The major purpose of this study was to test the relationship between students' cerebral lateralization for the Arabic language and their achievement in science. A secondary purpose was to investigate handedness as a factor in that relationship. The experiment was conducted in the City of Jeddah, Saudi Arabia, using dichotic listening.

A test consisting of eight introductory and 30 experimental trials of three pairs of monosyllabic Arabic words was administered to 280 male students in grade 11. The trial time was one and one-half seconds. Ten seconds following each trial was used for free recall. Using the dichotic test, students were classified as having right- or left-ear preference. Right- and left-handedness was determined by means of a questionnaire. Data were analyzed using one-way analysis of variance and correlation.

The conclusions drawn from the study were as follows:

1. Like other scriptive languages, the Arabic language was perceived
and processed in the left cerebral hemisphere in the majority of
the native speakers.

2. Achievement in science depends upon the organization of linguis-
tic functions in the cerebral hemisphere and the corresponding
pattern of language lateralization.

3. Left hemispheric lateralization of language furnishes a more
adequate substrate for a higher level of achievement in science
than does right hemispheric lateralization.

4. The degree of left hemispheric lateralization of language corre-
lated positively with science achievement.

5. Handedness is a factor in the relationship between science
achievement and language lateralization.

6. Right-handedness and left cerebral lateralization of language,
together, were associated with a high level of neurological
readiness for learning science.

7. Left-handedness and/or right hemispheric language can be viewed
as distracting elements which interferes with achievement in
science.

Numerous recommendations for further research were suggested.
Included was the recommendation that standardized dichotic listening
tests should be developed and made available for researchers, along
with normalized procedures for administering and scoring the tests.
The Relationship between the Cerebral Lateralization for Arabic Language and Achievement in Science

by

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THE RELATIONSHIP BETWEEN THE CEREBRAL LATERALIZATION
FOR ARABIC LANGUAGE AND ACHIEVEMENT IN SCIENCE

I. INTRODUCTION AND BACKGROUND

A. Introduction

A paradigmatic shift is intensifying in the field of psychology. The inclination is going from cognitive psychology to brain research. More and more practitioners in the field are coming to acknowledge neuroscientific conceptions and incorporate them in their psychological research (Ornstein, 1972). Since psychology is a major input source for education, the rising paradigmatic shift is also reaching the realm of education. This impact of neurosciences on education is embodied in the conferences that are arranged and attended by eminent psychologists, neuroscientists, and educators. Experts in these fields are also collaborating in the publishing of books which join their different interests. These books may help education personnel and teachers gain understanding of learning and behavior in terms of the neurological factors involved. As an example of this collaboration, the National Society for the Study of Education has devoted the entire volume of the second part of its Seventy-Seventh Yearbook to brain science and its relations to and implications for education (Chall and Mirsky, 1978).

Man's neurocortex is made up of two similar structures, the left and right cerebral hemispheres. An important discovery in neurosurgery which has attracted psychologists—and later educators—is that man has the potential for thinking in two different modes.
Each cerebral hemisphere has its characteristic organization of cognitive and perceptive functions (Bogen, 1977). This organizational differentiation of functions causes each hemisphere to outscore the other in particular types of functions. As a consequence of this discovery, various dichotomies have been used to describe the prevailing mode of performance of the two hemispheres. For example, the left hemisphere was regarded as verbal or analytic, the right hemisphere visuospatial or synesthetic (Levy, 1969; Ornstein, 1972). Others have called the left hemisphere serial or logical and viewed the right as parallel or intuitive (Cohen, 1973; Gur and Gur, 1977).

In normal people, nevertheless, the two hemispheres do not process information independently from each other. They are in continuous interaction. They interchange information through bundles of neural fibers called the commissures. The corpus callosum is the largest bundle which interconnects the two sides of the brain (Sperry, 1961; Kent, 1981).

Awareness of the mutual interaction between the two hemispheres gave rise to the term "lateralization of function." It refers to the fact that the two cortical halves are functionally asymmetric. The left hemisphere excels the right in verbal and analytic processes. The right hemisphere is superior to the left in visuospatial and holistic processes (Gazzaniga and LeDoux, 1978).

Since language acquisition is an important characteristic of man, neuroscientists have studied the linguistic functions of the brain. Most of the knowledge about the patterns of lateralization of language was gained by studying aphasics—people with speech disorders—and split brain patients—people who had their two cerebral hemispheres
disconnected by severing their corpus callosum fibers (Gur and Gur, 1977). These studies along with observation of patients with unilateral brain lesions indicated that language, in most people, was usually processed and produced by the left hemisphere. Thus, language was said to be lateralized to the left hemisphere. In other words, the left cerebral hemisphere was found to be more proficient than the right in handling verbal and linguistic tasks.

