREE ANALOGY SETS
EXAMPLE OF WORD SET ANALOGY

FLY  BIRD
SWIM

1 2 3
FISH  WATER  RING
EXAMPLE OF FIGURE SET ANALOGY

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EXAMPLE OF PICTURE SET ANALOGY

1. Radio
2. Toothbrush
3. Brushing teeth
APPENDIX F

LIST AND EXAMPLES OF PRETEST STIMULI
### LIST OF WORDS SPOKEN FOR THE WORD PRETEST

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<td>4. CLASS</td>
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LIST OF WORDS SPOKEN FOR THE PICTURE PRETEST

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<td>4. SNOWING</td>
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APPENDIX G

PRESENTATION ORDER OF THE RECOGNITION PRETEST
# Presentation of Practice Analogies for the Child Control Group

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*Note.* W = Word Set. F = Figure Set. P = Picture Set.
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Note. W = Word Set. F = Figure Set. P = Picture Set
# PRESENTATION OF PRACTICE ANALOGIES FOR THE LHD AND RHD GROUPS

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*Note. W = Word Set. F = Figure Set. P = Picture Set.*
APPENDIX H

ANSWER FORMS FOR THE PRETEST, PRACTICE ANALOGIES, AND THE TEST ANALOGIES
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PRACTICE ANALOGY ANSWER FORM

Word Set
1.
2.
3.

Figure Set
1.
2.
3.

Picture Set
1.
2.
3.

Note. The order of presentation of the practice analogy sets was counterbalanced.
## ANALOGY TEST ANSWER FORM

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### Figure Set

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### Picture Set

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APPENDIX I

RAW SCORES AND MEANS FOR THE CONTROL GROUPS AND THE EXPERIMENTAL GROUPS

94
### Individual Raw Scores and Means for the Control Groups

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APPENDIX J

COMPUTATION METHODS FOR POST HOC ANALYSIS
COMPUTATION METHODS FOR POST HOC ANALYSIS ILLUSTRATED
WITH THE COMPUTATIONS FOR TESTING THE DIFFERENCES
BETWEEN LHD AND RHD SUBJECTS' PERFORMANCE
ON THE COMBINED ANALOGICAL TASKS
(Neter et al., 1985)

Formulae:

MSE_3 = \frac{df_1 (MSE_1) + df_2 (MSE_2)}{df_1 + df_2} = SS_1 + SS_2

Results from Table 5

<p>| | |</p>
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<thead>
<tr>
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<tr>
<td>SS_1</td>
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<tr>
<td>df_2</td>
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\[ df_{app} = \frac{[df_1 (MSE_1) + df_2 (MSE_2)]^2}{[df_1 (MSE_1)^2 + df_2 (MSE_2)^2]} \]

Calculations:

MSE_3 = \frac{1771.5 + 1114.5}{42 + 84} = \frac{2886}{128} = 22.55

\[ df_{app} = \frac{2886^2}{42 (42.22) + 84 (13.32)} = 92.9 \text{ df} = (93) \]

t (.00625, 93) = 2.55 for one-tailed t-test

t (.00312, 93) = 2.80 for two-tailed t-test

One-tailed t-test: Two-tailed t-test:

L ± 22.55 (1/12 + 1/8) (2.55) = (2.17) (2.55) = 5.53

= 2.17 (2.80) = 6.08

Conclusions:

Figure Set: 15.42 (LHD) - 11.63 (RHD) ± 5.53 = 3.79 ± 5.53 or -1.94 to 9.32
- Not Significant at the .05 level of confidence

Word Set: 21.38 (RHD) - 16.17 (LHD) ± 5.53 = 5.21 ± 5.53 or -.32 to 10.74
- Not Significant at the .05 level of confidence

Picture Set: 15.25 (RHD) - 12.17 (LHD) ± 6.08 = 3.08 ± 6.08 or -3.00 to 9.16
- Not Significant at the .05 level of confidence

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APPENDIX K

SUBJECTS' CONSENT/ASSENT FORMS FOR PARTICIPATION IN THE STUDY

100
INFORMED CONSENT FORM FOR PARENTS
OF CHILD CONTROL SUBJECT

Please read carefully, sign and return to:

Letitia Gillespie, master's degree student
1913 Elkerton Building 4, Apartment 206
Kalamazoo, Mi. 49001

I give permission for my child to serve as a control subject in this investigation. I understand that his recognition and analogical thinking abilities will be tested during one one-half hour session and that all information provided to the investigator will be kept strictly confidential.

