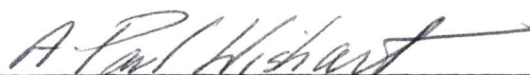


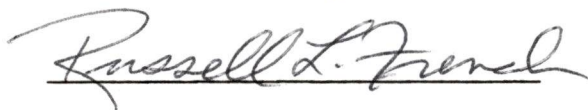
To the Graduate Council:

I am submitting herewith a dissertation written by Sandra Yancy McGuire entitled "An Exploratory Investigation of the Relationship Between Cerebral Dominance and Problem Solving Strategies Used by Selected High School Chemistry Students." I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Education.

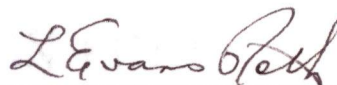


A. Paul Wishart, Major Professor

We have read this dissertation
and recommend its acceptance:



Accepted for the Council:



Vice Chancellor
Graduate Studies and Research

AN EXPLORATORY INVESTIGATION OF THE RELATIONSHIP BETWEEN
CEREBRAL DOMINANCE AND PROBLEM SOLVING STRATEGIES
USED BY SELECTED HIGH SCHOOL CHEMISTRY STUDENTS

A Dissertation
Presented for the
Doctor of Philosophy
Degree
The University of Tennessee, Knoxville

Saundra Yancy McGuire

March 1983

3065356

DEDICATION

This manuscript is dedicated to my parents, Robert E. and Delsie M. Yancy. Their support and encouragement of my educational activities have been a constant source of motivation and inspiration for me.

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The author wishes to express her sincere appreciation to all of the persons who contributed to the success of this project, many of whom must remain nameless. First of all, special thanks are extended to Dr. A. Paul Wishart, Chairman of her Doctoral Committee, for the many, many hours of advice, gentle but firm guidance, and constant encouragement that he provided throughout her graduate program. The assistance of Drs. Russell French, Charles Keenan, and Luther Kindall, in their roles as members of the author's Doctoral Committee, is also gratefully acknowledged. Drs. Carl Asp and Stephen Handel and Mrs. Pearl Gordon provided valuable technical assistance in the initial stages of this study; their assistance is greatly appreciated.

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Last, but certainly not least, the author wishes to express very sincere thanks to her husband, Steve, and daughters, Carla and Stephanie, for their patience, unwavering support, and encouragement throughout this project.

ABSTRACT

The purpose of this investigation was to explore the relationship between cerebral dominance and problem solving strategies used by high school chemistry students. Cerebral dominance was determined by dichotic listening, tachistoscopic viewing, and SOLAT. The dichotic listening task required the subjects to report the syllable heard best when two syllables were presented simultaneously, one to each ear, via headphones. Tachistoscopic viewing required the subjects to identify words that were briefly flashed to the right or left of a point at which the subjects were fixating. SOLAT, a written questionnaire, required subjects to report learning style preferences on a variety of tasks.

The problem solving task was conducted using a clinical mode, in which the subjects attempted to solve five problems aloud in the investigator's presence. On the basis of the problem solving task, the subjects were classified as either algorithmic or heuristic problem solvers, and a chi-square analysis was performed to determine if cerebral dominance was related to problem solving strategies.

The results of this study indicated that the three measures of cerebral dominance did not correlate significantly with each other even though the results of the individual measures agreed well with results previously reported by other researchers. It was concluded that the three tasks are apparently measuring different phenomena, and there is a need for more valid and reliable measures of cerebral dominance. A relationship between cerebral dominance, as measured

by SOLAT, and problem solving strategies used by subjects was determined to be statistically significant. However, the relationship between the subjects' problem solving strategies and school attended made it impossible to draw a definitive conclusion concerning the relationship of hemisphericity to problem solving strategy. The association between problem solving strategies and schooling implies that teaching style may have a strong influence on students' problem solving methodology.

Observations based on the data from this study indicate that students should receive instruction in algorithmic and heuristic problem solving methods. The method that is best for a particular student depends on the success attained from using each method as well as the individual preferences of the students.

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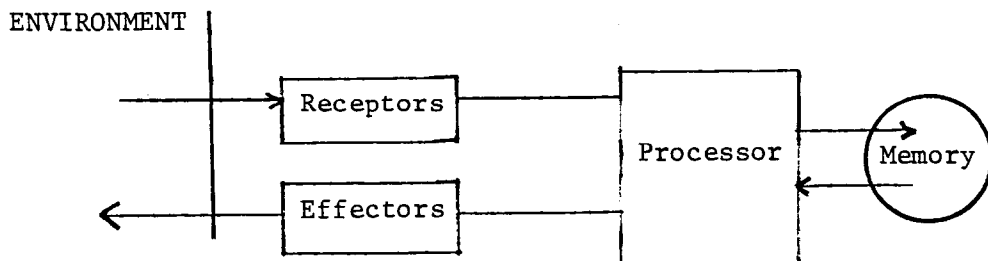
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CHAPTER I

INTRODUCTION

I. INTRODUCTION TO THE STUDY

How humans think and learn has long been of interest to educational psychologists and classroom teachers (Davis, 1973; Gagne, 1979; Johnson, 1972). The information in this area is vital to the development of effective and efficient instructional techniques. An information processing view of human thinking and learning has been proposed by some investigators (Newell and Simon, 1972). The information processing system consists of a memory that contains symbol structures, receptors that receive sensory input from the environment, effectors that serve to send information to the environment, and a processor that serves to translate sensory input into the symbols that can be understood by the symbol structure of the memory component and vice versa. Shown below is a schematic of the proposed information processing system.



Newell and Simon (1972) have proposed a theory of human problem solving that addresses the strategies used by individual problem solvers and the ways in which problem solvers arrive at the particular strategies they employ. Gagne (1979) refers to these problem solving strategies as cognitive strategies. Studies of problem solving behavior have demonstrated a wide variety of strategies employed by individual problem solvers (Larkin, 1980; Rubinstein, 1980). However, there has been little investigation of a possible relationship between the problem solving strategies employed by an individual and the organization and functioning of the brain as demonstrated by the cerebral dominance of the individual. The current study is designed in part to investigate the relationship between the two.

Recent advances in brain research have demonstrated that there are two modes of cognitive processing--the logical, rational mode that is characterized by sequential information processing, and the holistic, intuitive mode that is characterized by simultaneous information processing (Bogen, 1975; Wheatley, 1977; Ornstein, 1977). The different types of thought processes are thought to occur in different regions of the brain. The left cerebral hemisphere is hypothesized to be the center of activity for the logical, rational mode, and the right cerebral hemisphere is the center of activity for the holistic, intuitive mode (Bogen, 1975). Table I is a listing of the various thought processes commonly attributed to each cerebral hemisphere (Bogen, 1975; Edwards, 1979).

TABLE I
THOUGHT PROCESSES ATTRIBUTED TO EACH CEREBRAL HEMISPHERE

<u>Left Hemisphere</u>	<u>Right Hemisphere</u>
Verbal	Nonverbal
Analytic	Synthetic
Symbolic	Concrete
Rational	Nonrational
Digital	Spatial
Logical	Intuitive
Linear	Holistic
Sequential	Multiple
Objective	Subjective
Successive	Simultaneous

Certain subjects have also been assigned to the different cognitive modes. Mathematics, science, and language are considered to require use of the logical, rational mode, whereas art, music, and dance are considered to require use of the holistic, intuitive mode. Research (Bogen, 1975) on the structure and function of the brain shows that the two cerebral hemispheres of the cerebral cortex cause the brain to act as two brains instead of one. The two hemispheres are specialized to perform different modes of thought processing, as shown in Table I above. In approximately 95% of the adult population, language and speech are processed primarily in the left

hemisphere (Kinsborune, 1979), and spatial patterns and some auditory patterns are processed primarily in the right hemisphere (Wheatley, 1977). Whereas some researchers assert that cerebral dominance, or lateralization, is "invariant" or present at birth (Kinsbourne, 1975; Kinsbourne and Hiscock, 1977), other researchers theorize that lateralization is the endpoint of a developmental process that originates in an initial bisymmetric cerebral representation of verbal behavior. This view is known as the "progressive lateralization" view (Brown and Jaffee, 1975; Krashen, 1972; Lenneberg, 1967).

Kinsbourne (1973) suggests that lateralization, whether invariant or progressive, is an attentional phenomenon and that the development of hemispheric specialization involves increases in learning to allocate attention to a given hemisphere for a certain process. If Kinsbourne's model is correct, individuals can develop a preference for processing information either in the analytic, sequential left hemisphere mode, or in the holistic, intuitive right hemisphere mode. The hemisphere upon which an individual most relies for information processing tasks is said to be the dominant hemisphere. According to Wheatley (1977, p. 38) "there are some who have such dominance of one hemisphere that the other hemisphere is rarely activated." Because the Western culture emphasizes and rewards left hemisphere activities (Bogen, 1975) most individuals appear to be left hemisphere dominant.

Whereas some researchers (Borrowy and Goebel, 1976) report that there is a relationship between laterality and socioeconomic

status, Kinsbourne explains the apparent relationship in terms of differences in attention rather than differences in brain structure and function. One group of researchers who have claimed to demonstrate sex differences in laterality (Buffery and Gray, 1972) have been refuted by Kinsbourne (1979) who asserts that differences in individual strategies could suffice to account for all the data. The current study is designed to examine the possibility of a relationship between hemisphere dominance and problem solving strategies used by high school chemistry students, and to determine whether cerebral dominance is significantly different for White and Black students and for male and female students.

II. STATEMENT OF THE PROBLEM

The ability to solve problems is one of the most important skills that a student is expected to acquire in school, and also one of the most difficult to teach. Newell and Simon's (1972, p. 787) theory of human problem solving has suggested a "general theoretical statement about the processes of human problem solving . . ." and has proposed a mechanism by which problem solvers determine the strategy to be used in finding the solution to a given problem. However, Newell and Simon's theory does not address the potential role of hemispheric dominance; the necessary information in the brain sciences was not well developed at the time that Newell and Simon developed their theory. The current study was designed to determine what role, if any, laterality plays in problem solving. The laterality

tests used in the study were SOLAT (Your Style of Learning and Thinking) by E. Paul Torrence, tachistoscopic viewing, and dichotic listening.

This study was also designed to determine the correlation between the three different types of laterality measures named above.

Finally, this study was designed to determine whether differences exist between White and Black students and between male and female students on measures of cerebral dominance.

III. PURPOSES OF THE STUDY

The purposes of this study are as follows:

1. To correlate two physiological tests of hemisphericity--dichotic listening and tachistoscopic viewing--with SOLAT, a paper and pencil hemisphericity test.
2. To examine the relationship between laterality and race of selected high school chemistry students.
3. To examine the relationship between laterality and sex of selected high school chemistry students.
4. To examine if and how cerebral dominance correlates with problem solving strategies used by high school chemistry students.

IV. RATIONALE FOR THE STUDY

The ability to analyze and solve problems is essential for success in the study of all of the sciences--chemistry is no exception. However, problem solving in chemistry is most often taught

by stressing a set of rules (algorithms) that can be applied to the type of problem being discussed. It is widely believed that stressing the proper rules to be used will somehow make problem solving easier for the student. If the rules are memorized and recalled from memory at the proper time, students should be successful in their problem solving attempts. However, this type of learning strategy (i.e., learning sequential rules) is clearly a left hemisphere type of activity, and students who are right hemisphere dominant individuals may be hindered in their attempts to solve problems if the emphasis is on rule learning. In addition to there being an emphasis on rule learning in teaching problem solving, students are actively discouraged from using their own "intuition" in solving problems. Intuition is defined by Webster as "the power or faculty of attaining to direct knowledge a cognition without rational thought or inference." Often problem solving test items require students to "show all of the steps involved" in arriving at an answer, and credit is given based on the number of steps the student has correctly shown. Usually, no credit is given for a correct answer with no explanation of how the student arrived at the answer. (The obvious exceptions to this are standardized tests and multiple choice tests in which the student is graded only on the answer.) Since intuition is an important part of problem solving outside of the classroom, it could be useful if classroom problem solving activities in chemistry would recognize this as legitimate, and encourage students to utilize both intuition and analytical thinking in problem

solving activities. Since the right hemisphere is primarily responsible for intuitive, holistic cognitive strategies, legitimizing intuitive problem solving methods would benefit right hemisphere dominant students and would possibly improve their success in subjects that have traditionally favored left hemisphere dominant students.

The findings in this study should prove to be useful to at least four groups of people:

1. high school chemistry teachers and science supervisors,
2. students enrolled in high school chemistry courses,
3. theorists with an interest in human problem solving, and
4. writers and publishers of instructional materials used to teach problem solving skills and techniques.

The results of this study should provide information concerning the ways in which hemisphericity can be incorporated into the theoretical framework of human problem solving as well as suggest how the teaching of problem solving in high school chemistry classes can be changed to insure the maximum amount of learning for all students, regardless of laterality and preferred style of thinking.

V. HYPOTHESES

The hypotheses that were tested in this study are stated below:

1. There is a statistically significant correlation between the scores obtained on the three tests of hemisphericity used in this study. Those tests were dichotic listening, tachistoscopic viewing, and SOLAT.

2. There is a statistically significant relationship between hemisphericity and race, and between hemisphericity and sex. (The variables of sex and race are treated together in this study because the disadvantages suffered because of sex and race are similar. In recognition of this, the federal government treats women as minorities even though their population would not support this classification.)

3. On the basis of dichotic listening, tachistoscopic viewing, and SOLAT, more subjects are left hemisphere dominant than right hemisphere dominant.

4. Students who are left hemisphere dominant will most often employ algorithms in their problem solving attempts, and students who are right hemisphere dominant will most often employ heuristic strategies to solve problems.

5. Students who are left hemisphere dominant will be the more successful students according to chemistry grades and standardized test scores.

VI. ASSUMPTIONS AND LIMITATIONS OF THE STUDY

The following assumptions were made by the investigator in this study:

1. The test of hemisphericity developed by E. Paul Torrence is valid for high school students, based on validity studies reported for use of the instrument with college students.

2. The self-reported data that were collected from the students are accurate.

3. The students in a second semester chemistry course possess adequate verbal and reasoning ability to comprehend the experimental problems.

4. The subjects were motivated to try their best to solve the problems used in the study.

The major limitation of the study is its lack of generalizability due to the exploratory nature of the research. The subjects in the study were selected to include approximately equal numbers of males and females, and Black and White students. Since it was necessary to collect a large quantity of data on each subject, the study was restricted to a total of thirty-four students from three high schools within the Knoxville City School System. All of the subjects were selected from volunteers enrolled in a second semester chemistry course at one of the three high schools in the study.

A second limitation involves the reliance of the investigator on self-reported data for some parts of the study. The information that the students reported via questionnaire answers was based on the subjects' perception of reality. However, collecting the majority of the data individually from subjects allowed the investigator to evaluate the likelihood that a subject was deliberately falsifying data. Additionally, the self-reported data can be checked against existing data in the subjects' school records.

Although the subject pool is relatively small and the subjects were not randomly selected, the results of this study should be indicative of results that would be obtained using random selection from a population of all students enrolled in high school chemistry courses. Whether this is in fact the case will be determined only after investigative studies of a confirmatory nature are performed to verify or refute the findings in this exploratory study.

VII. DEFINITION OF TERMS

The following definitions are provided to assist the reader in understanding this report.

Algorithms. Algorithms are "problem solving methods that, if followed completely, guarantee a solution" (Bourne et al., 1979, p. 241). For example, a possible strategy for correctly unscrambling the set of letters "nlecpi" would be to try all possible combinations of letters until the correct combination is found. However, since there are $6!$ or 720 possible combinations of these letters, arriving at the word "pencil" could be a very long and tedious process if one resorts to using the algorithm described.

Cerebral dominance. The situation in which one of the two hemispheres of the cerebral cortex dominates the other hemisphere during an individual's thinking processes. Other terms used synonymously with cerebral dominance throughout this report include hemisphericity, hemisphere dominance, laterality, and lateral dominance. The hemisphere that individuals most rely upon for information processing is called the dominant hemisphere.

Heuristic device. A heuristic device is a problem solving method that involves using a "rule of thumb that may lead to a very quick solution or to no solution at all" (Bourne et al., 1976, p. 241). For example, a person attempting to unscramble the set of letters "nlecpi" may attempt to use the heuristic of placing the two vowels only in positions in which they appear between two consonants. This heuristic device would probably enable the problem solver to reach the correct answer of "pencil" faster than attempting the algorithm of trying all possible combinations of letters. On the other hand, if the problem solver attempted to use the heuristic that the "i" and "e" appear together, no solution would be found.

Problem solving strategy. A problem solving strategy is the method by which a subject attempts to solve a problem. For purposes of this study, the initial strategy used in the solution of a problem will be considered the preferred strategy of a subject.

Verbal protocol. A verbatim audio-taped account of a subject's efforts to solve a problem.

VIII. PROCEDURES

Population and Subjects

The population for this study consists only of American high school chemistry students. The subjects for this study, however, were selected from among volunteers from three high schools in the Knoxville, Tennessee City School District. All of the subjects were enrolled in the second semester of a high school chemistry course.

General Procedures

A group of thirty-four volunteers from three Knoxville high schools were tested using dichotic listening, tachistoscopic viewing, and SOLAT to determine whether they were left or right hemisphere dominant. Seventeen of the thirty-four were selected to participate in the problem solving section of the study. The seventeen students for the problem solving section of the study were randomly selected after stratifying the entire sample according to race. A complete description of the subjects in the subsample used for the problem solving aspect of the study is found in Chapter III of this report. The seventeen subjects were each given five problems to solve in a clinical session in which the researcher observed the problem solving strategies used by the subjects. Each subject was assessed as to whether the problem solving strategies used were based primarily on heuristics or on algorithms. The procedure used to classify the strategies is discussed in detail in Chapter IV of this report. In order to record the problem solving processes of each subject, verbal protocols were collected for each subject for each problem. Each subject was given a numerical score based on the success of the attempted solution to the problem. Whereas group data were most useful in correlating the findings of this study with previous studies and in analyzing potential trends, the primary focus of this investigation was the individual subject. The scoring procedures are also described in Chapter IV. The results of the problem solving exercises were used in conjunction with the cerebral dominance tests to determine

if there is a relationship between the subjects' hemisphericity and problem solving strategies.

IX. ORGANIZATION OF THE STUDY

This study is reported in six chapters and three appendixes as outlined below.

Chapter I provides a general introduction to the study, and includes the following sections:

- I. Introduction to the Study
- II. Statement of the Problem
- III. Purposes of the Study
- IV. Rationale for the Study
- V. Hypotheses
- VI. Assumptions and Limitations of the Study
- VII. Definition of Terms
- VIII. Procedures
- IX. Organization of the Study.

Chapter II provides a review of literature pertaining to hemisphericity studies, methods of determining hemisphericity, cultural differences in hemisphericity, and problem solving.

Chapter III provides a description of the methods and procedures used in the study, including the selection of subjects, instruments used to collect the data, the data collection process, and the methods used to analyze the data.

Chapter IV is a presentation of the data analysis and results.

Chapter V presents a discussion of the findings related to each of the research hypotheses proposed in the study.

Chapter VI contains the conclusions to be drawn from the study, suggestions for future research activities, and implications for teaching.

Appendix A contains the data collection forms used in the study.

Appendix B contains the problems used in the study and the problem solving protocols of one algorithmic and one heuristic problem solver as a case example of the seventeen subjects involved in the problem solving section of the study.

Appendix C contains a discussion of the statistical techniques used in the study.