The right hemisphere's capacity for comprehension of language has also been recognized by researchers. However, its level of comprehension is much lower than that of the left hemisphere (Bogen, 1973). Levy (1969) argued that the right hemisphere possessed some minimal ability to express language, but it was difficult to observe because of competition from the left hemisphere for control of the motor mechanisms for the production of language (p. 614-615).

Laterality of language may be conveniently measured by quantitative indices in order to make precise scientific research easier. Several techniques have been used for that purpose. The dichotic listening test is one of these techniques. In 1961 Doreen Kimura presented competing words (or digits) simultaneously and with a high speed to both ears of a group of individual subjects. She asked the subjects to report the words (or digits) they just heard. The majority of them reported the words (or digits) that were heard by their right ears more accurately. Kimura argued that as the right ear had much richer neural connections to the left hemisphere than to the right one, that this right ear superiority should be interpreted as superiority for the left hemisphere in processing language. She attributed, in other words, the right ear advantage to the idea that the
left hemisphere was dominant for language (Kimura, 1961, 1973). There are now hundreds of studies that confirm this right ear advantage in the majority of the normal population (Berlin, 1977).

The degree of lateralization varies among individuals. Some people may even have an inverted pattern where linguistic functions are subserved by their right cerebral hemisphere (Rossi and Rosadini, 1967). This may be natural or it may be the result of pathological causes. In general, the degree of lateralization for language varies with sex, age, and handedness (Bakker and Associates, 1976; Bryden and Allard, 1978; Levy and Gur, 1980).

The relationship between hemisphere laterality for language and learning disabilities has been of considerable interest to neuropsychologists. Individual clinical cases have demonstrated a coexistence between learning disabilities and incomplete lateralization for language (Kinsbourne and Hiscock, 1978). An increasing body of research tends to provide evidence that disabled learners show a lower degree of lateralization for language than do normal subjects (Leong, 1976; Satz and Associates, 1971). The majority of existing studies lend themselves to reading difficulties only. Performances under the average level for reading have been related to deficiencies in the functions of the left hemisphere (Leong, 1976; Pirozzolo and Rayner, 1979).

There have been no efforts made to specifically investigate the relationship between achievement in school science courses and the degree of lateralization of language. However, a relationship is logically possible. First, the learning of science requires a certain amount of knowledge in mathematics and quantitative reasoning.
Johnson and Johnson (1978) state that "it is quite rare for a child to have difficulty with language and not experience difficulty with arithmetic" (p. 14). They argue that disabled learners usually perform below average in computational skills because these skills depend on auditory memory and sequencing. It is logical, then, to infer that students with abnormalities in their cerebral language may have learning problems in science.

Second, a hunch is suggested by the learning-style literature. Learning styles of students have been related to their choice of subject matter specialization. Those who choose science and engineering are said to be field-independent. This style has been associated with superior left brain processes and with a relatively high degree of cerebral lateralization for language (Witkin and Goodenough, 1981; Wittrock, 1978). Guyer and Friedman (see Friedman and Associates, 1976) find that 63% of the learning disabled group are field-dependent (or field-sensitive) as compared to 37% of the normal controls. Field-sensitive subjects performed poorly on some left hemisphere tests of verbal ability. The authors also realize that those with learning disabilities rely on right hemisphere strategies for approaching verbal and mathematical tasks and such strategies are usually not successful (p. 261-262). Pizzamiglio (1976) contends that subjects who show right ear preference on dichotic listening tests are more field-independent. Thus, the possibility exists that concepts of field articulation and brain lateralization are related (p. 269). This in turn adds to the possibility of a linkage between cerebral lateralizations for language and achievement in science courses.

Third, examining the actual state of affairs for science
education in today's schools indicates a heavy dependence on sequentially organized topics which are inductively presented to students. Classroom teaching of science is generally verbal. Even in the laboratory, students communicate verbally, use laboratory manuals, and report their specific findings verbally. These findings are often loaded with mathematical and logical inferences (Bruner, 1960; Ausubel and Associates, 1978). Thus, it appears that a student has to have a certain level of competence in language and auditory sequencing in order to achieve the optimum level in science classes. All of this in turn hints of a possible relationship between the level of achievement in science and the degree of lateralization of languages. Investigating this relationship is the thesis of this study.