Signed, __________________________
Relationship to Subject __________________________
Date __________________________
INFORMED ASSENT FORM FOR THE
CHILD CONTROL SUBJECTS

Please read carefully, sign and return to:

Letitia Gillespie, master's degree student
1913 Elkerton Building 4, Apartment 206
Kalamazoo, Mi. 49001

My parent/guardian has told me about the tests I will be taking. I understand that the tests will take about one one-half hour. I know that no one else will know my name or the scores I get. I also know that it will be okay to quit at any time if I decide I want to.

Signed, ______________________

Date __________________________

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INFORMED CONSENT FORM FOR THE
ADULT CONTROL SUBJECTS

Please read carefully, sign and return to:

Letitia Gillespie, master's degree student
1913 Elkerton Building 4, Apartment 206
Kalamazoo, Mi. 49001

I understand that the purpose of this study is to determine the analogical thinking
abilities of stroke patients and that my participation is to serve as a control subject. I
understand and expect that information about myself will be kept strictly confidential.
I am also aware that this test will take approximately 15 minutes and that I can
withdraw from the study at any time without penalty.

Signed, ____________________________

Date __________________________

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INFORMED CONSENT FORM FOR THE EXPERIMENTAL SUBJECTS

Please read carefully, sign, and return to:

Letitia Gillespie, master's degree student
1913 Elkerton Building 4, Apartment 206
Kalamazoo, Mi.  49001

I understand that the purpose of this study is to determine the effects of unilateral brain damage on the analogical thinking abilities of people with left and right hemisphere strokes. I understand and expect that information about myself will be kept strictly confidential.

I freely give permission to participate in this study. I know that my recognition and analogical thinking abilities will be tested and that the examiner will have access to my medical records. The examiner will also have access to any information relating to my stroke and speech-language testing and therapy. I am aware that I can withdraw from the study at any time without penalty.

Signed, ______________________ ______________
patient date

Signed, ______________________ ______________
legal guardian (if any) date

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INFORMED ASSENT FORM TO EXPERIMENTAL
SUBJECT'S LEGAL GUARDIAN

Please read carefully, sign, and return to:

Letitia Gillespie, master's degree student
1913 Elkerton Building 4, Apartment 206
Kalamazoo, Mi. 49001

Dear guardian,

If Mr. or Mrs. ______________ has difficulty reading the information letter from Mr. Locke or the enclosed consent form, then the study must be explained to him. Given below is a checklist of the important information he/she is to understand. Could you and a family member or friend explain the study. You know his/her present level of understanding and how best to explain events to him/her.

   ______ There is a student from Western Michigan University conducting a study.
   ______ She needs patients who have had a stroke.
   ______ You will take two tests that will last approximately 30 minutes each.
   ______ You will look and point to pictures
   ______ You can stop at any time.
   ______ The information you give will be kept confidential.

If Mr. or Mrs. ______________ has difficulty understanding any of the information listed, please circle that sentence. Please check each statement he/she appears to understand and sign this form. Thank you for your time and cooperation.

Sincerely,

Letitia Gillespie

________________________________________  ____________________
legal guardian   date

________________________________________  ____________________
witness   date

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Humphreys, L. G. (1979). The construct of general intelligence. *Intelligence, 3.* 105-120.


Rubens, A. B. (1977). The role of changes within the central nervous system during recovery from aphasia. In M. Sullivan and M. Krommers (Eds.), *Rationale for adult aphasia therapy* (pp. 28 - 43). Lincoln, NE: University of Nebraska Medical Center.