CHAPTER II

REVIEW OF RELATED LITERATURE

I. INTRODUCTION

The brain of higher animals, including man, is a double organ, consisting of right and left hemispheres connected by an isthmus of nerve tissue called the corpus callosum (Gazzaniga, 1967). Although the differential specialization of the two cerebral hemispheres in the human brain has been documented for over a century (Ornstein, 1977), the neurological evidence for this differentiation has come primarily from the study of individuals whose brains have been damaged by accident or illness, and from the surgery performed on them. Milner (1965) has attempted to correlate disorders in specific kinds of tasks with lesions in specific areas of the brain. She found that a lobectomy (surgical removal) of the right temporal lobe severely impairs the performance of visual and tactile mazes, but left temporal-lobe lesions of equal extent produce little deficit. Milner's research also indicates that lesions in specific areas of the left hemisphere are associated with specific kinds of language disorders.

The neurological research on brain function advanced by a quantum jump as a result of the work of Drs. Roger Sperry, Joseph Bogen, and Michael Gazzaniga (Springer and Deutsch, 1981). Sperry, working at the California Institute of Technology, experimentally

severed the corpus callosum of laboratory animals. (Recall that the corpus callosum serves as the means through which the hemispheres are connected, and the means through which they communicate.) When Sperry and his associates severed the communication link between the hemispheres, each hemisphere could be trained separately. This research led to the adoption of a new treatment for severe epilepsy in several patients of Drs. Philip Vogel and Joseph Bogen of the California College of Medicine (Sperry, 1964; Gazzaniga, 1967). The treatment involved severing the corpus callosum in order to isolate the two hemispheres, thereby lessening the transmission of the seizures between the two. In many cases the severely disturbed patients improved dramatically. These individuals, who came to be known as "split-brain" people, provided the first human subjects for the study of hemisphericity. Sperry and his associates developed a number of specialized tests that clearly demonstrated the specialized functions of the two cerebral hemispheres (Ornstein, 1977). The results of the tests showed that the left hemisphere is superior for verbal tasks, and the right for spatial tasks. Ornstein described one of the tests in the following manner:

If, for instance, the patient held a pencil (hidden from sight) in his right hand, he could verbally describe it, as would be normal. But if the pencil was in his left hand, he could not describe it all. Recall that the left hand informs the right hemisphere, which possesses only a limited capability for speech. With the corpus callosum severed, the verbal (left) hemisphere is no longer connected to the right hemisphere, which communicates largely with the left hand; so the verbal apparatus literally does not know what is in the left hand. If, however, the patient was offered a set of objects--a key, a book, a pencil, and so on--and was to select the

previously given object with his left hand, he could choose correctly, although he still could not state verbally just what he was doing (Ornstein, 1977, p. 24).

Whereas the neurological research discussed above was conducted on individuals whose brains were functioning abnormally, several studies conducted using normal subjects illustrate a similar specialization in the hemispheric functioning in normal individuals. The evidence comes from a variety of sources--tests of vision, eye movements, reaction time, ear preference, and electrical signs of brain asymmetry (Kimura, 1966; Berlin and McNeil, 1976; Kinsbourne, 1972; Bakan and Strayer, 1973). During the past decade, a variety of researchers have investigated a potential relationship between hemispheric specialization and such variables as race, sex, and socioeconomic status (Buffery and Gray, 1972). The research results to date have been conflicting and inconclusive, and there have been methodological problems with much of the research conducted to date (Star, 1979).

The relationship of hemispheric specialization to problem solving strategies has not received serious attention by researchers in the area of problem solving. However, Caplan and Kinsbourne (1981) demonstrated a weak relationship between language lateralization (as measured by dichotic listening), and preferred cognitive style (as measured by a modified version of a word-shape sorting test initially developed by Galin and Ornstein (1974)) in elementary school children.

In contrast to previous studies, the current study examined the laterality of a sample of high school chemistry students using

tests of dichotic listening, tachistoscopic viewing, and SOLAT. The subjects' problem solving strategies were observed during a problem solving exercise administered by the researcher, and verbal protocols of the problem solutions were studied in order to determine if there was a relationship between hemisphericity and problem solving strategies utilized by the subjects in the study. The remaining sections of this chapter will survey prior studies utilizing dichotic listening, tachistoscopic viewing, and SOLAT, in addition to relevant aspects of problem solving research.

II. STUDIES INVOLVING DICHOTIC LISTENING

When two different stimuli are presented simultaneously to each of the two ears, most listeners perceive more of the right ear messages accurately. Although this effect was first presented by Broadbent (1956), Kimura (1961) was the first investigator to ascribe this right ear advantage (REA) to the dominance of the left hemisphere for speech. Kimura hypothesized that, since crossed pathways are prepotent in the auditory system, and since the left hemisphere is thought to be dominant for speech and language functions, the right ear advantage is related to the crossed nature of the pathways. This view of the right ear advantage is now widely accepted among researchers in the area of speech and language.

An important assumption underlying the study of left-right brain asymmetries in human beings is that most normal listeners are left-brained for speech and language. Geschwind and Levitsky (1968)

provided anatomical support for this position when they performed post mortem examinations on 100 adult human brains and showed that the area responsible for speech functions was larger on the left side in 65% of the brains, and larger on the right side in only 11% of the brains. Wittelson and Pallie (1973) have shown a comparable asymmetry in newborns. Physiological signs of left hemisphere dominance for speech have come from intracarotid sodium amytal injections, known as the Wada test (Wada and Rasmussen, 1960). The sodium amytal disables portions of the cortex, and speech loss is usually seen in conjunction with disabling the left hemisphere. Wada and Rasmussen (1960) reported a significant correlation between dichotic listening and intracarotid amytal results.

In one form of dichotic listening studies, the subject wears earphones, and is simultaneously presented with one message to one ear and another message to the other. The subject's relative efficiency in reporting the input is computed, and if better retrieval of information is demonstrated to one ear than the other (an "ear advantage"), language lateralization is attributed to the side opposite the ear that has the advantage. In other words, a subject who demonstrates a left-ear advantage is said to be right hemisphere dominant for speech.

There are several methods currently used to calculate degree of ear asymmetry. Two of the methods frequently used are: (1) number of correct responses to each ear and (2) percentage of correct responses to each ear (Berlin et al., 1973). However, the most widely

utilized formula for computing ear advantage is $(R-L/R+L)100$ (Caplan and Kinsbourne, 1981). In this formula R represents the number of correct right ear responses and L represents the number of correct left ear responses. Employing this index yields data that are in ratio form, and are therefore suitable for a wider variety of statistical tests to which to subject the data. This index was employed in the current study.

There are a number of modifications of the dichotic listening technique discussed above that are commonly used by researchers. In one, the subject is required to report the message to one ear and then to the other, the two orders being counterbalanced within the session. In another, the subject knows which stimuli to expect, but is asked to lateralize them (Kinsbourne and Hicks, 1977). Still another technique establishes asymmetries by monaural input, comparing the relative efficiency of each of the two ears across many trials (Morais and Darwin, 1974).

Several investigators have examined the possibility of a relationship between laterality as determined by dichotic listening and such variables as age, sex, and socioeconomic status. Caplan and Kinsbourne (1981) found that the size of the right ear advantage did not change significantly with age between the age range of five to thirteen. In a study of elderly subjects, Horning (1972) showed that the right ear advantage for young subjects was virtually identical with those for the older patients. Thus, the right ear advantage does not appear to be dependent on age, based on the empirical evidence to date.

The data on sex and socioeconomic status relationships to laterality are less conclusive. Whereas some researchers report that sex influences laterality on dichotic listening tasks (Caplan and Kinsbourne, 1981), other researchers report no relationship (Berlin and McNeil, 1976). The data relating race to dichotic listening have also been contradictory. Whereas Borrowy and Goebel (1976) report a relationship between ethnicity and laterality, Dorman and Geffner (1974) saw no such relationship when they conducted a study using Black and White six year olds. Kinsbourne (1979) ascribes the differences in laterality found in the Borrowy and Goebel study to differences other than laterality, and suggests that there is as yet no empirical evidence to suggest a difference in hemispheric specialization based on race.

Whereas dichotic listening studies have been used extensively to study differences in lateralization, Kinsbourne (1979, p. 94) warns against making the "simplistic assumption that an ear advantage indicates language representation on the opposite side and the degree of asymmetry indicates the degree of lateralization." The test-retest reliability of dichotic listening tests falls short of that required for psychometric instruments (Blumstein, Goodglass, and Tartter, 1975), and judgments of the lateralization of single individuals should not be based on dichotic listening information alone.

Whereas dichotic listening tests have proven useful in determining hemisphericity, other methods of determining laterality should be employed in conjunction with dichotic listening. The current

study used the dichotic listening technique of simultaneous presentation of stimuli in conjunction with tachistoscopic viewing and SOLAT to study the relationship of laterality to sex, race, and problem solving strategies of high school chemistry students.

III. STUDIES INVOLVING TACHISTOSCOPIC VIEWING

When verbal stimuli are briefly exposed in one or the other visual half field, an asymmetry score analogous to that in dichotic listening can be derived, expressing a visual half-field advantage for one or the other side in efficiency of recognition (Kinsbourne, 1979). It is inferred that language representation is contralateral to the advantaged visual half-field (Kimura, 1966).

The manner in which tachistoscopic viewing is carried out differs from study to study. Some of the aspects of the technique that differ are: (1) exposure duration of the stimulus materials, (2) the nature of the stimulus material--letters, words, pictures, etc., (3) the nature of the subject report of the material--whether the subject is asked to report all of the information given, or is asked to report a judgment relative to the material (e.g., whether the stimulus is a word or not), (4) whether stimuli are presented to only one visual half-field at a time (unilateral presentation), or to both visual half-fields simultaneously (bilateral presentation), and (5) whether the subject is required to report a central fixation digit (used to control for eye fixation) prior to report of the stimulus material. The studies reviewed by this researcher to

determine the tachistoscopic viewing technique used in the current study are discussed below.

Whereas most of the tachistoscopic viewing studies prior to the mid-1960's employed very long (150 to 300 millisecond) or uncontrolled exposure durations (Bradshaw et al., 1981), Saslow (1967) found that the latency of a voluntary saccadic eye movement is between 120 and 200 milliseconds. Thus, an exposure time of less than 120 milliseconds is necessary to eliminate the possibility of the subjects' altering the position of their eyes during the presentation of the stimuli, thereby precluding precise hemiretinal registration of the lateralized stimuli (Rosen et al., 1975). The present study utilized exposure times of 100 milliseconds--an exposure time commonly used by researchers in the field (Coltheart and Arthur, 1971).

The question of the effect of the nature of the stimulus material on left-right differences in tachistoscopic recognition has been studied extensively by Bryden (1966). In his study of the effect of the stimulus material, Bryden also researched the question of bilateral vs. unilateral presentation of stimuli. In the experiment that he conducted, Bryden tachistoscopically presented three types of material--letters, geometric forms, and outline drawings of familiar objects--to thirty-two subjects. In one series the stimuli were presented successively in either the left or the right visual field. In a second series, the stimuli were presented bilaterally, one in each field. Bryden found that in the bilateral presentations, all types of materials were more readily recognized in the left visual

half-field, whereas with the unilateral presentations, a right visual half-field superiority greatest for letters and least for geometric forms was observed. The phenomenon of the left visual field superiority in the bilateral presentations was explained on the basis of the effect of order of report. The order of report effect was first proposed and studied extensively by Bryden. Since most subjects reported simultaneously-presented material in a left-to-right order, Bryden suggested a fading-trace theory to account for the left-field superiority. There is more time between the stimulus presentation and subject report for the trace of the stimulus on the right to fade below threshold, thus causing subjects to correctly identify the right stimulus less often. Thus, Bryden's study supports the theory that bilateral presentation is more likely to yield results that are contaminated by the effects of directional scanning than is the case with unilateral stimulus presentation. Bradshaw et al. (1981) concur with Bryden that at least with unilateral presentations, in the absence of any central "fixation" digit, single syllable words can safely be employed in the knowledge that any resultant field differences are likely to reflect neural organization, and that any directional scanning or processing artifacts make, at the most, a minor contribution.

Tachistoscopic viewing measures of hemisphericity have taken a number of forms--unilateral and bilateral presentation of stimuli, identification of words and figures, horizontal and vertical presentation of information, etc. According to the literature reviewed by

this investigator, unilateral presentation of three and four letter words for a period of 100 milliseconds was determined to be the most effective manner of assigning hemisphericity classifications on the basis of tachistoscopic viewing. Thus, the current study utilized a design of unilateral stimulus presentation in the absence of a central, fixation digit. The stimuli used were three and four letter English words, each presented once to the left visual field and once to the right visual field of the subject. A complete list of the stimulus words is found in Appendix A of this report.

IV. STUDIES INVOLVING SOLAT

Your Style of Learning and Thinking (SOLAT), Forms A and B, was originally developed by Torrence to provide a paper and pencil test of hemisphericity. According to Torrence, the test items "are based upon empirical research findings concerning the specialized functions of the right and left hemispheres" (Torrence and Reynolds, 1980).

The need for Form C of SOLAT arose from the accumulation of research concerning hemisphericity, the extension of the research to education, and the efforts to draw educational implications of research findings in other fields.

The initial version of Form C of SOLAT consisted of fifty items based upon the research findings concerning the specialized functions of the two cerebral hemispheres. Each item provided the respondent three choices--one representing a specialized function

of the left cerebral hemisphere, a second representing a parallel specialized function of the right hemisphere, and the third representing the complementary or integrated functioning of both hemispheres. Test takers were asked to indicate which of these three specific styles of learning and/or thinking best described their own typical behavior (Torrence and Reynolds, 1980).

After the fifty-item instrument was administered to 154 undergraduate and graduate students at three major universities, the number of test items was reduced to forty after items showing low levels of internal consistency and items that seemed to overlap other items were eliminated. The forty-item version of Form C was used in the current study, and it appears in Appendix A of this report.

Test-retest reliability data were gathered by Torrence and Reynolds (1980) using a sample of thirty-three graduate students at the University of Georgia. The reported test-retest reliabilities were: right, 0.50; left, 0.70; and integrated, 0.60. All of these values are statistically significant at the 0.01 level of probability.

Validity studies by the test developer included a correlational study that correlated the scores on SOLAT with scores on seventeen tests of creative ability, personality, and motivation. Some of the tests included were the Rorschach Inkblot Test, the Torrence Tests of Creative Thinking, and Khatena's Creative Self-Perception Test (Khatena and Torrence, 1976). Torrence found that most of the creativity tests correlated positively and statistically significantly with the right hemisphere style of learning and

thinking, and negatively with the left hemisphere style. It was noted that only three of the measures used in the study correlated significantly with scores on the integrated style of learning and thinking. Torrence offered no possible explanation for the decrease in correlation in this area.

Whereas SOLAT has been utilized in several hemisphericity studies (Torrence and Reynolds, 1978; Wilson, 1982), no published reports of how SOLAT correlates with physiological measures of hemisphericity were found by this researcher. However, unpublished reports indicate a low correlation between SOLAT and physiological measures (Torrence, 1982, personal communication). The current study was designed, in part, to investigate the correlation between three different measures of hemisphericity--dichotic listening, tachistoscopic viewing, and SOLAT.

V. STUDIES INVOLVING PROBLEM SOLVING STRATEGIES

Problem solving skills are urgently needed whenever knowledge must be creatively used (i.e., in all tasks which require more than rote memorization or recall of information). Therefore, problem solving skills are of utmost importance to all of the sciences and to most other fields. Furthermore, there is an increased need to teach improved problem-solving skills to students who will be faced with a world characterized by growing complexity, rapid change, and vastly expanding knowledge (Tuma and Reif, 1980).

Because problem solving is such a vital part of the educational process, but such a difficult skill to teach, researchers have studied problem solving from a variety of perspectives, and there are numerous viewpoints on the nature of the problem solving process. Proposals on the nature of the problem solving process include scientific method paradigms, stimulus-response models, dual-process theories that distinguish "productive" from trial and error thinking, convergent and divergent thinking paradigms, developmental schemes (Piaget, 1957), and psychoanalytic approaches (Getzels, 1964).

One traditional approach to problem solving seeks to explain problem solving in terms of principles of associative learning derived from studies of classical and instrumental conditioning (Bourne and Dominowski, 1979). Bourne and Dominowski state that according to this view, an individual enters a problem situation with an existing complex of stimulus-response associations as a result of prior experience. The problem is more likely to elicit some of these associations than others, with the clear implication that problem difficulty will depend on the strength of the correct associations relative to the strength of other, incorrect associations. In the course of problem solving, the associative complex gets rearranged as some tendencies are weakened through extinction (failure) and others strengthened through reinforcement (success). This viewpoint stresses the transfer of prior learning to the problem situation, and to the learning which takes place during the problem solving process.

In describing the traditional Gestalt view of problem solving, Bourne and Dominowski (1979) state that the Gestalt view is very different from the associationist view. The Gestalt theorists emphasize the importance of the structure of the problem situation and the formation of new combinations of "old" ideas. Maier (1940), for example, distinguished between solving problems on the basis of direct transfer of prior learning (reproductive thinking) and solving problems by integrating previous experiences in a novel fashion (productive thinking). Maier argued that forming new combinations is guided by directions stemming from the problem situation itself (conversely, that analyzing past experience is not sufficient for understanding such problem solving).

Neither of the two traditional views of problem solving has proved sufficiently comprehensive to serve as a framework for understanding problem solving in its various manifestations. The major aspects of associative and Gestalt views have been incorporated into a general information-processing approach to problem solving in which the individual is considered an active processor of information who has certain processing limitations and who employs both general and specific processing routines.

Much of the research work involving the information-processing approach to problem solving has been based on relatively new research methodologies that differ from those traditional in educational research in at least two ways (Larkin, 1980). First, the data used consist of detailed observations of individuals rather than rough

measures such as test score distributions. Second, these observations are often used to construct relatively complete models that serve as computer-implemented, simulation models capable of producing some aspects of the behavior they seek to explain. For example, McDermott and Larkin (1978) are developing a computer-implemented model that simulates the order in which an expert subject applies physics principles in solving mechanics problems. The model makes extensive use of a planning method that first abstracts key features of the problem in order to construct a simplified problem. It then solves this abstracted problem and uses the resulting solution as a guide to solving the original problem.

Greeno (1976) developed a model that simulates some aspects of the problem solving of students in high school geometry. Greeno's model uses the general problem solving strategy of creating sub-goals in the problem solving process.

Researchers employing computer simulation in the study of problem solving behavior have made major contributions to the development of the information processing view of problem solving. This view formed the theoretical basis for the research described in this report.

The information processing view of problem solving distinguishes between two general classes of solution methods, algorithms and heuristics (Bourne and Dominowski, 1979). Algorithms are solution methods, which, if followed, guarantee a solution. For example, an algorithm for solving the anagram "efcta" would be a systematic method for generating all possible combinations of the five letters until

eventually the correct order is produced. Heuristics, on the other hand, are "rules of thumb" which might lead to very quick solutions or to no solution at all. Heuristics are selective or restricted solution methods which usually reduce cognitive strain. An example of a heuristic in solving the anagram "efcta" would be to try solutions in which the consonants and vowels are alternating, since this is a common arrangement of letters in the English language. This strategy would most likely result in a faster solution to the anagram than would the algorithmic strategy discussed.

Since algorithmic methods of problem solutions are logical, analytical, and sequential, whereas heuristic solution methods are more trial and error, intuitive, and holistic, it was hypothesized that students who are left hemisphere dominant individuals would be algorithmic in their problem solving approach, and individuals who are right hemisphere dominant would be heuristic in their problem solving approach. The only other investigators known to this researcher to have investigated a relationship between hemisphericity and preferred cognitive style are Caplan and Kinsbourne (1981). The design and results of their study are briefly described below.