B. The Problem Statement

The major objective of this study is to investigate the relationship between achievement in science and the pattern of cerebral lateralization for Arabic language in 11th grade students in a selected city in Saudi Arabia. A secondary objective is to examine whether or not students' handedness is a factor in the relationship between science achievement and language lateralization. In other words, the principle problem is to study the relationship between achievement in science (as measured by the ordinary final examinations) and the cerebral lateralization for Arabic language (as measured by the dichotic listening technique). The secondary problem is to study the relationship between the cerebral lateralization for Arabic language and science achievement for right- and left-handed students separately.
C. Hypotheses

The hypotheses being tested are as follows:

1. There is no significant difference in achievement in science between students with left cerebral lateralization for Arabic language and those with right cerebral lateralization.

2. There is no significant difference in achievement in science between the following groups of students:
   a. those who are left lateralized for Arabic language (or right-eared) and right-handed (ReRh),
   b. those who are left lateralized for Arabic language and left-handed (ReLh),
   c. those who are right lateralized for Arabic language (or left-eared) and right-handed (LeRh),
   d. those who are right lateralized for Arabic language and left-handed (LeLh).

D. Definitions

1. Laterality of language: a situation in which language is being processed more proficiently in one cerebral hemisphere than in the other.

2. Right cerebral lateralization for language: the right cerebral hemisphere is more proficient than the left in handling language. This is indicated by left ear preference on the dichotic listening test.

3. Left cerebral lateralization for language: the left cerebral hemisphere is more proficient than the right in handling
language. This is indicated by right ear preference on the
dichotic listening test.

4. Ear preference: a student is classified as having right ear
preference if his laterality index (see classification of the
cerebral speech, p. 49) is equal to or greater than the over-
all average index for the whole group, otherwise he has left
ear preference.\(^1\)

5. Hand preference: a student is classified as right-handed if
his handedness index is equal to or greater than the overall
average index for the whole group, otherwise he has a left
hand preference.\(^2\)

6. Degree of cerebral lateralization: the index value which is
achieved on the dichotic listening test.

7. Achievement in science: the average score a student obtains
on the final examination of the science courses which he has
taken during the last two academic years. These courses are
as follows:

a. the general sciences and health; given at the end of the
9th grade,

b. chemistry, physics and biology; given at the end of the
first semester of the 10th grade,

\(^1\)The class of left earedness thus subsumes all none-right ear prefer-
ence. Among those may exist some students who do not have a clear
ear preference.

\(^2\)All none-right-handed students are considered in this study as left-
handers.
c. chemistry, physics and biology; given at the end of the second semester of the 10th grade.

8. Significant difference: at the 0.05 level ($\alpha = 0.05$).

E. Need for the Study

Chall and Mirsky (1978) argue that the neurological findings need to be tested directly in the school in order to create a link between education and the neurosciences. This study is a preliminary effort which is intended to help establish such a linkage. The study may provide science educators and teachers with evidence of the importance of language organization in the brain for learning science. This study may then stimulate the interest of educational researchers in developing some direct connections between neurological factors and educational variables.

This study also provides some knowledge about the prevailing pattern of cerebral lateralization of Arabic language in the population of the native speakers. A data base is provided by the study, concerning the percentage of non-right-handedness in the Saudi public boys schools.

F. Assumptions

The assumptions made by the study were as follows:

1. Cognitive functions as well as motor functions are asymmetrically organized in the human brain;

2. lateralization of language can be measured with validity and reliability by dichotic listening tests of words;

3. the instrumental techniques which are used to develop
dichotic listening tapes in English are applicable in producing such tapes in Arabic; and

4. scores on final examinations in science are valid and reliable measures of achievement in science.

G. Limitations

The study was limited by the following:

1. The validity and reliability of the dichotic listening tape, the handedness questionnaire, and the final examinations given in the science classes;

2. the differences in atmosphere and setting in the two schools;

3. the efficiency and level of performance of the stereo deck and the headphone used; and

4. the participation of only male students in the 11th grade, 16 to 18 years of age.

H. Design of the Study

The research was conducted in the city of Jeddah, Saudi Arabia. After the 10th grade, Saudi students can choose one of two fields of specialization, the sciences or the letters. This study utilized students from both divisions who had just started their 11th grade, the second year of the secondary school level.

Five classes were drawn at random from each of two randomly selected schools. A dichotic listening test was administered individually. Students were divided into left and right eared groups, according to their scores on the dichotic test. The science achievement scores of the two ear groups were contrasted, using the one-way
analysis of variance (ANOVA), fixed model. Students handedness was measured by a handedness questionnaire. Left- and right-eared students were then divided into subgroups according to their hand preference, left or right. Four ear-by-hand subgroups were thus differentiated. The one-way ANOVA was then applied in order to contrast the mean science achievement scores of the four subgroups.