The Caplan and Kinsbourne study examined the relationship among sex, verbal dichotic listening asymmetry, cognitive strategic preference, and reading ability in young children. One of the hypotheses in the study was that children who showed evidence of a strong right-ear advantage (REA) on the dichotic listening test would show a stronger preference for verbal strategies on a word-shape

sorting test than would children with a smaller right ear advantage (REA). Caplan and Kinsbourne found that there was indeed a small, but statistically significant correlation between dichotic listening asymmetry and a degree of preference for verbal strategies. They suggested a number of possible interpretations for their findings, one of which was that the true relationship was masked due to the difference in information processing modes tapped by the dichotic listening (auditory) and cognitive style (visual) tests. They suggest that the presence of the correlation between dichotic asymmetry and verbal preference observed in their study is possibly derived from the fact that both tests may reflect the extent to which a child displays a verbal orientation during testing, which may represent a stylistic preference.

V. SUMMARY

The review of the literature and research related to cerebral dominance and problem solving revealed the following information.

1. The brain is divided into two hemispheres that communicate through the corpus callosum. The two hemispheres are specialized in their functions, with the left hemisphere being superior for verbal tasks and the right for spatial tasks.

2. One technique commonly used to determine the dominant hemisphere in an individual is dichotic listening. In the most commonly used variation of the dichotic listening technique, a subject is asked to identify stimuli presented aurally. A right ear advantage

in identifying stimuli indicates a left hemisphere dominance for speech and language, and a left ear advantage indicates a right hemisphere dominance for speech and language. Previous studies indicate no definite relationship between hemisphericity and sex or age, but there is not conclusive evidence to indicate whether or not hemisphericity, as determined by dichotic listening, is related to race or socioeconomic status.

3. Tachistoscopic viewing studies assign hemisphere dominance on the basis of a visual presentation of stimuli to the left or right visual half-field of the subject. The tachistoscopic viewing studies appearing in the literature to date indicate that a majority of the American population demonstrate a right visual half-field advantage. Tachistoscopic viewing studies have not established a relationship between hemisphericity and sex or race.

4. The first written test of hemisphericity to appear in the literature is Your Style of Learning and Thinking (SOLAT), developed at the University of Georgia by E. Paul Torrence. Test-retest reliability for SOLAT has been established, and validity studies have been conducted. The reliability and validity of SOLAT have been accepted by researchers since 1979. However, it has been established that SOLAT does not generally lead to the same hemisphericity classification as do physiological measures.

5. Problem solving research efforts are currently employing the model of an information processing approach, and have identified at least two different types of problem solving strategies--algorithmic

and heuristic. A relationship between problem solving strategies and hemisphericity has been postulated, but has not been widely tested.

The procedures used in the current investigation to examine the relationship between hemisphericity and preferred method of problem solving are described in Chapter III of this report.

CHAPTER III

METHODS AND PROCEDURES

I. PREPARATION FOR THE STUDY

The following procedures were executed in preparation for this study:

1. Permission to execute the study was obtained from the Human Subjects Committee at The University of Tennessee, Knoxville, and from the Director of Research of the Knoxville City School District.

2. The three measures of hemisphericity to be used in the study were selected and the necessary materials were collected or constructed.

3. Interviews were held with two researchers in the fields of Speech Pathology and Audiology and one researcher in Psychology at The University of Tennessee, Knoxville, to determine the most appropriate methods of collecting data for the dichotic listening and tachistoscopic viewing sections of the study.

4. The problems to be used in the study were collected and deemed suitable for the study by a panel of experts. The three member panel consisted of the science supervisor of a local school system, a local supervisor of talented and gifted education programs, and a chemistry teacher at a local high school.

5. The three high schools to be used in the study were determined on the basis of student population demographics.

6. The student information questionnaire for collecting supplemental data on the subjects was constructed.

7. The chemistry instructors whose students were to be used in the study were briefed on the objectives and procedures of the study.

8. The parental and student consent forms were constructed. The forms are presented in Appendix A of this report.

II. HEMISPHERICITY MEASURES USED IN THE STUDY

Dichotic Listening

The dichotic listening measure employed in this study utilized a dichotic listening tape prepared by Dr. Charles I. Berlin of the Louisiana State University Medical Center (Berlin and McNeil, 1976). The stop consonants "p," "t," "k," "b," "d," and "g" were each paired with /a/ (sounded "ah") to create six discrete stimuli, hereafter referred to as CV stimulus pairs. Each syllable was matched with each of the others to create two sets (each with 30 items) of randomly ordered CV stimulus pairs, with an interstimulus interval of approximately 4 seconds. Onset alignment of the CV stimulus pairs was done by computer (Berlin et al., 1973) and was accurate within $\pm 2\frac{1}{2}$ milliseconds, and amplitudes of the vowel segments of the stimuli were within 2-1/2 decibels of one another. Each set of stimuli was presented to each subject, the headphones being reversed after the first set of stimuli in order to control for any variations in channel intensity. Before administration, the subject

was familiarized with the task, told which six sounds would be played, and listened to each of them monaurally. Subjects had to report the monaural sounds with 95% accuracy before being included in this section of the study. Only one potential subject was eliminated on this basis, and most of the other subjects identified the monaural sounds with 100% accuracy. The tape was played on a SONY CFS-45 stereo tape recorder at a level of 85 decibels. The subjects listened to the stimuli through KOSS-K6LC headphones that had been calibrated using a condensor microphone, pistonphone, and artificial ear. Additionally, the stimuli from the master tape were calibrated through each earphone to 85 db using the calibration signal at the beginning of the tape. The dichotic listening exercise was administered in a quiet room away from the major hallways in each of the three schools in the study. The subjects recorded their responses on an answer sheet provided by the investigator (see Appendix A), and an index of ear advantage was calculated for each subject using the formula $(R-L/R+L)100$, discussed in Chapter II of this report.

Tachistoscopic Viewing

The tachistoscopic viewing section of this study involved preparation of 25 pairs of stimulus words to be presented tachistoscopically to each subject. (See Appendix A for a list of the stimulus words used in the study.) Two slides of each stimulus word were prepared by the staff of the Teaching Materials Center at The University of Tennessee, Knoxville. One member of each pair of

slides had the stimulus word to the right of center of the slide, and the other member of the pair had the stimulus word to the left of center of the slide. This design allowed for each subject to identify each word twice--once in the right visual half-field and once in the left visual half-field. Each pair of slides was prepared from a master that contained the stimulus word in Helvetica Medium 12 point print on a 4-3/8" by 3-1/8" section of acetate.

The stimulus words were presented for a duration of 100 milliseconds using a tachistoscopic shutter in conjunction with a Kodak carousel slide projector. All stimulus words were back projected on a translucent screen onto which a black central fixation point was attached. (A central fixation point is sometimes used in tachistoscopic viewing studies to insure that subjects are fixating in the center of the screen prior to stimulus exposure.) The subjects' eyes were positioned 12 inches in front of the screen. When exposed on the screen, each word was centered $11^{\circ}42'$ to one side of the central fixation point, and subtended a visual angle of $10^{\circ}36'$. The central fixation point was visible in the pre-exposure field, and the subjects were reminded to focus on the fixation point prior to exposure of each stimulus word.

The subjects were instructed to write down each stimulus word on a sheet of paper provided by the investigator. (See Appendix A for a copy of the answer sheet.) A response was considered correct when the subject identified the word properly. An index of visual half-field superiority was calculated using the same formula as was used in the dichotic listening section of the study, $(R-L/R+L)100$.

SOLAT

The forty-item SOLAT (Your Style of Learning and Thinking), Form C, was administered to each subject in a small group setting. The subjects were instructed to circle the statement--A, B, or C, which they felt best reflected their style of learning and thinking. All subjects were instructed to ask for clarification of any items that were not entirely clear to them, and several subjects did indeed ask for clarification of some questions. There was no time limit on the test administration, and all subjects completed the exercise in less than 30 minutes. (A copy of SOLAT Form C and the scoring key appears in Appendix A of this report.)

III. THE PROBLEM SOLVING TASK

Five problems were identified for inclusion in this study. The problems were selected based on the criteria that they must be easily understood by high school chemistry students, and they must have at least two readily identifiable solution strategies--one that could be classified as algorithmic, and one that could be classified as heuristic. The five problems are presented and discussed in detail in Chapter IV of this report, and are listed in Appendix B.

The seventeen subjects selected for the problem solving aspect of the study were scheduled to meet individually with the investigator for the administration of the problem solving task. Each of the problems was presented to the subject on a separate sheet of paper. All subjects received the problems in the same order. Each

subject was given a set of oral instructions prior to performing the problem solving task. These instructions were as follows:

The next phase of the study involves a look at how you go about solving problems. I will ask you to try to solve five problems during this session, and to orally report exactly what you are doing and thinking when you are solving each problem. The most important thing that I am interested in is how you as an individual go about solving problems, and it is not important whether you get the right answer or not. If you have any questions or need any clarification on any of the problems, feel free to ask me anything you would like. There are no time limits on the exercise, so take as much time as you need. Each problem will be given to you on a separate sheet of paper, and you can write or draw anything you wish on this sheet of paper. Please remember to think aloud as you are solving the problems. Please read each problem out loud before you begin working. Do you have any questions?

Any questions the subjects may have had were answered at this point, and the subjects were then presented with each of the five problems.

During the clinical sessions in which the problem solving exercises were conducted, a nonthreatening tone of mutual cooperation was the goal. The investigator continued to stress the point that the subjects' ability or lack of ability to solve the problem would not be regarded as any indication of the subjects' intelligence or classroom ability. These comments were made so that subjects would not "feel dumb" if they failed to arrive a problem solution without the aid of the investigator. All of the sessions were held in a quiet room at the subjects' schools, and the sessions lasted an average of 40 minutes per subject.

For each problem, the following data were recorded on the appropriate data collection forms (see Appendix A): problem number,

strategies and processes used, were the strategies algorithmic or heuristic, and additional comments. Chapter IV presents a detailed discussion of how the strategies were classified. Tape recordings of each session provided verbal protocols of each subjects' problem solving efforts. Each subject was given a numerical score for the problem solving task based on the scoring procedure presented in Chapter IV.

IV. SELECTION OF SUBJECTS

The Sample Population

The population from which subjects were chosen for this investigation consists of high school students enrolled in chemistry.

Selection of the Sample

The subjects in this study were 34 students enrolled in chemistry at one of three high schools in Knoxville, Tennessee. The schools to be included in the study were selected on the basis of the characteristics of the student body in order to get an adequate number of males, females, Blacks, and Whites in the sample. One of schools selected (School X) serves primarily a middle to upper-middle class predominantly White clientele group. (All twelve of the subjects from this school were White.) The second school (School Y) serves primarily a lower to lower-middle class integrated clientele group. (Seven subjects from this school were Black; five students were White.) The third school (School Z) serves primarily a middle class integrated clientele group. (Nine of the ten subjects from this school were Black.)

The three schools in the study differed considerably in the type of chemistry course that the students were taking. School X placed a considerable amount of emphasis on problem solving and laboratory exercises. School Y offered a course that was entirely a lecture-discussion experience. The students conducted no laboratory exercises and were therefore unable to engage in investigatory activities. School Z, while not emphasizing laboratory experiences, did allow the students to participate in some laboratory experiences.

It is conceivable that the type of chemistry course in which subjects are enrolled will have an effect on either their problem solving strategies or their hemisphericity designations, or both. Thus, any findings in which relationships are suggested involving the subject characteristics of race or sex may be in part attributable to differences in school experiences.

An overview of the experiment was presented orally to each of the three chemistry classes from which volunteers were sought. Each subject who volunteered for the study was given a subject consent form and a parental consent form to be turned in to the investigator at the next meeting. The subjects for the study were those students who turned in their consent forms and had the time available to meet with the investigator.

Composition of the Sample

The thirty-four subjects in this study consisted of 12 students from School X, 10 students from School Y, and 12 students from School Z. The sample included 9 seniors, 23 juniors, and 2 sophomores. There were 9 Black females, 7 Black males, 9 White females,

and 9 White males in the sample. The age breakdown of the subjects was as follows: 1 fifteen year old, 13 sixteen year olds, 16 seventeen year olds, and 4 eighteen year olds.

Whereas a total of thirty-four subjects participated in at least one aspect of the study, the number of subjects participating in each section differed slightly. All thirty-four subjects were administered the SOLAT questionnaire, thirty-three subjects participated in the dichotic listening exercise, thirty-two subjects participated in the tachistoscopic viewing exercise, and seventeen students participated in the problem solving section of the study. (One subject did not pass the hearing test required for inclusion in the dichotic listening task, and two students left school before the tachistoscopic viewing data were collected.) The different numbers of subjects in the different sections of the study did not affect the validity of the statistical techniques used, however. The significance tests used did not require equal numbers of subjects per group.

V. COLLECTION OF DATA

A separate folder was compiled for each subject in the study. All answer sheets, subject profiles, data collection forms, and consent letters were placed in these folders. Each form described below is included in Appendix A of this report.

The Subject Profile

This form was completed by each subject during an initial interview with the investigator. The form records background data

about each subject, including name, grade, birthdate, address, sex, race, science courses completed, assessment of prior experiences with problem solving tasks, hobbies, and favorite subjects in school. The information gathered in this form was used to classify subjects as well as to provide for more comprehensive portrayals of each subject.

Student and Parental Consent Forms

In each of these forms there was a brief description of the research project, including a simple explanation of the tasks in which the subjects would be involved. Space was provided at the bottom of each letter for the signature of the parent or student to indicate a willingness to participate in the study.

Hemispheric Dominance Answer Sheets

Answer sheets for the dichotic listening task and tachistoscopic viewing task, in addition to the entire SOLAT test were also placed in each subject's folder. This information was used in assigning hemisphere dominance to individual subjects in the study.

Problem Solving Strategy Analysis Sheet

This form was devised to assist the researcher in analyzing the verbal solutions to the problems used in the study. The form was used to assign problem solvers a status of either heuristic or analytic, and was also used in the assignment of numerical grades for the problem solving task.

Additional Data Sources

Subjects' answers and drawings, written on the problem sheets, were collected by the investigator. Pertinent incidental comments were noted. Scores on the Fall 1979 Metropolitan Achievement Test in the areas of reading, science, and mathematics problem solving were acquired from the students' cumulative records. These scores were used to complete the profile for each subject. These additional data sources are not found in the Appendix for reasons of confidentiality.

VI. ANALYSIS OF DATA

Several organizational schemes were used to facilitate the data analysis in this study. These will be briefly described below.

Data Charts

Separate charts were compiled for data on the hemisphericity measures, problem solving tasks, and questionnaire responses of the subjects in the study. The charts were designed to facilitate comparison of individual subjects' responses, and to enable subgroup performances on specific tasks to be readily compared. Each subject was designated throughout the analysis by a number corresponding to his/her position in an alphabetical arrangement of subjects by schools. Subgroup means were calculated where feasible, and statistical comparisons were made.

Statistical Analyses

The statistical techniques employed to analyze the data in this study included Pearson product moment correlation coefficients, one way analysis of variance (ANOVA), t-tests for significance of difference between means, Spearman's rank-difference correlation coefficients, and analysis of chi square. The way in which the statistical techniques and data charts were used to analyze each of the research questions is discussed briefly below. (A complete discussion of each technique is presented in Appendix C).

Question 1: Do the two physiological tests of hemisphericity correlate significantly with SOLAT?

The answer to this question was determined by three methods:

1. Calculating the Pearson product moment correlation coefficients for the indices calculated for each of the three hemisphericity measures--dichotic listening vs. tachistoscopic viewing, dichotic listening vs SOLAT, and tachistoscopic viewing vs. SOLAT.
2. Calculating the Spearman rank-difference correlation coefficients when the subjects were arranged in order of increasing index of hemisphericity. The index for each measure was $(R-L/R+L)100$.
3. Classifying the subjects as either right, left, or integrated using each of the three hemisphericity tests, and determining the degree of agreement in classifications.

Question 2: Is there a relationship between sex and hemisphericity and between race and hemisphericity for selected high school chemistry students?

The answer to this question was determined by using one way analysis of variance and t-tests to determine if the scores on the hemisphericity measures differed according to sex or race.

Question 3: Will more students be left hemisphere dominant than right hemisphere dominant on the basis of dichotic listening, tachistoscopic viewing, and SOLAT?

This question was answered by first assigning laterality to subjects based on the laterality index $(R-L/R+L)100$ in the cases of dichotic listening, and tachistoscopic viewing, and on the basis of the Torrence and Reynolds (1980) norms reference manual classifications in the case of SOLAT. The percentage of students who are classified as right, left, and integrated were compared for each of the three measures.

Question 4: Do students who are left hemisphere dominant more often employ algorithms in their problem solutions, and students who are right hemisphere dominant more often employ heuristics in their problem solving efforts?

This question was answered by classifying students as heuristic or algorithmic problem solvers based on the criteria detailed in Chapter IV. A 2 X 2 chi square table was constructed showing the number of algorithmic problem solvers who are left hemispheric and right hemispheric, as well as the number of heuristic problem solvers who are classified in each of these ways. Any statistically significant relationship will emerge from the chi square analysis.

Question 5: Are students who are left hemisphere dominant more successful students according to chemistry grades and standardized test scores?

This question was answered by comparing the average grade of left hemisphere dominant students with that of right hemisphere dominant students, as classified by each of the three tests of laterality used in this study. Additionally, the average science score on the Metropolitan Achievement Test was compared for the two groups of subjects.

CHAPTER IV

ANALYSIS OF DATA

I. INTRODUCTION

This chapter contains the results of the data analysis for each of the tests of hemisphericity administered in this study. Also contained herein are a thorough discussion of the problems used in the study and the analysis of the problem solving strategies employed by the subjects in the study.

It is important to point out that the results of the hemisphericity tests presented in this chapter should be considered as three separate sets of data. For example, the subjects who were classified as left hemisphere dominant on the basis of dichotic listening were not necessarily the same group of students who were classified as left hemisphere dominant on the basis of tachistoscopic viewing or SOLAT. As will be seen later, the correlation among the three tests was not statistically significant. However, the results of each test, taken separately, agreed well with results obtained by other researchers.

It is also important to note that the primary focus of this investigation (and of any investigation examining learning or thinking styles and problem solving strategies) was the individual subject. Group data that were calculated were most useful in correlating the findings of this study with previous studies, and in analyzing potential trends.

II. THE HEMISPHERICITY MEASURES

Dichotic Listening

On the dichotic listening task each subject was assigned four different scores (see Appendix C): R, L, E, and I, representing the following information:

R = number of correct responses for stimuli to the right ear,

L = number of correct responses for stimuli to the left ear,

E = number of responses that were erroneous (i.e., the CV stimulus reported was neither the right ear stimulus nor the left ear stimulus),

I = the index of ear advantage, $(R-L/R+L)100$.

(Note that I is positive in the case of a right ear advantage and negative in the case of a left ear advantage.)

As shown in Table II, 66.6% of the members of the sample showed a distinct right ear advantage (i.e., a left brained dominance for speech). Table II also shows the percentages of males, females, Blacks, and Whites who showed an ear advantage to the right or left, and those who showed no ear advantage (integrated).

When the sample was subdivided into the subgroups of Black females, Black males, White females, and White males, the percentages shown in Table III were obtained.

As can be seen from Table II, each of the subgroups contained more individuals who demonstrated a right ear advantage (i.e., were left-brained). It is interesting to note that the Black subject

TABLE II
DICHOTIC LISTENING CLASSIFICATIONS OF
SUBJECTS' HEMISPHERICITY

Group	No. of Subjects	Brain Dominance		
		% Left	% Right	% Integrated
Females	17	70.6	29.4	0.0
Males	16	62.5	25.0	12.5
Blacks	15	80.0	13.3	6.7
Whites	18	55.5	38.9	5.6
Total Sample	33	66.7	27.3	6.0

TABLE III
DICHOTIC LISTENING CLASSIFICATIONS OF SUBJECTS'
HEMISPHERICITY BY SUBGROUPS

Subgroup	No. of Subjects	Brain Dominance		
		% Left	% Right	% Integrated
Black Females	8	100.0	0.0	0.0
Black Males	7	57.1	28.6	14.3
White Females	9	45.5	55.5	0.0
White Males	9	66.7	22.2	11.1
Total Sample	33	66.7	27.3	6.0

group contained fewer individuals who were right-brained (13.3%) than the White subjects (38.9%). These results support the conclusion of Dorman and Geffner (1974) that Blacks are not more right-brained than Whites. The hypotheses that many urban Blacks do not succeed in school because the left-brained school tasks are not relevant (Wheatley, 1977) is not supported by the results of this study.

Table III shows the percentages of right-brained and left-brained individuals when the sample is subdivided into Black females, Black males, White females, and White males. Only the White females contained more right-brained subjects (55.5%), but the ratio of right to left brained subjects (5:4) is almost even.

The percentages for the total sample are consistent with the findings of earlier dichotic listening studies that generally assessed 70%-90% of all subjects as being left lateralized for speech (Springer and Deutsch, 1981).

In order to determine whether a statistically significant right ear advantage was present in the entire sample, and for each of the subgroups shown in Table III, a one-way analysis of variance was performed on the data, and the results shown in Table IV were obtained. Each of the subgroups demonstrated a statistically significant right ear advantage.

On the basis of the F values shown in Table IV, all of the subgroups demonstrated right ear advantages that were concluded to be due to a factor other than chance with a 95% probability. The

TABLE IV
RESULTS OF ANALYSIS OF VARIANCE FOR SIGNIFICANCE OF
RIGHT EAR ADVANTAGE

Subgroup	N	Degrees of Freedom	F	Level of Significance
Black Females	8	2, 21	23.3	<0.01
Black Males	7	2, 18	3.61	<0.05
White Females	9	2, 24	15.7	<0.01
White Males	9	2, 24	12.6	<0.01
Total Sample	33	2, 96	43.0	<0.01

large difference in the F values of the Black females and Black males (23.3 vs. 3.61) is due to the total Black female subgroup demonstrating a right ear advantage. This may be due to the circumstance that more males were classified as integrated (showed neither a right nor left ear advantage) than were the females.

In determining whether the subgroups differed from each other, a one way analysis of variance was again used. The analysis determined whether the number of correct right ear responses, left ear responses, and erroneous responses were statistically significant for each of the subgroups involved. The results of this analysis are shown in Table V.

On the basis of the F values in Table V, it was concluded that the subgroups were not significantly different in their degree of laterality. These results are consistent with those of Dorman and

TABLE V
RESULTS OF ANALYSIS OF VARIANCE FOR DICHOTIC LISTENING
DIFFERENCES AMONG SUBGROUPS

Direction	No. of Subjects	Degrees of Freedom	F	Level of Significance
Right	33	3, 29	0.92	>0.05
Left	33	3, 29	2.24	>0.05
Error	33	3, 29	1.01	>0.05

Geffner (1974) who also found no statistically significant differences on the basis of race or sex on tasks of dichotic listening.

Thus each of the subgroups demonstrated a significant right ear advantage, but the degree of laterality was not significantly different between groups.

Tachistoscopic Viewing

As was the case with dichotic listening, on the tachistoscopic viewing task each subject was assigned four different scores: R, L, E, and I, representing the following information:

R = number of correct responses for stimuli in the right
visual half field,

L = number of correct responses for stimuli in the left
visual half field,

E = number of incorrect responses,

I = the index of visual half-field superiority, $(R-L/R+L)100$.

As shown in Table VI, 75.0% of the members of the sample showed a right visual half-field superiority for the stimuli used in this study. Visual half-field superiority indicates the direction for which subjects identified the greater number of stimulus words. If a subject correctly identified more words that were flashed to the right of the center of the screen, a right visual half-field superiority is demonstrated, and the subject was classified as left hemisphere dominant on the tachistoscopic viewing task.

TABLE VI
TACHISTOSCOPIC VIEWING CLASSIFICATIONS
OF SUBJECTS' HEMISPHERICITY

Group	No. of Subjects	Brain Dominance		
		% Left	% Right	% Integrated
Females	16	81.2	18.8	0.0
Males	16	68.8	12.5	18.7
Blacks	15	60.0	26.7	13.3
Whites	17	82.4	11.7	5.9
Total Sample	32	75.0	15.6	9.4

As can be seen from Table VI, each subgroup had more students who had a right visual half-field superiority than those who had a left visual field superiority. These findings are generally consistent with those of Kinsbourne (1981) who reported that a right side

advantage is typically obtained in 70% to 80% of all subjects on binocular tachistoscopic viewing tasks involving verbal material.

When the sample was divided into the subgroups of Black females, Black males, White females, and White males, the percentages of subjects showing right, left, and no visual half field advantages are shown in Table VII below.

TABLE VII
TACHISTOSCOPIC VIEWING CLASSIFICATIONS OF SUBJECTS'
HEMISPHERICITY BY SUBGROUPS

Group	No. of Subjects	Brain Dominance		
		% Left	% Right	% Integrated
Black Females	8	87.5	12.5	0.0
Black Males	7	42.8	28.6	28.6
White Females	8	75.0	25.0	0.0
White Males	9	88.9	11.1	0.0
Total Sample	32	75.0	15.6	9.4

As Table VII shows, each subgroup contained more individuals who were left-brained than individuals who were right brained. However, the Black male subsample was the only group that contained fewer than 50% left-brained subjects. This may be due to the fact that 28.6% of this group demonstrated no visual half-field superiority, i.e., they were classified as integrated. Although it is not clear why this group was the only subgroup in which some members were

integrated, these findings are consistent with the dichotic listening results in which the male subsample contained individuals who were integrated, but the female subsample did not.

In order to determine whether a statistically significant right visual half field advantage was present in the entire sample, and for each of the subgroups shown in Table VII, a one way analysis of variance was performed on the data, and the results are shown in Table VIII.

On the basis of the F values shown in Table VIII, all of the subgroups demonstrated right visual field superiorities that were concluded to be due to a factor other than chance, with a 99% probability.

TABLE VIII
RESULTS OF ANALYSIS OF VARIANCE FOR SIGNIFICANCE
OF RIGHT VISUAL HALF-FIELD ADVANTAGE

Subgroup	No. of Subjects	Degrees of Freedom	F	Level of Significance
Black Females	8	2, 21	19.7	<0.01
Black Males	7	2, 18	7.3	<0.01
White Females	8	2, 21	9.2	<0.01
White Males	9	2, 24	14.2	<0.01
Total Sample	32	2, 93	52.7	<0.01

The smaller F values for the Black males and White females are probably due to the smaller percentages of these groups that were classified as left hemisphere dominant. Only 42.8% of the Black males were left hemisphere dominant and 75.0% of the White females. It is not clear why these two subgroups should have fewer left hemisphere dominant individuals than the other two subgroups in the study. Since both the race and sex of the subjects in these groups was different, this may provide even more evidence that hemisphericity is unrelated to race and sex.

In determining whether the subgroups differed from each other, a one way analysis of variance was carried out. This analysis was used to determine whether the number of correct right visual half-field responses, correct left visual half-field responses, and erroneous responses was significantly different for each of the subgroups involved.

On the basis of the F values in Table IX, it was concluded that the subgroups were not significantly different in their degree of laterality. Each of the subgroups demonstrated a significant right visual half field advantage, but the degree of laterality was not significantly different between groups.

SOLAT

On the basis of SOLAT, each subject was assigned four different scores: R, L, In, and I, representing the following information:

TABLE IX
RESULTS OF ANALYSIS OF VARIANCE FOR TACHISTOSCOPIC
VIEWING DIFFERENCES AMONG SUBGROUPS

Stimulus Direction	No. of Subjects	Degrees of Freedom	F	Level of Significance
Right	32	3, 28	0.08	>0.05
Left	32	3, 28	0.59	>0.05
Error	32	3, 28	0.33	>0.05

R = number of responses indicating a preference for right
brained thinking,

L = number of responses indicating a preference for left
brained thinking,

In = number of responses indicating a preference for the inte-
grated mode of thinking,

I = the index of hemispheric preference, $(R-L/R+L)100$.

Note that in calculating I for the SOLAT test, only the R and L responses were considered. The number of integrated responses was not included in this parameter because the investigator sought to determine whether the subject selected more responses in the right-brained or left-brained category for those items on which a preference was indicated. The items on which the subjects expressed no preference were treated as neutral responses. The determination of the SOLAT index in this manner made this index analogous to the dichotic listening and tachistoscopic viewing indices discussed earlier.

As shown in Table X, 41.2% of the sample was classified as integrated thinkers (i.e., no dominance of either the left or right hemisphere in thought processes). The subjects were classified using the norms given by Torrence and Reynolds (1980). Only 8.8% of the sample was classified as left brain dominant, and 32.4% of the sample could not be assigned any classification because their responses were about evenly distributed among the categories.

TABLE X
SOLAT CLASSIFICATIONS OF SUBJECTS' HEMISPHERICITY

Group	No. of Subjects	Brain Dominance			% Unclassifiable
		% Left	% Right	% Integrated	
Females	18	5.5	27.8	38.9	27.8
Males	16	12.5	6.2	43.8	37.5
Blacks	16	6.25	25.0	31.2	35.5
Whites	18	11.1	11.1	50.0	27.8
Total Sample	34	8.8	17.6	41.2	32.4

Whereas the results in Table X are in striking contrast to the results of the dichotic listening and tachistoscopic viewing exercises, the results agree very well with those of Wilson (1982), who administered SOLAT to a sample of Engineering Graphics students at a technical school in Knoxville. The results also agree very well with results reported by Torrence and Reynolds (1980). They reported

the SOLAT scores of a sample of selected groups that included undergraduates and graduates at the University of Georgia, University of Nebraska at Lincoln, University of Nebraska at Omaha, and Florida International University, Miami. In the Wilson (1982) and the Torrence and Reynolds (1980) studies, when the unclassifiable subjects were disregarded, the number of subjects classified as integrated was highest, followed by the number of students classified as right-brained. The number of left-brained students was the smallest of the three groups. Thus, the results of the physiological tests do not agree with the results that are obtained from SOLAT. A possible explanation for this discrepancy is discussed in Chapter V of this report.

When the sample was further divided into the subgroups of Black females, Black males, White females, and White males, the percentages shown in Table XI were obtained.

As can be seen from Tables X and XI, each of the subgroups had a very low number of subjects who could be classified as either left hemispheric or right hemispheric on the basis of SOLAT. Most of the sample was classed as either integrated thinkers or unclassifiable thinkers.

The results in Table IX are a graphic indication that the SOLAT test and dichotic listening exercise are measuring different phenomena. Whereas the dichotic listening task indicated that all of the Black females were left brain dominant, the SOLAT test indicated that none of this group was left-brained. On SOLAT the Black

TABLE XI
SOLAT CLASSIFICATIONS OF SUBJECTS'
HEMISPHERICITY BY SUBGROUPS

Group	No. of Subjects	Brain Dominance			% Unclass- ifiable
		% Left	% Right	% Integrated	
Black Females	9	0.0	33.3	33.3	33.3
Black Males	7	14.3	28.6	14.3	42.8
White Females	9	11.1	22.2	44.4	22.2
White Males	9	11.1	0.0	55.6	33.3
Total Sample	34	8.8	17.6	41.2	32.4

female subjects were evenly divided among the right, integrated, and unclassifiable categories. Additionally, whereas 66.7% of the entire sample was classified as left-brained by dichotic listening and 75.0% by tachistoscopic viewing, only 8.8% were classified as left-brained on the basis of SOLAT. It is quite evident that the physiological tests and SOLAT are not measuring the same subject characteristic.

In order to determine whether the differences in the response frequencies were statistically significant, a one way analysis of variance was performed. The results are shown in Table XII below.

For the sample used in this study, the White subjects were less likely to consistently choose either the left or the right hemisphere method of thinking, and were more likely to be integrated or unclassifiable in their style of learning and thinking.

TABLE XII
RESULTS OF ANALYSIS OF VARIANCE FOR SIGNIFICANCE OF
LATERALIZED THINKING ON SOLAT

Subgroup	No. of Subjects	Degrees of Freedom	F	Level of Significance
Black Females	9	2, 24	3.44	<0.05
Black Males	7	2, 18	6.27	<0.01
White Females	9	2, 24	2.88	<0.10
White Males	9	2, 24	1.74	>0.10
Total Sample	34	2, 99	11.45	<0.01

In determining whether the subgroups differed from each other on the manner in which they responded to the SOLAT questionnaire items, a one way analysis of variance was performed and the results shown in Table XIII were obtained.

In addition to scoring the SOLAT test using Torrence and Reynolds' norms, an index of hemisphericity was also calculated in a manner analogous to that used in the dichotic listening and tachistoscopic viewing parts of the study. Hemisphericity assignments were made on the basis of the index, and the results are shown in Tables XIV and XV.

As can be seen in Table XIV, the male and female subgroups differed very little in the number of subjects who were classified as right hemisphere dominant or left hemisphere dominant. However, the Black and White subgroups differed significantly. Whereas the

TABLE XIII

RESULTS OF ANALYSIS OF VARIANCE FOR DIFFERENCES
ON SOLAT AMONG SUBGROUPS

Response Category	No. of Subjects	Degrees of Freedom	F-Ratio	Level of Significance
Right	34	3, 30	0.46	>0.05
Left	34	3, 30	0.82	>0.05
Integrated	34	3, 30	0.06	>0.05

TABLE XIV

SOLAT CLASSIFICATIONS BASED ON
HEMISPHERICITY INDEX

Group	No. of Subjects	Brain Dominance		
		% Left	% Right	% Integrated
Females	18	38.9	55.6	5.5
Males	16	50.0	50.0	0.0
Blacks	16	18.7	81.2	0.0
Whites	18	66.7	33.3	0.0
Total Sample	34	44.1	52.9	2.9

TABLE XV
SOLAT CLASSIFICATIONS BY SUBGROUPS
BASED ON HEMISPHERICITY INDEX

Subgroup	No. of Subjects	Brain Dominance		
		% Left	% Right	% Integrated
Black Females	9	22.2	66.7	11.1
Black Males	7	14.3	85.7	0.0
White Females	9	55.6	44.4	0.0
White Males	9	77.8	22.2	0.0
Total Sample	34	44.1	52.9	2.9

Black subgroup contained 81.2% of subjects who were classified as right-brained, the White subgroup contained only 33.3% of subjects who were classified as right-brained. These values may be still another indication that the SOLAT test is measuring the subjects' preference in terms of learning style and not their physiological brain dominance. If preference is related to cultural background, as has been suggested by Torrence and Sato (1979), the Black-White difference in hemisphericity may be directly attributable to cultural differences. Future studies of subjects from different cultural backgrounds should help to clarify this issue.

When the SOLAT data are analyzed in the manner described above, considerably more of the Black subjects are classified as right hemisphere dominant than are their White counterparts, and considerably

more Whites are classified as left dominant. Whereas these differences do not reach statistical significance, it is important to recognize the differences in the two groups of subjects in an exploratory study of this nature.

Whereas no research studies have been reported in which the SOLAT test performance of Black and White subjects was compared, the Torrence and Sato study (1979) demonstrated a difference in SOLAT scores of Japanese and United States college students. The Japanese students scored significantly higher than their United States counterparts on both the right and left hemisphere scales and lower on the integrated scale. Torrence and Sato point out that the differences in thinking styles between the two groups of students became clearer when the differences for specific SOLAT items were noted and grouped. Consistent differences appeared in three major areas--intuitive-creative thinking vs. logical-rational thinking, planning and precision vs. spontaneity and open-endedness, and verbal modes of learning, teaching and communicating vs. non-verbal modes. Torrence and Sato suggest that the differences in thinking style are due to the "value differences between the East and West--intuition and creativity vs. logic and intellect" (p. 147). The results of the current study support the hypothesis that preferred style of learning is related to cultural background.

III. THE PROBLEM SET

The five problems used in the problem solving aspect of this study are presented below. A discussion of the strategy classification procedure follows the presentation of each problem.

1. A man who is looking at a picture says the following: "Brothers and sisters have I none, but that man's father is my father's son." Who is the man in the picture? (Source: Atkin, 1977, p. 186.)

In assigning the classification for this problem, the following criteria were followed:

Algorithmic strategy: Making a substitution of the word "me" for "my father's son." When this substitution is made, the problem can be reread as "Brothers and sisters have I none, but that man's father is me." The riddle can then be solved, and it is readily seen that the man is looking at a picture of his son.

Heuristic strategy: The heuristic strategies for solving this problem included "picturing" the relationship in the mind and producing the correct answer, making an analogy between this situation and another one, such as the subject's own family, and drawing a diagram of the situation to show the relationships involved. The process of picturing an image during the problem solving process was described by Kabanova-Meller (1971). She found that generalized images serve as carriers for techniques, and that images of spatial solutions guide substantiation efforts and mediate between memory processes and other mental operations. Whenever students used visual images

in their solution strategies, the strategy was classified as heuristic.

On Problem 1 only two of the subjects correctly solved the problem on the first attempt. One of these students used the algorithmic strategy of making the proper substitutions for the word phrases. The other successful subject used the heuristic strategy of "visualizing" the relationships in his head, and then proceeded to verbalize the correct answer. When asked how he arrived at the answer, he was unable to fully explain his reasoning, but he was confident that his answer was correct. (The two subjects referred to are Subject 9 and Subject 11. Their protocols are presented in Appendix B of this report.)

Eight of the subjects had no strategy for solving this problem; they simply replied "I don't know" after having read the problem. Seven subjects attempted to use a heuristic strategy and two subjects utilized an algorithmic strategy in solving this problem. The subjects' mean performance on this problem was 4.71. The table shown on page 74 presents a summary of the data collected in the problem solving section of this study.

2. If substance B and substance D are both more active than substance C, while substance A is less active than substance B but more active than substance D, which substance is the least active and which one is the second least active? (Source: Whimbey and Lochhead, 1980, p. 37.)

In assigning the classification for this problem, the following criteria were followed:

Algorithmic strategy: Taking each of the relationships presented and expressing them in terms of inequalities, in serial fashion. For example,

$$B, D > C$$

$$A < B, B > A$$

$$A > D$$

When the individual relationships are expressed in this manner, the order of increasing activity is readily identified as $B > A > D > C$.

Heuristic strategy: "Visualizing" the entire relationship holistically without having to write down the individual relationships as separate components of the problem solution.

Nine of the subjects utilized an algorithmic strategy to solve this problem, and eight subjects utilized heuristics. The subjects were very successful in solving this problem; the mean performance was 17.65. The success of the subjects on this problem was not dependent on type of strategy used; heuristic problem solvers were as successful as algorithmic solvers.

3. One tree is seven times as old as another. Five years from now it will be four times as old. What are the present ages of the trees? (Source: Brandes, 1975, p. 194, number 36.)

In assigning the classification for this problem, the following criteria were used:

Algorithmic strategy: Using an algebraic equation to solve the problem. If the equation $4(x+5) = 7x+5$ is correctly applied to this problem, it is readily discovered that one tree is currently five years old, and the other tree is thirty-five years old.

Heuristic strategy: Substituting potential values into the problem conditions and determining if the substituted values satisfy the conditions. For example, the values 1,7; 3,21; or 6,42 could be tried until the correct values of 5 and 35 are discovered.

Fifteen of the subjects attempted to solve this problem algorithmically, and only two subjects used heuristics in their first attempt to solve the problem. One probable reason that the subjects tried to solve the problem algebraically was the similarity of this problem to word problems that they had faced in algebra. In fact, several subjects alluded to the fact that the problem was similar to the word problems that they had encountered in algebra. Although all of the subjects were familiar with this type of problem, they were largely unsuccessful in their attempts to arrive at the correct solution. The mean score achieved by the subjects on this problem was 8.53 out of a possible 20. Invariably, the equation that was set up was incorrect, and the majority of the subjects seemed unable or unwilling to use another strategy to determine the correct answer. Whereas all five of the subjects who correctly solved the problem first attempted to set up an algebraic equation, three of the five had to resort to the heuristic strategy of trying different number combinations in order to solve the problem. The unsuccessful subjects abandoned their attempts to solve the problem when their equations yielded incorrect results. The willingness to try alternative strategies was one attribute that separated the successful problem solvers from the unsuccessful ones.