I. Organization of the Thesis

The rest of the thesis is divided into four chapters. The second chapter presents the literature review. It discusses the structure and function of the human brain, the methods of measuring hemispheric functions, and the lateralization of cognitive functions. The third chapter introduces the procedure and design of the study. Students selection is indicated. The handedness questionnaire and the dichotic listening test are then explained. The chapter also explains the methods of classification on handedness and earedness which are used in the study. A reliability is then established for the dichotic listening test. The one-way analysis of variance (ANOVA), fixed model, and the Pearson's r-correlation coefficient are presented. The fourth chapter of the dissertation presents the data and the findings. The results of the one-way ANOVA and of the correlation are reported and explained. The fifth chapter then gives the summary, conclusions, implications for science education, and recommendations.
II. LITERATURE REVIEW

A. Introduction

With the advancement of brain research, neurology and neuropsychology began to be of interest to educators. They were particularly interested in obtaining insight into the neurological basis of human behavior and performance. The main reason for this interest was that educators were trying to find some acceptable resolutions to theoretical and practical issues in education. Chapter II reviews those aspects of the brain research which are considered informative and productive for the purpose of education. It is divided into three main sections as follows: (1) the structure and function of the human brain; (2) the measurement of hemispheric functions; and (3) lateralization of cognitive functions. Each section is subsequently divided into subtitles.

The first section is divided into three parts: (1) the neuron and its mechanism; (2) the macrostructure of the brain as a whole; and (3) the psychological significance of the two cerebral hemispheres. The second main section deals with the measurements of hemispheric functions. Five methods are reviewed, two of which are clinical methods. The other three methods apply to normal subjects as well. The final section is divided into three subtitles: (1) the origin and development of the lateralization of language; (2) individual differences; and (3) learning disabilities and cerebral language.
B. The Structure and Function of the Human Brain

1. The Microstructure

The basic unit in the brain is the neuron. A typical neuron has a cell nucleus and the necessary machinery for metabolism. A large number of short branches stem out from the cell body of the neuron and are called dendrites. The neuron also has one long branch called the axon (see Figure 1). At birth, the human possesses from 20 to 200 billion neurons. Lost neurons are not replaced. Neurons are incapable of increasing their number by cell division or by regeneration (Tyler, 1978).

The major function of the neuron is storing and transmitting information. The nature of the storage process is not well known. The transmission of information is an electrochemical process. Information is transmitted out from the neuron via the axon. The dendrites are specialized in receiving the information transmitted to the neuron from the axons of other neurons. The end of an axon in the human, however, is not physically connected to the receiving dendrites. There is a brief gap between the two, called a synapse. Similarly, there is a synapse where an axon is connected to a muscle (Tyler, 1977).

The electrochemical process of the neural transmission of information takes place in three instant stages. The first is called the resting potential stage. The neuron in this stage shows an electrical potential of about -60 millivolts. Its inside is negatively charged because of the existence of the negative protein ions. Potassium ions (K+) are of a greater concentration in the inside of the
FIG. 1

A Prototype neuron and a synapse
neuron than on the outside. The opposite is true for the chloride (Cl\textsuperscript{−}) and sodium (Na\textsuperscript{+}) ions. The membrane of the neuron and its axon are impermeable to the ions in this stage. When the neuron receives a relatively strong stimulus, the second stage begins. It is called the action potential. The membrane of the neuron immediately becomes permeable to small ions. Sodium ions rush inside the neuron through the unmyelinated spots along the axon. The potassium ions then rush out of these exposed points on the axon. The inflow of Na\textsuperscript{+} lowers the negative charge of the interior of the neuron swinging the potential to about +20 millivolts. This action potential causes the axon terminals to secrete a chemical called a neurotransmitter which fills the synaptic gap and allows the pulse of information to reach the dendrites. In some cases the chemical secreted by the axon terminal prohibits instead of facilitates the transmission of the signal (Eccles, 1973; Tyler, 1977, 1978).

Immediately after the nerve impulse is fully received by the dendrites of the next neuron, the transmitting neuron enters its third stage. This is the absolute refractory period during which even unusually strong stimuli cannot evoke any action potential in the neuron. During this period the neuron is completely involved in the process of regaining its resting potential. Sodium ions rush back to the outside of the axon membrane, while potassium ions emerge inside.