4. On the Celsius temperature scale, the freezing point of water is 0°C and the boiling point of water is 100°C . If a new temperature scale were created on which the freezing point of water was defined as 200 U and the boiling point of water as 600 U, what would be the equivalent of 25°C on this scale? (Source: Adapted from Kleinfelter, D. and Peterson, J., 1980, p. 9, number 14.)

In assigning the classification for this problem, the following criteria were used:

Algorithmic strategy: Systematically figuring out the distance between freezing and boiling points on each scale, and using this relationship to figure out that the correct temperature on the U scale is one-fourth the distance from the freezing point. This is shown below.

$600 - 200 = 400$ units between freezing and point points on
the U scale.

Thus, four units on the U scale are equivalent to one unit on the C scale, and 25°C is equivalent to 300 U.

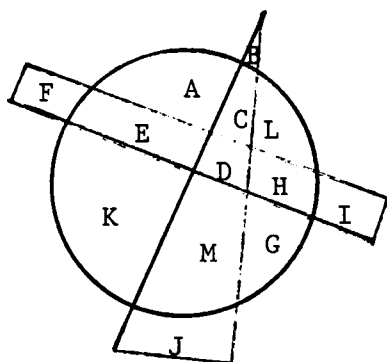
Heuristic strategy: Drawing a picture of the two scales and deducing from the pictorial representation that 25°C is equivalent to 300 U. Another heuristic strategy is that of attempting to use ratio and proportion to solve the problem. For example,

$$\frac{600}{100} = \frac{x}{25}$$

Nine of the subjects attempted to use heuristics in solving this problem, seven attempted to use an algorithmic strategy, and one subject employed no strategy at all. All of the five subjects who

solved the problem correctly used an algorithmic solution method. Most of the subjects who used a heuristic approach became confused after arriving at an incorrect answer and were unable to persist until they could arrive at a correct solution. They gave up too quickly. The average performance on this problem was 12.35.

5. In working this problem, consider the diagram below to be made up of three major geometrical figures--a triangle, a circle, and a rectangle. How many letters are in exactly two (but not three) of these figures? (Source: Whimbey, A. and J. Lockhead, 1980, p. 72.)



In assigning the classification for this problem, the following criteria were used:

Algorithmic strategy: Writing down each figure and the letters that appear inside that particular figure. After all letters are written, systematically counting all the letters that are written two times and only two times was the second step in this strategy.

Heuristic strategy: Looking at the picture and visualizing the letters that are common to two, but not three of the figures.

Nine of the subjects attempts to solve this problem heuristically, and eight subjects used an algorithmic approach. Of the six subjects who correctly solved the problem, three used a heuristic approach, and three used an algorithmic approach. Thus, the problem appeared to lend itself equally well to both types of strategies. The mean performance of all subjects on this problem was 12.35.

A summary of the data discussed above is presented in Table XVI below.

TABLE XVI
SUMMARY OF PROBLEM SOLVING STRATEGIES AND
PERFORMANCE ON EACH PROBLEM*

Problem	Mean Performance	Subjects Using Heuristics	Subjects Using Algorithmics	No Strategy
Problem 1	4.70	7	2	8
Problem 2	17.65	8	9	0
Problem 3	8.53	2	15	0
Problem 4	12.35	9	7	1
Problem 5	12.35	9	8	0

*The problem set is presented in Appendix B, and a discussion of heuristic and algorithmic strategies is found in pages 68-73 of this report.

Only one subject in the study used the same type of strategy for all five of the problems, but seven subjects used the same type of strategy on four of the five problems. Subjects were classified

as either heuristic or algorithmic based on the strategy used on a majority of the five problems.

In addition to classifying the strategy used to solve each problem, a numerical score on the problem solving task was assigned to each subject. The numerical score assigned was based on whether the subject arrived at the correct answer in solving the problem, and on the number of attempts needed to correctly solve the problem. Each problem was assigned a maximum point value of 20 points. The system used to assign point values is as follows:

Correct solution on first attempt	20 points
Correct solution on second attempt with no assistance	15 points
Correct solution on second attempt with assistance	10 points
Correct solution on third attempt with assistance	5 points

The overall mean score on the problem set was 55 points out of a possible 100. The mean score achieved by each of the subgroups identified in the study is shown in Table XVII.

The results shown in Table XVII indicate that males were generally more successful on the problem solving task than were females, and Whites were more successful than Blacks. Although these results are generally consistent with previous research studies, the results are not generalizable due to the small numbers of subjects in the problem solving section of the study.

TABLE XVII
PROBLEM SOLVING PERFORMANCE OF SUBGROUPS IN STUDY

Subgroup	No. of Subjects	Mean Score	Range
Black Females	3	30	5- 45
Black Males	5	49	35- 90
White Females	6	50	30- 80
White Males	3	85	70-100
Total Sample	17	55	5-100

When the problem solving performance of the subjects was compared by considering strategy preference, the results shown in Table XVIII were obtained.

TABLE XVIII
PROBLEM SOLVING PERFORMANCE OF SUBJECTS
ACCORDING TO STRATEGY PREFERENCE

Strategy Preference	No. of Subjects	Mean Score	Range
Heuristic	7	42.1	5- 90
Algorithmic	9	61.7	30-100
Unclassifiable	1	45.0	--

Although the algorithmic problem solvers were more successful than the heuristic problem solvers, there were unsuccessful and successful problem solvers in each group of subjects, as shown by the range of scores for each category.

In order to determine if the relationship between problem solving strategy and hemisphericity as determined by SOLAT was statistically significant, a chi-square analysis using Yates' correction was performed on the SOLAT hemisphericity data. The results are shown in Table XIX. SOLAT was the instrument selected to serve as the basis for the hemisphericity classification because it is the only one of the three measures of hemisphericity used in this study that is easily accessible to high school teachers and can be administered to groups of students. The results of the comparison of hemisphericity as determined by dichotic listening and tachistoscopic viewing, and problem solving strategies used by subjects are shown in Tables XX and XXI.

TABLE XIX

COMPARISON OF PROBLEM SOLVING STRATEGY AND
HEMISPHERICITY AS DETERMINED BY SOLAT

	Left	Right
Heuristic	1	5
Algorithmic	7	3
Mixed	1	0

TABLE XX

COMPARISON OF PROBLEM SOLVING STRATEGY AND HEMISPHERICITY
AS DETERMINED BY DICHOTIC LISTENING

	Left	Right	Integrated
Heuristic	3	2	1
Algorithmic	5	5	0
Mixed	1	0	0

TABLE XXI

COMPARISON OF PROBLEM SOLVING STRATEGY AND HEMISPHERICITY
AS DETERMINED BY TACHISTOSCOPIC VIEWING

	Left	Right	Integrated
Heuristic	3	1	2
Algorithmic	8	1	1
Mixed	0	1	0

The relationship between SOLAT hemisphericity and problem solving strategy was significant at the 0.10 probability level, but did not reach significance at the 0.05 probability level. This investigator interprets these results as indicative of a probable relationship between the two properties.

When Tables XIX, XX, and XXI are considered as a group, it is evident that the tachistoscopic viewing hemisphericity classifications yield the same general relationship between laterality and

problem solving strategies as does SOLAT when one considers the algorithmic problem solvers. The left hemisphere dominant subjects are the algorithmic problem solvers. Although the results are less dramatic when dichotic listening hemisphericity is considered, a majority of the left-brained subjects were algorithmic problem solvers. Thus, all three of the hemisphericity measures demonstrate a relationship between left hemisphere dominance and preferred problem solving strategy.

When the problem solving strategy employed by subjects was examined with respect to the school each attended, the results shown in Table XXII were obtained.

TABLE XXII
PROBLEM SOLVING STRATEGIES OF SUBJECTS
ACCORDING TO SCHOOL ATTENDED

Type of Strategy	No. of Subjects Employing Strategy		
	School X	School Y	School Z
Heuristic	0	5	1
Algorithmic	5	1	5

It can be seen from Table XXII that the problem solving strategy utilized by subjects was strongly related to the school that the subject attended. School X had no heuristic problem solvers, whereas 83.33% of the problem solvers from School Y were heuristic. School Z, like School X, had a preponderance of algorithmic problem

solvers. The relationship between the school that the subjects attended and their problem solving strategies may have been due largely to the different types of chemistry courses being taught at the three high schools involved in the study. The chemistry instructor in one of the schools placed heavy emphasis on problem solving and laboratory experiences. The students in this school were able to perform independent investigations in the laboratory in addition to their group laboratory experiments. The chemistry course in the second school had no laboratory component, and the students were unable to experience the investigatory aspect of chemistry first-hand. The third chemistry course whose members participated in the study was also primarily a lecture-discussion class, but the students did perform a limited amount of laboratory work.

In addition to the differences in availability of laboratory exercises, the three classes also differed in the demands placed on the students and in the grading procedures of the teachers. These uncontrolled variables undoubtedly affected the results obtained in the study. However, inclusion of these uncontrolled variables was a necessary evil due to the total number of subjects required for the investigation.

Based on the data presented above, it is not possible to determine whether the hemisphericity is responsible for the problem solving strategy, or whether classroom instruction is primarily responsible for the strategies subjects employed. However, a possible relationship between hemisphericity and problem solving strategy is supported by these results.

CHAPTER V

FINDINGS

I. QUESTION 1

The first research question in this study examined the degree of correlation between three measures of hemisphericity--dichotic listening, tachistoscopic viewing, and SOLAT. After the three tests were administered to all subjects, Pearson product moment correlation coefficients were calculated for each pair of tests in order to determine if the tests correlated significantly with each other. The correlation coefficients for each pair of tests are shown in Table XXIII.

TABLE XXIII
CORRELATION OF HEMISPHERICITY TESTS

Tests Compared	Correlation Coefficient	Significance Level
Dichotic Listening and Tachistoscopic Viewing	-0.07	>0.10
Dichotic Listening and SOLAT	-0.05	>0.10
Tachistoscopic Viewing and SOLAT	-0.16	>0.10

Since none of the correlation coefficients were significant, this investigator concluded that either the three instruments are not measuring the same phenomenon-hemisphericity, or that the reliability of the test instruments was not sufficient to produce a significant correlation even though the tests were measuring the same phenomenon. This investigator feels that the former explanation is more likely to be correct--the three tests are not measuring the same phenomenon to the same extent. Himes and Katz (1974) have suggested that the poor correlation within subjects between visual (tachistoscopic viewing) and auditory (dichotic listening) asymmetries indicates that a given person may be differently lateralized for visual and auditory language representation. However, Kinsbourne (1979) p. 95 feels that the more economical explanation "that the mediating variables have differential impact between the two test situations" should not be ruled out. More data need to be collected before this question can be answered definitively.

As for SOLAT, this investigator feels that the instrument is not measuring laterality at all, but is instead measuring a preferred style of learning and thinking. Because the instrument is a self-report measure, subjects may report the manner in which they would like to think and act, and may in some cases be unaware that they think and act differently than the way they picture themselves.

The largest discrepancy between SOLAT and the physiological measures of laterality is the number of subjects who are classified as integrated thinkers. This investigator asserts that the number

of integrated thinkers is grossly inflated on SOLAT because of the structure of the test items. It is always easier for a subject to choose a neutral response when it is difficult to decide which of two items is really better at describing ones self. Thus, many persons who select the "integrated" response to a given item may do so merely to avoid the cognitive strain that would be caused by an indepth consideration of the other two choices available, and a decision as to which one of them really describes the subject. Both factors mentioned above may work in tandem to prevent correlation between SOLAT and the physiological measures.

Whatever the causative factor, there was no significant correlation when comparing the physiological measures with each other or with SOLAT in this investigation.

Another method of comparing the agreement on dichotic listening, tachistoscopic viewing, and SOLAT is to examine the percentage of subjects for which each pair of tests agree. This information is shown in Table XXIV.

It is interesting to note that the two physiological measures were in better agreement with each other than they were with SOLAT. Although the agreement of no two measures was particularly good, the agreement of the three taken together was very poor. It is apparent that more valid and reliable hemisphericity measures must be devised before classification based on any one measure can be regarded with confidence. This study utilized the SOLAT score to assign hemisphericity because it is the only one of the three measures that is

TABLE XXIV
AGREEMENT BETWEEN HEMISPHERICITY TESTS

Tests	Number of Subjects for which Tests Agreed	% of Subjects for which Tests Agreed
Dichotic Listening and Tachistoscopic Viewing	18	56%
Tachistoscopic Viewing and SOLAT	16	50%
Dichotic Listening and SOLAT	14	42%
All Three Tests	8	25%

both convenient and economical for a classroom teacher to use. Although SOLAT does not measure hemisphericity per se, it apparently measures preferred style of learning and thinking--a student characteristic that may influence success in the classroom.

II. QUESTION 2

The second question investigated by this study concerned a possible relationship between sex and hemisphericity or race and hemisphericity.

Based on the analyses presented in Chapter IV, the current study found no significant differences in laterality due to sex or race. The current research literature concerning sex and laterality provides conflicting information. Whereas several verbal dichotic listening studies have reported greater right ear advantages among

males than among females (Springer and Deutsch, 1981), other studies have reported no significant difference (Briggs, 1976; Carr, 1969). The discrepancy in the research studies reported to date has been explained in a variety of ways. Those researchers who have found no significant differences between the sexes argue that the studies that have found significant differences suffer from Type I statistical error. Type I statistical error occurs when the null hypothesis is rejected even though it should not be. This would mean that the sex differences observed in these studies is due to chance and not to real differences between the sexes. On the other hand, those investigators who have found statistically significant differences argue that the researchers who have not found differences used instruments whose sensitivity was insufficient to detect the real differences that existed. These researchers, claiming a real difference in laterality, note that the tremendous variability in lateralization makes it quite difficult to detect real, but small differences between the sexes.

Currently, this investigator agrees with the hypothesis that the sexes do not differ significantly in degree of hemispheric specialization. However, only time and additional studies will resolve the conflict between these two hypotheses.

As stated in Chapter II of this report, the limited data on race differences and hemisphericity agree with the findings of this study that no significant differences exist based on race. However, more studies are needed before any relationship between race and hemisphericity can be totally ruled out.

III. QUESTION 3

The third research question in this study examined the relative numbers of subjects who could be classified as left hemisphere dominant and right hemisphere dominant. It was hypothesized that a majority of subjects would be classified as left hemisphere dominant. Because the American educational system emphasizes left hemispheric activities to a greater extent than right hemisphere activities (Wheatley, 1977), it might be expected that students will rely more heavily on the left hemisphere to process information. This expectation is based on the theoretical concept of "progressive lateralization" (hemisphericity develops as a result of experiences), rather than "invariant lateralization" (hemisphericity is present at birth and does not change). Hence, this hypothesis indirectly tests which of the two theoretical positions is likely to be correct. Since "infants tend to be right-hemisphere dominant" (Wheatley, 1977, p. 38), a finding that more subjects are left-hemisphere dominant supports the progressive lateralization view.

On the basis of the physiological tests of hemisphericity, the majority of the subjects were classified as left hemisphere dominant. However, as stated earlier, the majority of the subjects were classified as "integrated" by the SOLAT test. The invariant lateralization theory is not supported by these results because none of the hemisphericity tests classified a majority of the subjects as right hemisphere dominant.

Whereas the postulated left-hemispheric dominance was demonstrated by the physiological measures of hemisphericity, it is not possible to determine empirically whether this dominance is due in any part to the American schooling system.

It would appear that the effect of schooling would be more evident on SOLAT than on the physiological tests because SOLAT seems to measure learning style preference. Since the importance of thinking logically and rationally is stressed again and again in school, students can be expected to internalize the notion that the left hemisphere mode of thinking is superior to that of the right hemisphere, and to demonstrate this notion on self-report measures of preferred style of learning and thinking. However, this was not the case in this study.

Many writers have referred to the predominance of left hemisphere activities in the American school system (Wheatley, 1977; Springer and Deutsch, 1981). Joseph Bogen (1975) feels that society has over emphasized the left-brained mode of thinking at the expense of right-brained thinking. The traditional school curricula that emphasize speaking, writing, and calculation exercises rely more on information processing by the left hemisphere than by the right hemisphere. IQ tests are aimed at left-hemisphere dominant abilities (Springer and Deutsch, 1981), and the school world is mainly a verbal, symbolic world (Edwards, 1979). However, recent information concerning the specialized functioning of the cerebral hemispheres has caused more and more educators to make an appeal for more

spatial-visualization and non-verbal tasks in our national curricula. Some writers (Prince, 1978) even suggest methods to develop the right side of the brain.

However, the question of the effect of schooling on hemisphericity is much more complex than many educational writers imply. Unqualified statements concerning any relationship between the two are tenuous at best at the present time.

IV. QUESTION 4

The fourth research question addressed the relationship of hemisphericity to types of problem solving strategy used by high school chemistry students. The hemisphericity index calculated for SOLAT was used as the classification measure for this part of the study because this instrument is the only one of the three instruments utilized in this study that is readily available to educators and needs no special conditions for administration. This is the only instrument that is likely to receive widespread use by educators because the time and special conditions required to administer the physiological tests prohibit their frequent utilization by teachers.

As stated in Chapter IV of this report, the current study demonstrated a statistically significant relationship between the hemisphericity index calculated for SOLAT and type of problem solving strategy used by the subjects. Those students who were classified as left hemisphere dominant were more likely to utilize algorithmic problem solution methods, whereas those students who were classified as right hemisphere dominant were more likely to use heuristic methods in their problem solving attempts.

However, when the subjects were classified according to school attended, it was apparent that there was a strong relationship between school and problem solving strategy. The presence of this relationship made it impossible to determine whether the relationship between hemisphere dominance and problem solving strategy was simply an artifact of the relationship between school and problem solving strategy. If problem solving strategy is more dependent on schooling than on hemisphericity, a study of the teacher's teaching style may indicate a strong relationship between teaching style and type of problem solving strategy used by students. A teacher who relies mainly on printed matter may produce students who are algorithmic problem solvers, whereas a teacher who relies more on aural transfer of information may produce students who are intuitive problem solvers. Future studies will be needed to answer this question.

V. QUESTION 5

In order to answer question 5, "Will students who are left hemisphere dominant be more successful students according to Chemistry grades and standardized test scores?" the first semester chemistry grades for each school were considered separately. However, due to grossly different grading practices at the three schools involved in the study, no useful information was gained from the examination of the grades. The distribution of grades at the three schools was as follows:

School X--11 A's; 1 B; and 0 C's, D's or F's.

School Y-- 0 A's; 4 B's; 3 C's; 2 D's; and 1 F.

School Z-- 0 A's; 4 B's; 5 C's; 3 D's; and 0 F's.

Since all of the A's were received at School X, and all but one of the students at School Y were classified as right brain dominant, the answer to question of the relationship of course grade to hemisphericity will await future studies.

To consider the relationship of hemisphericity with standardized test scores, the September, 1979 Metropolitan Achievement Test scores were analyzed. Scores in the areas of reading, math problem solving, and science were used in this study. The average performance in each of the areas by right and left hemisphere dominant students is shown in Table XXV.

The left hemisphere dominant students performed better than the right hemisphere dominant students on each of the subtests considered. However, this result is not surprising when one considers that standardized tests are largely tests of reading skill and comprehension--activities that are largely associated with left brain activities.

Whereas no conclusions can be drawn from this study concerning hemisphericity and course grades, there is an apparent relationship between hemisphericity and performance on standardized tests for the subjects in the study.

TABLE XXV
AVERAGE STANDARDIZED TEST SCORES OF SUBJECTS GROUPED ACCORDING
TO SOLAT HEMISPHERICITY CLASSIFICATION

	N	Average Percentile Score (Maximum = 99)		
		Mathematics	Reading	Science
		Problem Solving		
Right Hemisphere Dominant Subjects	18	59.4	55.9	55.9
Left Hemisphere Dominant Subjects	15	70.9	70.2	66.3
Integrated Subjects ^a	1	20.0	38.0	44.0
Total Sample	34	63.3	61.7	60.1
Difference in scores of left and right-brained subjects		11.5	14.3	10.4

^aSince only one student was classified as integrated, the scores cannot be interpreted as indicative of the performance of all integrated students.

CHAPTER VI

CONCLUSIONS, RECOMMENDATIONS, AND IMPLICATIONS

I. CONCLUSIONS

An exploratory investigation of the relationship of hemisphericity to the problem solving strategies used by high school chemistry students was conducted. Thirty-four students attending one of three Knoxville area high schools served as subjects for the study. The subjects' hemisphericity was determined by using two physiological tests--dichotic listening and tachistoscopic viewing, and one written test--Your Style of Learning and Thinking (SOLAT). There were five questions posed for investigation. These concerned: (1) the correlation between the different hemisphericity measures, (2) the relationship of sex and/or race to hemisphericity, (3) the ratio of left brain dominant individuals to right brain dominant, (4) the types of problem solving strategies used by left hemisphere dominant and right hemisphere dominant students, respectively, and (5) the relative success of students with different hemisphericity on standardized tests and in high school chemistry classes.

Seventeen of the thirty-four subjects were selected to participate in the problem solving aspect of the study. Each of the subjects attempted to solve five problems in a clinical session with the investigator. The subjects' attempts to solve the problems were recorded, and these verbal protocols were used in the analysis of the problem solving strategies.

Whereas each of the measures of hemisphericity yielded results that were consistent with findings of previous studies, there was little correlation between them. Thus, it was concluded that the three tests are measuring different phenomena. Dichotic listening tests measure aural laterality whereas tachistoscopic viewing measures visual laterality. Although these lateralities are certainly related, they did not appear to be synonymous in this study. The SOLAT is apparently measuring preferred style of learning and thinking, or preferred laterality, and is therefore not measuring the same phenomenon as the physiological measures.

When the results of each of the hemisphericity measures were analyzed for any statistically significant sex and/or race relationships to hemisphericity, none were found. This investigator therefore concludes that there is no significant effect of either race or sex on hemisphericity.

This study demonstrated that a majority of the subjects were left hemisphere dominant when using either dichotic listening or tachistoscopic viewing as measures of laterality. However, on the basis of SOLAT, the majority of subjects were integrated thinkers, i.e. neither right hemisphere nor left hemisphere dominant. These findings cannot, however, lead one to conclude that schooling is a major influence on hemisphericity, or that the American educational system is responsible for the predominance (on the basis of the physiological tests) of left brained individuals. In view of the conclusion that SOLAT is measuring the students' preferred laterality and not actual brain dominance, no further conclusions can be drawn

concerning the influence of schooling on hemisphericity until more reliable measures of hemisphericity are developed. When more reliable measures are developed, it should be possible to determine the extent to which individual teachers influences learning style. Some teachers may encourage the use of left-hemispheric information processing by relying on printed matter to the exclusion of other teaching methods. Other teachers may encourage right-hemispheric information processing by relying on visual presentation of information. Hemisphericity may be more fluid than is currently thought.

When the subjects were classified as algorithmic or heuristic problem solvers on the basis of their verbal protocols, a statistically significant relationship between problem solving strategy and hemisphericity was demonstrated. The right hemisphere dominant subjects tended to use heuristic strategies, whereas the left hemisphere dominant subjects tended to use algorithmic strategies. There is therefore reason to theorize that the type of problem solving strategy one uses is somehow related to hemisphericity. However, when the problem solvers were grouped according to school attended, most of the algorithmic problem solvers attended one school, and most of the heuristic problem solvers attended another. Thus, the differences in problem solving strategies may be due more to schooling (i.e. problem solving instruction), or to different teacher styles, than to hemisphericity. Future studies will be necessary to resolve this issue.

When the standardized test scores of subjects were analyzed, it was found that the left hemisphere dominant students consistently

out performed the right hemisphere dominant students in the areas of reading, mathematics problem solving, and science. This result led to the conclusion that standardized tests in the areas specified examine left-hemisphere thinking more than right hemisphere thinking. The chemistry grades of the subjects did not lend themselves to statistical analysis because the distribution of grades in one of the schools involved in the study did not approach a normal distribution. Hence, no conclusions could be drawn relative to the effect of laterality on performance in high school chemistry.

II. RECOMMENDATIONS FOR FUTURE RESEARCH

Although this study has suggested some answers to questions related to hemisphericity and problem solving strategies, it has raised several additional questions that suggest potential areas for future research. The first question raised by this investigation concerns the lack of agreement between the hemisphericity measures. It may be true that a dichotic listening test using real words instead of nonsense syllables, or a tachistoscopic viewing task involving pictures instead of words might correlate better with SOLAT. It is recommended that future studies involving the physiological measures used in this study be conducted while varying the material that is presented dichotically and tachistoscopically to determine if the type of stimulus presented has an effect on the correlation between the hemisphericity tests. Additionally, studies investigating the relationship between subjects' preferred perceptual styles, preferred laterality, and results of physiological

tests of hemisphericity should be conducted. Gilley (1975) developed a Multi-Modal Paired Associates Learning Test (MMPALT) for the determination of perceptual styles, i.e., whether subjects receive information in printed form, aurally, orally (interactively), visually, kinesthetically, or haptically. These styles were first postulated by French (1975). Cherry (1981) revised Gilley's instrument and added the olfactory perceptual style. It would be enlightening to determine whether an individual's perceptual style is related to cerebral dominance.

A second question that future investigations should address is whether requiring subjects to think aloud during the problem solving process affects their success. It is conceivable that talking--a left brain process--may interfere with the use of left brain functions in problem solving. On the other hand, students who would ordinarily utilize right brain functions are forced into a left brained mode of thinking because they are required to think aloud. Future studies that allow subjects to solve some problems aloud and others silently will provide answers to the questions raised above.

A third question raised by this study is whether high school chemistry students, as a group, are different from other groups of students. Since chemistry is not a required subject, chemistry students may be more similar than students in an English class or history class. Studies in which students from English classes or art classes serve as subjects may yield results that are different from the results of this investigation. To address these issues, future studies should be conducted in which classes other than

chemistry classes are used for the investigation. English classes, mathematics classes, or foreign language classes should be tested for hemisphericity and given a problem solving task to determine if the results are similar to this study involving chemistry students.

Fourth, the question of the effect of school environment upon SOLAT is raised. Since the subjects in this study demonstrated a strong relationship between school and hemisphericity, it would be interesting to see if other studies involving multiple schools show a similar relationship between SOLAT score and school attended. If this is the case, educators should be aware of how a student's learning style is shaped by the school environment.

Finally, the question of the effects of sex and race on hemisphericity need to be explored more fully in studies that have larger sample populations. If true differences exist, they will probably not be uncovered until studies with subjects numbering in excess of one hundred are conducted.

III. IMPLICATIONS FOR TEACHING

The results of this investigation suggest that high school chemistry students' problem solving strategies are affected by their preferred mode of thinking (i.e. right hemispheric mode or left hemispheric mode), but they are flexible enough to use different modes of thinking when engaged in problem solving activities. This implies that teachers should be instructing students in a variety of problem solving methods, including both heuristic and algorithmic methods. Students should be encouraged to use the method that comes

naturally to them, and should not be forced to use an algorithmic method when they are more comfortable and successful with heuristics. Instructors must be flexible enough to realize that there is always more than one correct way to solve a problem.

In a discussion of algorithmic vs heuristic problem solving strategies, it was pointed out to this investigator by one member of her Doctoral Committee that any novel problem must be solved initially by heuristics before an algorithmic solution can be developed. For example, the search for a unification theory of forces can not use an algorithmic approach because none exists. On a smaller scale, this phenomenon may be responsible for the difficulty experienced by problem solvers when they are faced with a problem that is new to them. Students who are trained extensively in the use of algorithms to solve problems are likely to be unsuccessful at finding solutions to problems that require creative heuristic solutions.

A second implication of this study is that the hemisphericity or degree of lateralization of students cannot be glibly inferred from the race or sex of the student. The current investigation does not confirm reports that constantly appear in the popular literature claiming that women are less lateralized than men, or men are more left-brained than women. These statements are often misinterpreted to mean that males are more suited to subjects such as mathematics or science---subjects thought to require more left hemispheric thinking. However, Wittrock (1980) offers the following admonition to those who would use hemisphericity data in this manner:

Although as groups, men, women, left-handers, and right-handers sometimes differ in cognitive proficiency and in the ways they process information, the groups also overlap substantially in cognitive proficiency and in methods of processing information. One educational implication of these findings is that although some individuals will be more proficient than others at academic learning, students should not, by reason of sex or handedness, be discouraged from the pursuit of any academic subject matter taught in schools.

A third implication of this study is that educators should work to construct tests that are less partial to students who are left hemisphere dominant. Tests that require students to reproduce material verbatim to that presented in a lecture or in a textbook favor the student who is proficient at linear information processing. On the other hand, tests that allow for open ended responses and encourage creativity in answers favor students who process information holistically. It should be possible to incorporate both types of questions into course examinations so that students are encouraged to do both types of thinking.

Developers of standardized tests are already beginning to incorporate the results of hemisphericity studies into test construction. Herbert (1982) reports that a new intelligence test, the Kaufman Assessment Battery for Children (KABC) was developed by Alan and Nadeen Kaufman for the American Guidance Service, an educational publisher. The Kaufmans, both psychologists at the California School of Professional Psychology in San Diego, claim that the KABC is the only existing intelligence test to draw on recent advances in neuropsychological research. The test was designed to measure mental processing, and is referred to by the publishers as a "revolutionary new way to measure intelligence." There are some

tasks on the test that measure ability to process information, sequentially, and other tasks that measure simultaneous reasoning ability. Although the test has yet to undergo extensive validity and reliability testing and is viewed skeptically by many members of the testing community, it is nevertheless the first attempt to incorporate hemisphericity into standardized testing. Other attempts are likely to follow.

A fourth implication of this investigation is that student self-report data concerning hemisphericity or learning style should not be interpreted as indicative of the actual learning style of the student. The findings in this study support those of Cherry (1981) that physiological indications of learning style preference do not correlate well with subjects' responses to questionnaire items. Therefore it is an unsound educational practice for teachers to individualize instructional strategies based on students' reports of their own learning style. The recommendation by Dunn and Dunn that teachers should "allow each youngster to analyze his own learning style" (1972, p. 30) as a first step in individualizing instruction should be viewed with caution. An individualized program developed from false premises will not increase learning.

Yet another implication of this investigation is that the overall school environment and individual teachers may influence hemisphericity by the teaching strategies they emphasize in their classes. Related to this idea is the potential effect of instructional materials used in the classroom on thinking styles of students. Textbooks that provide little opportunity for students to become

involved in kinesthetic learning activities may produce students who are forced to become more reliant on left-hemisphere information processing than on right-hemisphere processing. Textbook publishers should produce educational materials that allow students to use a variety of perceptual styles during the process of acquiring information.

Still another implication is that there is an urgent need to develop more valid and reliable methods of determining cerebral dominance. The poor agreement between the measures used in this investigation attest to the inadequacy of the methods currently used to determine cerebral dominance. Educators are very anxious to apply the information recently made available in the brain sciences to instructional practice. More effective and efficient measuring instruments are necessary to make this a reality.

A final implication of this study is that research in the area of hemisphericity is not likely to provide a panacea for the problems that are facing education today. Brain researchers may provide information that can be used to aid curriculum developers, but this information should not overshadow the fact that each learner is an individual whose individual characteristics must be considered in any teaching/learning situation.

BIBLIOGRAPHY

BIBLIOGRAPHY

- Atkin, Julia. An Information-Processing Model of Learning and Problem Solving. Unpublished Ph. D. Thesis, Cornell University, 1977.
- Ausubel, D. P., J. D. Novak, and H. Hanesian. Psychology: A Cognitive View. New York: Holt, Rinehart, and Winston, 1978.
- Bakan, P., and F. F. Strayer. "On Reliability of Conjugate Lateral Eye Movements." Perceptual and Motor Skills, 36: 429-430, 1973.
- Berlin, C. I., L. F. Hughes, S. S. Lowe-Bell, and H. L. Berlin. "Dichotic Right Ear Advantage in Children 5 to 13." Cortex, 9: 394-401, 1973.
- _____, S. S. Lowe-Bell, J. K. Cullen, C. L. Thompson, and C. F. Loovis. "Dichotic Speech Perception: An Interpretation of the Right Ear Advantage and Temporal Offset Effects." Journal of the Acoustical Society of America, 53: 699-709, 1973.
- _____, and M. R. McNeil. "Dichotic Listening." In N. J. Lass, ed. Contemporary Issues in Experimental Phonetics. Springfield, IL: Charles C. Thomas, 1976.
- Bogen, J. E. "Some Educational Aspects of Hemisphere Specialization." U. C. L. A. Educator, 17: 24-32, 1975.
- Borrowy, T., and R. Goebel. "Cerebral Lateralization in Speech: The Effects of Age, Sex, Race, and Socioeconomic Class." Neuropsychologia, 14: 363-370, 1976.
- Bourne, L. E., R. R. Dominowski, and E. F. Loftus. Cognitive Processes. Englewood, NJ: Prentice-Hall, Inc., 1979.
- Bradshaw, J. L., N. C. Nettleton, and M. J. Taylor. "The Use of Laterally Presented Words in Research into Cerebral Asymmetry: Is Directional Scanning Likely to be a Source or Artifact?" Brain and Language, 14: 1-14, 1981.
- Briggs, G. G., and R. D. Neves. "The Effect of Handedness, Family History, and Sex on Performance of a Dichotic Listening Task." Neuropsychologia, 14: 129-134, 1976.
- Broadbent, D. E. "Successive Responses to Simultaneous Stimuli." Quarterly Journal of Experimental Psychology, 8: 145-152, 1956.
- Brown, J. W., and J. Jaffe. "Hypotheses on Cerebral Dominance." Neuropsychologia, 13: 107-110, 1975.

- Bryden, M. P. "Left-Right Differences in Tachistoscopic Recognition: Direction Scanning or Cerebral Dominance?" Perceptual and Motor Skills, 23: 1127-1134, 1966.
- Buffery, A. W. H., and J. A. Gray. "Sex Differences in the Development of Spatial and Linguistic Skills." In C. Ounsted and D. C. Taylor, eds. Gender Differences: Their Ontogeny and Significance. Edinburgh: Churchill Livingstone, 1972.
- Caplan, B., and M. Kinsbourne. "Cerebral Lateralization, Preferred Cognitive Mode and Reading Ability in Normal Children." Brain and Language, 14: 349-370, 1981.
- Carr, B. M. "Ear Effect Variables and Order of Report in Dichotic Listening." Cortex, 5: 63-68, 1969.
- Cherry, Clarence E. The Measurement of Adult Learning Styles: Perceptual Modality. Unpublished Doctoral Dissertation, The University of Tennessee, Knoxville, 1981.
- Coltheart, M., and B. Arthur. "Tachistoscopic Hemifield Effects with Hemifield Report." American Journal of Psychology, 84: 355-364, 1971.
- Crocker, A. C. Statistics for the Teacher. New York: Humanities Press, Inc., 1974.
- Davis, G. A. Psychology of Problem Solving. New York: Basic Books, 1973.
- DeBono, Edward. The Use of Lateral Thinking. London: Jonathan Cape Publishers, 1967.
- Dorman, M. F., and D. S. Geffner. "Hemispheric Specialization for Speech Perception in Six Year Old Black and White Children from Low and Middle Socioeconomic Classes." Cortex, 10: 171-176, 1974.
- Dunn, Rita, and Kenneth Dunn. Practical Approaches to Individualizing Instruction: Contrasts and Other Effective Teaching Strategies. West Nyack, NY: Parker Publishing Co., Inc., 1972.
- Edwards, Betty. Drawing on the Right Side of the Brain. Los Angeles, CA: J. P. Tarcher, 1979.
- French, Russell L. "Individualization in Teacher Education: Some Thoughts and Assumptions. Unpublished paper, Department of Curriculum and Instruction, The University of Tennessee, 1980.
- _____. "Teaching Style and Instructional Strategy." Unpublished paper, Department of Curriculum and Instruction, The University of Tennessee, Knoxville, 1975.

- Gagne, Robert. "Learnable Aspects of Human Thinking." In A. E. Lawson, ed. The Psychology of Teaching for Thinking and Creativity. Columbus, OH: ERIC Clearinghouse for Science, Mathematics, and Environmental Education, 1979.
- Galín, D., and R. Ornstein. "Individual Differences in Cognitive Style I. Reflective Eye Movements." Neuropsychologia, 12: 367-376, 1974.
- Gazzaniga, M. S. "The Split Brain in Man." Scientific American, 210, No. 1: 42-52, 1964.
- Geschwind, N., and W. Levitsky. "Human Brain: Left-Right Asymmetries in Temporal Speech Region." Science, 161: 186-187, 1968.
- Getzels, J. W. "Creative Thinking, Problem Solving, and Instruction." Theories of Learning and Instruction: Sixty-Third Yearbook of the National Society for the Study of Education, Part I. Chicago, IL: University of Chicago Press, 1964.
- Gilley, Daryl V. Personal Learning Styles: Exploring the Individual's Sensory Input Processes. Unpublished Ed. D. Dissertation, The University of Tennessee, Knoxville, 1975.
- Greeno, J. G. "Indefinite Goals in Well-Structured Problems." Psychological Review, 83: 479-491, 1976.
- Guilford, J. P., and Benjamin Fruchter. Fundamental Statistics in Psychology and Education. New York: McGraw-Hill Book Co., 1978.
- Herbert, Wray. "Intelligence Test: Sizing Up a New Comer." Science News, 122: 280-281, 1982.
- Hines, D., and P. Satz. "Cross-Modal Asymmetries in Perception Related to Asymmetry in Cerebral Function." Neuropsychologia, 12: 239-247, 1974.
- Horning, J. K. "The Effects of Age on Dichotic Listening." Unpublished Master's Thesis, San Diego State College, 1972.
- Johnson, D. M. Systematic Introduction to the Psychology of Thinking. New York: Harper and Row, 1972.
- Kabanova-Meller, E. N. "The Role of the Diagram in the Application of Geometric Theorems." In J. Kilpatrick and I. Wirszup, eds. Soviet Studies in the Psychology of Learning and Teaching Mathematics. Vol. IV. Stanford, CA: School Mathematics Study Group, 1970.
- Khatena, J., and E. P. Torrence. Manual for Khatena-Torrence Creative Perception Inventory. Chicago, IL: Stoeling, 1976.

- Kimura, D. "Cerebral Dominance and Perception of Verbal Stimuli." Canadian Journal of Psychology, 15: 166-171, 1961.
- _____. "Dual Functional Asymmetry of the Brain in Visual Perception." Neuropsychologia, 4: 275-285, 1966.
- Kinsbourne, M. "Eye and Head Turning Indicates Cerebral Lateralization." Science, 176: 539-541, 1972.
- _____. "The Control of Attention by Interaction Between the Cerebral Hemispheres." In S. Kornblum, ed. Attention and Performance IV. New York: Academic Press, 1973.
- _____. "Cerebral Dominance, Learning, and Cognition." In H. R. Myklebust, ed. Progress in Learning Disabilities III. New York: Grune and Stratton, 1975.
- _____. "Language Lateralization and Developmental Disorders." In C. Ludlow and M. Doran-Quine, eds. Neurological Bases of Language Disorders in Children: Methods and Directions for Research. Bethesda, MD: NIH Publication #79-440, 1979.
- _____, and M. Hiscock. "The Development of Cerebral Dominance." In S. Segalowitz and F. A. Gruber, eds. Language: Developmental and Neurological Theory. New York: Academic Press, 1977.
- _____, and P. E. Hicks. "Functional Cerebral Space: A Model for Overflow, Transfer, and Interference Effects in Human Performance." In J. Requin, ed. Attention and Performance VII. Hillsdale, NJ: Lawrence Erlbaum Associates, 1979.
- Kleinfelter, David D., and Joseph R. Peterson. Study Guide/Workbook to Accompany Sixth Edition General College Chemistry and General College Chemistry with Qualitative Analysis. San Francisco: Harper and Row, 1980.
- Krashen, S. D. "Language and Left Hemisphere." Working Papers in Phonetics. 24: 85, 1972.
- Larkin, J. "Teaching Problem Solving in Physics: The Psychological Laboratory and the Practical Classroom." In D. T. Tuma and F. Reif, eds. Problem Solving and Education: Issues in Teaching and Research. Hillsdale, NJ: Lawrence Erlbaum Associates, 1980.
- Lenneberg, E. H. Biological Foundations of Language. New York: Wiley, 1967.
- McDermott, J., and J. Larkin. "Representing Textbook Physics Problems." In Proceedings of the 2nd National Conference of the Canadian Society for Computational Studies of Intelligence. Toronto: University of Toronto, 1978.

- Milner, B. "Brain Mechanisms Suggested by Studies of Temporal Lobes." In F. L. Dailey and C. H. Millikan, eds. Brain Mechanisms Underlying Speech and Language. New York: Grune and Stratton, 1965.
- Morais, J., and C. J. Darwin. "Ear Differences for Same-Different Reaction Times to Monaurally Presented Speech." Brain and Language. 1: 383-390, 1974.
- Newell, A., and H. A. Simon. Human Problem Solving. Englewood, NJ: Prentice-Hall, Inc., 1972.
- Ornstein, R. The Psychology of Consciousness, 2nd ed. New York: Harcourt Brace Jovanovich, 1977.
- Piaget, J. "Development and Learning." In R. E. Ripple and V. N. Rockcastle, eds. Piaget Rediscovered. Ithaca, NY: School of Education, Cornell University, 1964.
- Prince, G. "Putting the Other Half of the Brain to Work." Training: The Magazine of Human Resources Development. 15: 57-61, 1978.
- Rosen, J. J., F. Curcio, W. Mackavey, and J. Hebert. "Superior Recall of Letters in the Right Visual Field with Bilateral Presentation and Partial Report." Cortex, 11: 144-154, 1975.
- Rubinstein, Moshe. "A Decade of Experience in Teaching an Interdisciplinary Problem-Solving Course." In D. T. Tuma and F. Reif, eds. Problem Solving and Education: Issues in Teaching and Research. Hillsdale, NJ: Lawrence Erlbaum Associates, 1980.
- Saslow, M. "Latency for Saccadic Eye Movement." Journal of the Optical Society of America. 57: 1030-1033, 1976.
- Scandura, J. M. Problem Solving: A Structural/Process Approach with Instructional Implications. New York: Academic Press, 1977.
- Sperry, R. W. "The Great Cerebral Commisure." Scientific American. 210: 42-52, 1964.
- Springer, S. P., and G. Deutsch. Left Brain, Right Brain. San Francisco: W. H. Freeman and Co., 1981.
- Star, Susan L. "Sex Differences and the Dichotomization of the Brain: Methods, Limits, and Problems in Research on Consciousness." In R. Hubbard and M. Lowe, eds. Genes and Gender: Pitfalls in Research on Sex and Gender. New York: Gordian Press, 1979.
- Torrence, E. Paul, and Saburo Sato. "Differences in Japanese and United States Styles of Thinking." Creative Child and Adult Quarterly. 4: 145-151, 1979.

- Torrence, E. P., and C. R. Reynolds. "Images of the Future of Gifted Adolescents: Effects of Alienation and Specialized Cerebral Functioning." Gifted Child Quarterly. 22: 40-54, 1978.
- _____. Norms-Technical Manual for Your Style of Learning and Thinking--Form C. Athens, GA: University of Georgia, Department of Educational Psychology, 1980.
- Tuma, D. T., and F. Reif. Problem Solving and Education: Issues in Teaching and Research. Hillsdale, NJ: Lawrence Erlbaum Associates, 1980.
- Wada, J., and T. Rasmussen. "Intracarotid Injection of Sodium Amytal for the Lateralization of Cerebral Speech Dominance." Journal of Neurosurgery. 17: 266-282, 1960.
- Wheatley, Grayson. "The Right Hemisphere's Role in Problem Solving." Arithmetic Teacher. 48: 36-39, 1977.
- Whimbey, Arthur, and J. Lockhead. Problem Solving and Comprehension: A Short Course in Analytical Reasoning. Philadelphia: The Franklin Institute Press, 1980.
- Wilson, G. Hemispheric Dominance and Student Performance in an Engineering Graphics Course. Unpublished Doctoral Dissertation, The University of Tennessee, Knoxville, 1982.
- Witelson, S. F., and Pallie W. "Left Hemisphere Specialization for Language in the Newborn: Neuroanatomical Evidence of Asymmetry." Brain. 96: 641-646, 1973.
- Wittrock, M. C. The Brain and Psychology. New York: Academic Press, 1980.

APPENDIXES

APPENDIX A

SAMPLES OF DATA COLLECTION FORMS

AND CONSENT LETTERS

Subject Profile

Name: _____ School: _____

Grade: _____

Birthdate: _____ Age: _____

Sex: _____ Race: _____

Chemistry Teacher: _____

Home Address: _____ Phone: _____

List of high school science courses already taken (including chemistry):

- | | |
|----|----|
| 1. | 2. |
| 3. | 4. |

How would you describe your experience with problem solving? Circle one.

- | | |
|-----------------------------|---------------------------|
| A. Success and Enjoyment | B. Success but Dislike |
| C. Difficulty but Enjoyment | D. Difficulty and Dislike |

List your hobbies below.

- 1.
- 2.
- 3.

Briefly discuss your favorite subjects in school and tell why they are your favorite.

Signature: _____ Date: _____

THE UNIVERSITY OF TENNESSEE
KNOXVILLE 37916
COLLEGE OF EDUCATION

DEPARTMENT OF
CURRICULUM AND INSTRUCTION

March 25, 1982

Dear Student:

This research activity involves a study of the problem solving behaviors of chemistry students. If you agree to participate in this study, it will be necessary for you to meet with the researcher on three or four occasions during a free period in your school day. You will be asked to complete two questionnaires, to undergo two tests involving viewing and listening (the details will be explained verbally), to solve five problems in the presence of the researcher, and to allow the researcher to have access to some of your school records. The purpose of the study is to determine whether the problem solving techniques used by high school chemistry students are related to the students' preferred way of thinking.

There are no anticipated risks or discomforts to you. All of the information that is obtained from you will be kept confidential.

Your participation in this study is voluntary, and you may remove yourself from the study at any time you would like. Refusal to participate or dropping out of the study will involve no penalty or loss of benefits to you.

If you have any questions regarding this research, you may contact the researcher named below at any time.

Saundra Y. McGuire, Doctoral Candidate
Department of Curriculum and Instruction
The University of Tennessee
Knoxville, TN 37996
Phone: 974-4161 - Work
691-7937 - Home

Please sign this form in the space below if you agree to participate in this study.

I, _____, agree to participate in
(please print)
the research project described above. I understand that my participation is voluntary and that I can discontinue my enrollment at any time.

(signature)

/pc

THE UNIVERSITY OF TENNESSEE
KNOXVILLE 37996-3400
COLLEGE OF EDUCATION

DEPARTMENT OF
CURRICULUM AND INSTRUCTION

March 24, 1982

Dear Parent:

A research project involving the learning styles and problem solving techniques of high school chemistry students is being conducted by Saundra McGuire, a Ph.D. candidate at The University of Tennessee. The study is under the direction of Professor A. Paul Wishart in the College of Education. The study will involve asking your son/daughter to identify sounds presented on a tape, identify words and pictures presented on slides, solve word problems, answer some questions about how he/she learns best, and provide the researcher access to some school records. The purpose of the study is to determine whether problem solving techniques used by high school chemistry students are related to the students' preferred way of thinking. It is hoped that the results from this and similar studies can be used to improve chemistry instruction in high schools.

There are no anticipated risks or discomforts to the students who agree to participate in the study, and all of the information that is obtained from students will be kept confidential. Participation in the study is voluntary, and students may drop out of the study at any time. Refusal to participate or dropping out of the study will not involve a penalty to any students.

If you will allow your son/daughter to participate in the study, please sign one copy of this letter and return it to school. If you have any questions regarding this research, you may contact the researcher at any time by calling the numbers listed below. Thank you very much for your cooperation.

Saundra M. McGuire, Ph.D. Candidate
Department of Curriculum and Instruction
The University of Tennessee
Knoxville, TN 37996
974-4161 (Work)
691-7937 (Home)

I, _____, agree to allow my son/daughter
(please print)
_____, to participate in the research project
(student's name)
described above.

(parents signature)

/pc

DICHOTIC LISTENING TASK

ANSWER SHEET

Name _____

Date _____

Please write the name of the sound you hear most clearly in the space provided. The possible sounds are TA, BA, GA, PA, DA, and KA.

- | | | |
|-----------|-----------|-----------|
| 1. _____ | 21. _____ | 41. _____ |
| 2. _____ | 22. _____ | 42. _____ |
| 3. _____ | 23. _____ | 43. _____ |
| 4. _____ | 24. _____ | 44. _____ |
| 5. _____ | 25. _____ | 45. _____ |
| 6. _____ | 26. _____ | 46. _____ |
| 7. _____ | 27. _____ | 47. _____ |
| 8. _____ | 28. _____ | 48. _____ |
| 9. _____ | 29. _____ | 49. _____ |
| 10. _____ | 30. _____ | 50. _____ |
| 11. _____ | 31. _____ | 51. _____ |
| 12. _____ | 32. _____ | 52. _____ |
| 13. _____ | 33. _____ | 53. _____ |
| 14. _____ | 34. _____ | 54. _____ |
| 15. _____ | 35. _____ | 55. _____ |
| 16. _____ | 36. _____ | 56. _____ |
| 17. _____ | 37. _____ | 57. _____ |
| 18. _____ | 38. _____ | 58. _____ |
| 19. _____ | 39. _____ | 59. _____ |
| 20. _____ | 40. _____ | 60. _____ |

TACHISTOSCOPIC VIEWING EXERCISE

ANSWER SHEET

Name _____

Date _____

Please write the word that you see on the screen in the space provided for each trial.

- | | |
|-----------|-----------|
| 1. _____ | 26. _____ |
| 2. _____ | 27. _____ |
| 3. _____ | 28. _____ |
| 4. _____ | 29. _____ |
| 5. _____ | 30. _____ |
| 6. _____ | 31. _____ |
| 7. _____ | 32. _____ |
| 8. _____ | 33. _____ |
| 9. _____ | 34. _____ |
| 10. _____ | 35. _____ |
| 11. _____ | 36. _____ |
| 12. _____ | 37. _____ |
| 13. _____ | 38. _____ |
| 14. _____ | 39. _____ |
| 15. _____ | 40. _____ |
| 16. _____ | 41. _____ |
| 17. _____ | 42. _____ |
| 18. _____ | 43. _____ |
| 19. _____ | 44. _____ |
| 20. _____ | 45. _____ |
| 21. _____ | 46. _____ |
| 22. _____ | 47. _____ |
| 23. _____ | 48. _____ |
| 24. _____ | 49. _____ |
| 25. _____ | 50. _____ |

FORM C
YOUR STYLE OF LEARNING AND THINKING

INSTRUCTIONS: On the answer sheet provided, describe your style of learning and thinking by blackening the appropriate blanks. Try to describe your strengths and preferences as accurately as possible.

1. (a) read for main ideas
(b) read for specific details and facts
(c) read for main ideas and for details and facts equally.
2. (a) usually learn or remember only those things specifically studied
(b) good memory for details and facts in the environment not specifically studied
(c) have noticed no difference in my abilities in these areas.
3. (a) like to read fantasy stories
(b) like to read realistic stories
(c) no preference between fantasy and realistic stories.
4. (a) equally as much fun to dream as to plan realistically
(b) more fun to dream
(c) more fun to plan realistically.
5. (a) solve problems logically, rationally
(b) solve problems intuitively
(c) equally skilled in solving problems intuitively and logically.
6. (a) listen to music or radio while reading or studying
(b) must have total quiet in order to read or study
(c) listen to music or radio only if reading for enjoyment, not if studying.
7. (a) would like to write fiction books
(b) would like to write non-fiction books
(c) No preference between writing fiction and non-fiction.
8. (a) if seeking mental health counseling, would prefer group counseling and sharing of feelings with others.
(b) if seeking mental health counseling, would prefer the confidentiality of individual counseling
(c) have no preference for group over individual counseling.

9. (a) enjoy drawing my own images and ideas
(b) enjoy copying and filling in details
(c) enjoy drawing my own images and copying and filling in equally.
10. (a) believe I would be easily hypnotized
(b) could probably be hypnotized but it would be difficult
(c) do not believe I could be hypnotized.
11. (a) just as exciting to me to improve something as to invent something new
(b) more exciting to improve something
(c) more exciting to invent something new
12. (a) prefer to learn through free exploration
(b) prefer to learn systematically through ordering and planning
(c) no preference between learning through free exploration and learning through more systematic ways.
13. (a) no preference between mystery stories and action stories
(b) prefer action stories
(c) prefer mystery stories.
14. (a) no preference between algebra and geometry
(b) prefer algebra
(c) prefer geometry.
15. (a) like to organize things sequentially
(b) like or organize things to show relationships
(c) no preference for sequential over relational organization.
16. (a) skilled in sequencing ideas
(b) skilled in showing relationships among ideas
(c) equally skilled in sequencing and showing relationships
17. (a) good at remembering verbal materials
(b) good at tonal memory
(c) equally good at verbal and tonal memory.
18. (a) paces personal activity to time limits with ease
(b) uses time to organize self and personal activities
(c) has difficulty in pacing personal activities to time limits.
19. (a) have frequent mood changes
(b) have few mood changes
(c) stable; almost no mood changes.
20. (a) skilled in communicating with animals
(b) moderately good in communicating with animals
(c) cannot communicate very well with animals.

21. (a) no preference for cats over dogs or vice versa
(b) preference for cats
(c) preference for dogs.
22. (a) enjoy clowning around
(b) can clown or be serious depending upon the occasion
(c) do not enjoy clowning around.
23. (a) conforming or nonconforming depending upon the situation
(b) generally conforming
(c) generally nonconforming.
24. (a) frequently somewhat absentminded
(b) occasionally absentminded
(c) almost never absentminded.
25. (a) no preference for well structured over openended assignments
(b) preference for openended assignments
(c) preference for well structured assignments.
26. (a) when viewing advertisements, am most often influenced by attractive signs, pleasant scenes, and sensual overtones
(b) when viewing advertisements, am most often influenced by the information comparing several products
(c) primarily influenced by the advertising medium only when accompanied by information on the quality of the product.
27. (a) enjoy analyzing stories
(b) enjoy creative storytelling
(c) enjoy equally analyzing stories and creative storytelling.
28. (a) equally valuable to discuss stories and illustrate them
(b) more valuable to discuss stories read
(c) more valuable to illustrate stories read.
29. (a) equally valuable to tell stories and to act out stories
(b) more valuable to tell stories
(c) more valuable to act out stories.
30. (a) moving rhythmically and rhyiming are equally enjoyable
(b) moving rhythmically is more fun
(c) rhyiming is more fun.
31. (a) producing ideas and drawing conclusions are equally enjoyable
(b) drawing conclusions is more fun
(c) producing ideas is more fun.

32. (a) would like to do interpretative dancing
(b) would like to do ballet dancing
(c) no preference for ballet over impromptu interpretative dancing.
33. (a) enjoy interacting affectively with others
(b) enjoy interpreting the affective interaction of others
(c) equal preference for affective interaction and interpretation of the affective interaction of others.
34. (a) strong in recalling verbal materials (names, dates, etc.)
(b) strong in recalling spatial imagery
(c) equally strong in recalling verbal and spatial imagery.
35. (a) can think better while lying down
(b) can think better while sitting up straight
(c) equal preference for lying down and sitting up straight.
36. (a) would like to be a music critic
(b) would like to be a music composer
(c) would enjoy equally music criticism and composition.
37. (a) skilled in the intuitive prediction of outcomes
(b) skilled in the statistical, scientific prediction of outcomes
(c) equally skilled in intuitive and statistical-scientific prediction.
38. (a) generally attentive to verbal explanations
(b) generally restless during verbal explanations
(c) can control attention during verbal explanations.
39. (a) no preference between outlining and summarizing readings
(b) preference for outlining over summarizing
(c) preference for summarizing over outlining.
40. (a) no preference for demonstration over verbal instructions
(b) prefer demonstration
(c) prefer verbal instructions.

SCORING KEY FOR SOLAT FORM C

<u>Item</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Item</u>	<u>A</u>	<u>B</u>	<u>C</u>
1	R	L	I	21	I	R	L
2	L	R	I	22	R	I	L
3	R	L	I	23	I	L	R
4	I	R	L	24	R	I	L
5	L	R	I	25	I	R	L
6	R	L	I	26	R	L	I
7	R	L	I	27	L	R	I
8	R	L	I	28	I	L	R
9	R	L	I	29	I	L	R
10	R	I	L	30	I	R	L
11	I	L	R	31	I	L	R
12	R	L	I	32	R	L	I
13	I	L	R	33	R	L	I
14	I	L	R	34	L	R	I
15	L	R	I	35	R	L	I
16	L	R	I	36	L	R	I
17	L	R	I	37	R	L	I
18	I	L	R	38	L	R	I
19	R	I	L	39	I	L	R
20	R	I	L	40	I	R	L

PROBLEM SOLVING STRATEGY

ANALYSIS SHEET

Name _____

[illegible]

APPENDIX B

THE PROBLEM SET AND PROBLEM SOLVING PROTOCOLS

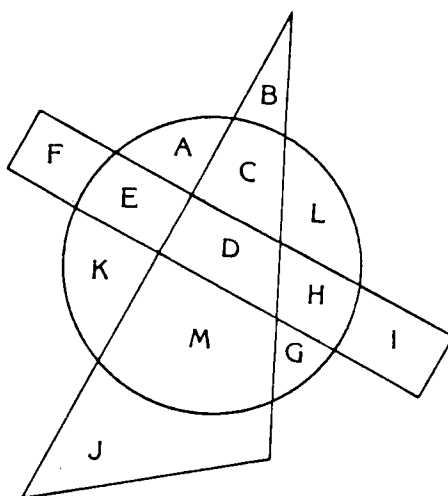
THE PROBLEM SET

1. A man who is looking at a picture says the following:

"Brothers and sisters have I none, but that man's father is my father's son."

Who is the man in the picture?

2. If Element B and Element D are both more active than Element C, while Element A is less active than Element B but more active than Element D, which element is the least active and which one is the second least active--or can this not be determined from the information?
3. One tree is 7 times as old as another. Five years from now it will be four times as old. What are the present ages of the trees?
4. On the Celcius temperature scale, the freezing point of water is 0°C and the boiling point of water is 100°C . If a new temperature scale were created on which the freezing point of water was defined as 200 U and the boiling point of water as 600 U, what would be the equivalent of 25°C on this scale?
5. A problem that deals with spatial visualization skills will be used. In working this problem, consider the diagram to be made up of 3 major geometrical figures. 1. a triangle; 2. a circle; and 3. a rectangle. How many letters are in exactly 2 (but not 3) of these figures?



PROTOCOL OF
HEURISTIC PROBLEM SOLVER

Problem 1

Subject: (Reads problem aloud). Thinking.

Investigator: Are you rereading the problem, too?

(Note) Hereafter the subject will be designated by the letter S, and the investigator will be designated by the letter I.

S: Uh, huh, rereading the problem. (Seven second pause) Is it the son?

I: How did you get that?

S: (Pause)

I: Now what was your answer?

S: Is the father's son?

I: Is who the father's son?

S: His father?

I: Wait. You said is he the son? Did you mean is the man in the picture his son?

S: Yes.

I: Yes, that's correct. How did you get that?

S: I, uh, just...I don't know... It, you know, just came to me I guess. It says "but that man's father is my father's son and brothers and sisters I have none." So that man's father must be the father's son, I guess. (Laugh) I don't know how I did it. It just came to me I guess.

I: O.K. That's fine.

Problem 2

S: (Reads problem aloud). Rereading.

I: O.K.

S: (After 11 second pause) Is, uh, C the least active and D is the second least active?

I: Yes. How did you get that?

S: Let's see. B is the strongest because, let's see...B and D are both more active than C, and A is less active than B but it's more active than D. So it has to be...C is already left out, and D is after that.

I: O.K. Very good...Would it have occurred to you to write down the relationships individually or did you just see them?

S: I just saw it in my mind.

I: O.K.

Problem 3

S: (Reads problem aloud). Rereading problem. I think I'll write this one down.

I: O.K. (After 14 second pause) What are you doing now?

S: A little algebra.

I: Oh, O.K.

S: (Mumbles) That'll be 4 times as old.

I: Talk a little bit louder even when you're thinking.

S: Oh, O.K. Five years from now it will be 4 times as old... So $7x + 5$ is its present age right now. I meant $7x$ is its age right now. Five years from now it'll be four times as old, right?

I: Right.

S: This might take a little longer.

I: O. K.

S: As you can see I'm weak in word problems.

I: Well, the other two problems that you just did were word problems. I wouldn't say you're weak in word problems.

S: (Continues to try to solve problem algebraically).

I: Is that an algebraic equation?

S: Yes. Somehow, uh, I didn't get it right. That's wrong. No, oh no, no, no. (After 4 second pause) Is one of them 35 and the other one 5?

I: O.K. How did you get that?

S: Is that right?

I: Yes that's right.

S: Uh, right here it said...It took me a little while, but right here it says 5 years from now it'll be four times as old. I made a mistake and put the seven right there and timesed it by four, which I wasn't supposed to do. So it'll be 4x right there (Subject is pointing to equation he has written.) And when you move that over it'll be 3x and that'll be 15 and that'll be 5. 5 times 7 is 35.

I: Oh, O.K. Now when you started with the algebraic equation and that didn't work, you came up with 5 and 35. When you were getting the answer did you change your algebraic equation and solve that first, or did the numbers 5 and 35 come to mind and then you saw how you had to change your equation to get 5 and 35?

S: No, I changed that first (pointing to equation).

I: You changed the algebraic equation first?

S: Yeah.

I: O.K. Fine.

Problem 4

S: (Reads problem aloud). Uh, let's see. Rereading. (Subject then begins to draw a diagram). This is trial and error right here.

I: O.K.

S: Um. Naw. That couldn't be right.

I: What had you tried?

S: Uh. I don't even know what it is. I was just trying something to be trying it.

I: But what did you try?

S: Uh. I changed 200 by 0.25 for some reason. But it wouldn't have come out right.

I: O.K. Do you know why you were using 0.25?

S: No. Just something said use 0.25. That's all.

I: O.K. Well, 0.25 does have something to do with solving that problem.

S: (Perks up.) Oh, it does?

I: Yes

S: 0.25. Uh, hmm.

I: Well let me ask you this. If I asked you to just guess at the answer, what would you guess it would be?

S: Between 200 and 600 (laughter).

I: Which would be what?

S: I'm doing it now. (9 second pause) Fifty, no that ain't right. Oh, I messed up. Excuse me. I doubt that's right too. (Subject points to his multiplication.)

I: No, the first one you had was right in terms of multiplication. It was 150.

S: It was?

I: Yes.

S: And then you have to subtract it from that?

I: No, I'm not saying that was the right answer. You changed that to 420. Why did you change that to 420.

S: Because I made a mistake in multiplication.

I: No you didn't.

S: I didn't?

I: No, that's what I was saying. You hadn't made a mistake the first time. When you multiply that, you do get 150. (Subject had multiplied 0.25 times 600.)

S: Alright.

- I: When you got 150 you said "No, that's not right." How did you know that's not right?
- S: It just don't seem right. But is it?
- I: No. And remember you told me that it had to be between 200 and 600 didn't you?
- S: Right...If I add it on to there it'll be more than the 1/4 though.
- I: O.K. Does 1/4 keep coming back to mind?
- S: Yes. I get the same thing if I divide 4 into that (600). For some reason I'm not thinking... What is U?
- I: It's just a name for the temperature scale. It could stand for Uranus or something else. It's just a name for the scale.
- S: It's got me baffled right now.
- I: O.K. Let's go back to having you guess again. You had told me it would be between 200 and 600. Can you narrow it down any more than that?
- S: About 350. I mean not 350, about 300.
- I: O.K. Now how did you get 300?
- S: Let's see. (Pause)
- I: First you said 350, and then you said "no, not 350, about 300. Now what made you..
- S: 350 might be right, but then again 300 might be right. I don't know.
- I: What made you say "not 350, no 300."
- S: It just didn't seem right to me. Is that right, though, 350?
- I: No. Did 300 seem right?
- S: It seemed better.
- I: O.K. Yes. 300 is the right answer.
- S: Ah ha.
- I: Given that 300 is the right answer can you tell me why that's the right answer?

S: Wait a minute. (Starts to write). It might be a fourth of it. Is that a fourth of it? (Pointing to the U temperature scale.)

I: Yes.

S: I was going to do that later on after I had guessed 300.

I: I see. (Proceeds to explain problem to subject.)

Problem 5

S: (Looks at problem) Is this geometry?

I: You could say that I guess, but not really.

S: Oh Lord. (Reads problem aloud.) (After 3 second pause) In exactly two of them? M and C and E and H. That's it. One, two, three, four. Four?

I: Right. Please write those down. Thank you very much.

The subject subsequently told the investigator that he did not like geometry because of the proofs of theorems. He said he could understand the relationships but had difficulty with the proofs. He told the investigator "It's easier for me to just look at it and tell."

PROTOCOL OF
ALGORITHMIC PROBLEM SOLVER

Problem 1

S: (Reads problem aloud) I'll read it again.

I: O.K.

S: Right now I'm just trying to figure out the relationships.

I: O.K.

S: Well, I figured it out. I, un, I know that it was a riddle using, uh, words . . . they're trying to throw me off here. But, uh, you want me to tell the answer?

I: Yes.

S: Uh, the man in the picture is the guy who's talking. Because the man in the picture's father is . . . No, wait a minute, I'm wrong.

I: What keyed you off to the fact that you were wrong?

S: Because the picture is the man's father and not him so . . . so the man in the picture is his son. That's right.

I: How did you get that? I'm not saying that's right or wrong, but I want to know how you arrived at that answer.

S: Because...well, I figured out first of all that...uh... obviously at the end "my father's son" means himself because he doesn't have any brothers or sisters. So all I have to do is figure out "that man's father" what that means. And so because whoever that man's father is ill correspond to the last part and since I figured out that the last part's himself then that man's father is gonna be himself. So that man has gotta be his own son.

I: Yes, that is the correct answer. I noticed you didn't write anything down. Was it easy for you to visualize the relationships?

S: Yeah. But I got it wrong at first because I just thought it was right without thinking about it too much. I thought it was easier than it was.

I: O.K. Good.

Problem 2

S: (Reads problem aloud) I'm just gonna read it again. O.K.
I'm gonna write down, uh, what this is saying. What I know for sure...what's given...by using equal signs.

I: O.K.

S: O.K. I figured it out. I wrote down just that B and $D > C$, and $D < A$, and $A < B$. So, I figured out that C is less active than everything, so C is the least active because at the very beginning we know that D is more active than C . But at the same time it's less active than A , which is less active than B . So D is less active than A and B but it's more active than C , so C is gonna be the least active and D is gonna be the second least active, and then A and then B .

I: O.K. Good.

Problem 3

S: (Reads problem aloud) I'm gonna read it again and try to write down an equation, or write down what it's actually gonna be saying here.

I: O.K.

S: (After 15 second pause) O.K. I'm gonna write down the equation assigning, uh, the first three they talk about as x and the second tree as y . So $x = 7y$ because the first three is seven times as old as the other. Then I'm gonna say $x + 5 = 7y + 5$ because you can add 5 years to both of those. Oh no. O.K. Wrong. (Scratches out this equation) I'll write a new equation saying $x + 5$ equals (pause) ...So my second equation is gonna be $x + 5 = 4y + 5$ (Seems unsure).

I: O.K. You seem to have doubts.

S: Well, I'm just trying to figure... What I'm trying to figure out is 5 years from now it'll be four times as old. Does that mean that five years from now the first tree will be four times older than the second tree is now or the second tree is five years from now?

I: Five years from now.

S: O.K.

I: So you're thinking of both of them five years from now?

- S: Now I'm thinking that something is wrong with my second equation so I'm just kinda thinking in my head and plugging in numbers to see what I can do.
- I: O.K.
- S: (After 48 second pause) O.K. I'm just testing running through the second equation to see if I'm gonna get anywhere.
- I: O.K.
- S: Now what I did...I don't know if it's right yet, but what I did was I wrote my second equation and then I plugged in what I knew from my first equation. Since $x = 7y$ I plugged in $7y$ for x . And I've got an answer but I don't know if it's right so I'm gonna go back and check it.
- I: O.K.
- S: O.K. I've got it right. I'm saying that, uh, the tree that's seven times as old as the other is going to be 35 years old, and the tree that's younger is gonna be five. So, in five years the first tree will be 40 years old, and the second tree will be ten years old, and so 40 is 4 times 10.
- I: After you had written down your second equation for the first time, and it looked strange to you. . . .
- S: Yeah. What I had down was, uh, $x + 5 = 4y + 5$ and I knew that couldn't be right because all I had to do was mark out the $+5$'s and that couldn't be right. So then I thought back and I just kinda analyzed the problem and I realized that, uh, it's gonna be 4 times parentheses $x+5$ because when I plugged in the numbers in my head just as an example to myself and I realized it was gonna be, uh, 4 on the outside, $4(x+5)$. So I got the equation right and I plugged in $7y$ for x and solved for y and got y , and then got x .
- I: Do you remember which number you plugged in when you just started plugging in numbers?
- S: Yes. I said that if $x = 7$, then y will equal 1. I just said the easiest one that would come to my mind. Then I said then if $7 + 5 = 12$ and I tried to figure out, uh, the second part of the equation by, uh, I don't remember, but I was just trying to see what was gonna be right. I hadn't realized that I wasn't gonna add 5 after I multiplied it by four, I was gonna add it before I multiplied by four. And by plugging it in I realized that.

- I: O.K. So, in other words you started working the problem by one method and when that didn't work you switched to another method. Then in the process of working it by the second method, you realized what was wrong with the first method. Is that right?
- S: Well, I just more or less brainstormed. I wrote down the first equation which I thought. But I knew that it was pretty much right but it wasn't exactly right so I experimented to see if it was gonna be right or not. And then after I made it right, it was pretty much right, all I needed was the parentheses, I just solved the equations.
- I: O.K. Good.

Problem 4

- S: (Reads problem aloud) O.K. I'll just look over the problem again. And then I'll figure out that on 0 to 100, 25 is gonna be a fourth of the way from 0 to 100, or 0.25. Then all I have to do is figure out the difference between 200U and 600U, which is 400, and uh, multiply by $1/4$ or 0.25 to find the difference between, uh, 200 and the number I'm trying to find. And, uh, so that's gonna be equal to 100, so the answer is gonna be 300U, I think. Wait a minute. That's right.
- I: O.K. Good.
- S: (Reads problem aloud) I'm just reading the problem again. O.K. when I look at this problem I know that I'm looking for letters which are in two of the shapes at the same time. So what I'm gonna do is I'm first gonna figure out the letters what are in both the triangle and the circle, then the triangle and the square, and then the square and the circle. And then I'm gonna add them together after that. There's two in both the triangle and the circle. I can't have the letters in all three, so there's two in the triangle and the circle that aren't in the rectangle. And now I'm gonna look for the ones in the triangle and the rectangle. The only letter that they both share is also in the circle, so there's not any letters only in the triangle and the rectangle, so that's zero. And then between the circle and the rectangle without the triangle there's two, so that's two more. So the answer is four. I'll check it out again. The answer is four.
- I: Can you tell me which letters they are?
- S: Yeah. C and M and E and H.
- I: O.K. Good. Thank you very much.

APPENDIX C

STATISTICAL TECHNIQUES USED
IN THE INVESTIGATION

Pearson Product Moment Correlation Coefficient

A coefficient of correlation is a number that indicates to what extent two variables are related (Guilford and Fruchter, 1978). The Pearson product moment correlation coefficients in this study were calculated by using the equation below:

$$r_{XY} = \frac{N\sum XY - (\sum X)(\sum Y)}{\sqrt{[N\sum X^2 - (\sum X)^2][N\sum Y^2 - (\sum Y)^2]}}$$

X and Y are the scores on variables X and Y, and N is the number of data pairs. In this investigation the X and Y represented the hemisphericity indices calculated for each subject. Each test was correlated with each of the other tests in the study. The correlation coefficients were tested for significance at the 0.05 probability level by consulting a table of significant correlation coefficient values.

Spearman's Rank-Difference Correlation Coefficient

When data are expressed in terms of rank orders, the Spearman's rank-difference method can be used to determine if the orders are significantly correlated with each other. The formula used to calculate the correlation coefficients in this study is shown below:

$$r_p = \frac{6\sum D^2}{N(N^2 - 1)}$$

where D^2 = sum of squared differences between ranks, and N = number of squared measurements in the data. The significance of r was determined by consulting a table of significant r_p values.

Analysis of Variance

Analysis of variance is used to determine whether the differences between groups of data are significant, or whether they are due to chance (Crocker, 1974). The significance of differences is determined by calculating the ratio of two variances--the variance between the groups of data being considered, and the variance within the data groups. The ratio of these variances is called an F-ratio, or simply F. When the F-ratio is equal to or less than 1, the difference must be determined by consulting a table of significant F-ratio values.

Each of the variances in the F-ratio is calculated by using the formulas shown below:

$$\text{Between groups variance} = \frac{\text{Sum of squares between groups}}{\text{Degrees of freedom between groups}}$$

$$\text{Within groups variance} = \frac{\text{Sum of squares within groups}}{\text{Degrees of freedom within groups}}$$

The sum of squares between groups, or SS_B , is calculated by using the following formula:

$$SS_B = n \sum_{i=1}^n d_i^2, \text{ where } d_i = \bar{X}_i - \bar{X}_t \text{ (deviation of a group mean from the grand mean)}$$

The sum of squares within groups, or SS_W is calculated using the following formula:

$$SS_W = \sum x^2,$$

where x = deviation of an observation from its group mean. The degrees of freedom between groups equals $k-1$, where k represents the number of groups. The degrees of freedom within groups equals $N-k$, where N = number of observations, and k again equals the number of

groups. Thus, if three groups of data containing eight observations each are being compared, the between groups degrees of freedom would equal 2, (k-1), and the within groups degrees of freedom would equal 21, (N-k, or 24-3). Both degrees of freedom values are usually reported when an F-ratio value is reported, and they are reported in the order of between groups degrees of freedom first, and within groups degrees of freedom last. The tables presented in Chapter IV of this report adhere to this convention. The calculation of F-ratio values is summarized below:

$$F\text{-ratio} = \frac{\text{Between groups variance}}{\text{Within groups variance}} = \frac{\frac{SS_B}{k-1}}{\frac{SS_W}{N-k}} = \frac{\frac{\sum d_i^2}{k-1}}{\frac{\sum x^2}{N-k}}$$

The assumptions underlying the F-test validity include independent observations within sets, normal distribution of population values between sets, and approximately equal variances within sets. However, the F-test is a robust test (Guilford and Fruchter, 1978) and is generally rather insensitive to variations in the shape of the population distribution and in population variances. In this study the homogeneity of variances was established by employing Bartlett's test of equality of variances. The variance heterogeneity was determined to be non-significant at the 0.05 probability level.

T-Test

The T-test is used to determine significance of difference between means of sets of data. The T-tests in this investigation were calculated by using the following formula:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\left(\frac{\Sigma x_1^2 + \Sigma x_2^2}{N_1 + N_2 - 2}\right) \left(\frac{N_1 + N_2}{N_1 N_2}\right)}}$$

where $\bar{X}_1$ and $\bar{X}_2$ = means of the two data sets, Σx_1^2 and Σx_2^2 = sums of squares in the two sets, and N_1 and N_2 = numbers of cases in the two sets. The value of t is tested for significance by consulting a table of significant t values.

Chi Square

A chi square analysis was used in this study to determine whether the hemisphericity of the subjects was related to their problem solving strategies. The fourfold chi-square contingency table is shown below.

	Right	Left	
Heuristic	A	B	A + B
Algorithmic	C	D	C + D
	A+C	B+D	

The equation for computing chi-square is shown below:

$$\text{Chi-square} = \frac{N(BC-AD)^2}{(A+B)(C+D)(B+D)(A+C)}$$

Because the expected frequencies of some of the cells in the contingency were less than 10, Yates' correction for continuity (Guilford and Fruchter, 1978) was applied to the data. This correction consists of reducing by 0.5 each obtained frequency that is greater than expected, and in increasing by 0.5 each frequency that is less than expected. Applying this correction produced a correction in the size of chi-square and increased the validity of the chi-square analysis.

VITA

Saundra Yancy McGuire was born in Baton Rouge, Louisiana on December 13, 1949 to Robert E. and Delsie M. Yancy. She attended elementary and secondary school in Baton Rouge, and enrolled at the Baton Rouge campus of Southern University in September 1966. During her tenure at Southern from 1966-1970, she received Carnegie Foundation fellowships to attend Columbia University during the summer of 1968 and Harvard University in Cambridge, Massachusetts during the summer of 1969. She also received a Crown Zellerbach Foundation fellowship to attend the University of California at Berkeley during the 1968-69 academic year.

After graduating magna cum laude from Southern University in June 1970 with a Bachelor of Science degree in Chemistry, she entered Cornell University in Ithaca, New York with the support of a Danforth Foundation fellowship. She received a Master of Arts in Teaching Chemistry from Cornell in December 1971.

Saundra taught chemistry at the State University of New York at Brockport, Cornell University, Ithaca College, and The University of Tennessee, Knoxville between 1971 and 1980. She began her doctoral studies at The University of Tennessee, Knoxville, in 1979, and received the Doctor of Philosophy in Education with a major in Curriculum and Instruction in March 1983. While enrolled at The University of Tennessee, she was supported by a Teaching Assistantship in the Department of Chemistry, a Hilton A. Smith Graduate Fellowship and a University of Tennessee Alumni Scholarship.

She served as Director of the Pre-Medical Enrichment Program at The University of Tennessee from September 1981 until August 1982.

She is a member of the Alpha Kappa Mu Honor Society, Pi Mu Epsilon Mathematics Honor Society, Phi Kappa Phi Honor Society, the American Chemical Society, the American Association for the Advancement of Science, the National Organization of Black Chemists and Chemical Engineers, and the National Association of Medical Minority Educators, Inc.

She is married to Stephen C. McGuire of New Orleans, Louisiana. They have two daughters, Carla Abena and Stephanie Niyonu.