2. The Macrostructure

The human brain can be divided, for illustrative purposes, into three general areas: the brainstem, the midbrain, and the forebrain. The brainstem consists of several kinds of brain nuclei and nerve tracts which come from different parts of the nervous system.
Through the brainstem, the cerebellum—which controls ongoing bodily activities and voluntary movements—communicates with several brain areas. The midbrain mainly consists of the reticular formation and the hypothalamus (see Figure 2). The reticular formation is a widespread structure. It is connected to almost every part of the higher brain sections. It is believed that the reticular formation is involved in arousal. The hypothalamus is a nuclear structure, located above the roof of the mouth. It is a very important brain center which controls the homeostasis process. The hypothalamus also works as a pleasure center (Tyler, 1977; Pelletier, 1978).

The third area is the forebrain. It subsumes the limbic system, thalamus, and cerebral cortex. The functions of the limbic system are not clearly understood. It seems to regulate emotions. One part of the limbic system, the hippocampus, seems to serve the short term and the permanent memory. The thalamus is regarded as a major sensory relay station in the brain. It relays information coming from each of the sense receptors (Novack and Demarest, 1972; Tyler, 1975, 1978).

The third section in the forebrain is the cerebral cortex. It consists of two similar, but not identical, structures, the right and left hemispheres. Both hemispheres consist of four lobes which have highly specialized functions. A lobe is divided into sensory, motor, and associated zones according to the type of the neurons each zone contains. Sensory cells receive and process the impulses which come from the sense organs in the body. Motor cells generally produce orders to the muscles to move. The association cells are involved with the understanding of language and other complex sensory inputs.
The association areas in the human brain are much larger than those in the brains of lower animals. Thus, they are described as playing a major role in the cognitive aspects of behavior (Eccles, 1973; Sagan, 1977; Tyler, 1977).

The four lobes in each hemisphere are the frontal, parietal, temporal, and occipital. The frontal lobe is responsible for initiating and processing the motor functions of all bodily muscles, including the tongue. The parietal lobe deals with the sensory information that comes from receptors located in the skin, the joints, and other areas. The temporal lobe is concerned with linguistic and other auditory functions. The occipital lobe works upon input coming from the eyes (Tyler, 1978).

The control of the body by the two hemispheres of the cerebral cortex is described as contralateral. This means that each hemisphere controls the opposite side of the body. For example, stimuli reaching the right ear are perceived by the left hemisphere. Each side of the body is also connected to the ipsilateral hemisphere. However, this is a much weaker connection than the contralateral. This crossed presiding of the two hemispheres over the sides of the body has been known since ancient times. The Greeks realized that a lesion to one side of the brain rendered the opposite side of the body paralyzed (Maruszewski, 1975; Calvin and Ojemann, 1980). Besides, one cerebral hemisphere is capable of maintaining and regulating all of the activities of the living individual. Early in the 19th century a neurosurgeon was testing the dead body of a friend of his. It was to the surgeon's astonishment to find that his friend had only one cerebral hemisphere developed in his brain. Man was
FIG. 2

A vertical cross-section of the right hemisphere with its major structures
thus said to possess two brains (Restak, 1979).

In normal people, however, the two brains work together as a unified and integrated brain. The two cerebral hemispheres are connected by a number of fiber bundles called the commissures. The corpus callosum is the largest bundle that connects parallel centers in the two hemispheres. The corpus callosum is crucial for sharing learning and memory between the two hemispheres. For instance, it helps in correlating images in the two halves of the visual field. It also facilitates motor coordination of the limbs. The corpus callosum is also involved in unifying the cerebral processes necessary for attention and awareness. In general, it allows for all aspects of the mutual interaction between the two hemispheres (Sperry, 1964).

3. The Psychological Significance of the Two Hemispheres

It has been known for a long time that humans are capable of two different types of thinking. Philosophers and early scholars have recognized the existence of two modes of thinking. They described the first mode as rational, constrained, logical, realistic, and the like. The other mode of knowing was called intuitive, creative, and prelogical (Neisser, 1967).

With the rise of behavioral psychology and the modern sciences, the distinction between the two ways of thinking has been gradually forgotten. People started to emphasize only one aspect of human thinking, i.e., the logical and rational mode. It was the mode which matched very well with the scientific and technological environment of Western man (Capra, 1975; Ferguson, 1980).

Consequently, the normalized patterns of behavior and the rational schemes of thinking along with language became powerful
constituents of the value system in the West. This was the theme that ran through several aspects of societal life such as education, psychology, and politics. Schools in the West were mainly concerned with educating the intellect of man as seen through scientific goggles. Intelligence was generally equated with a high level of logical thinking and verbalism. The majority of psychologists and learning theorists viewed man as fully and "normally" developed only when he attained the "prescribed" levels of "conservation" and "formal" thinking (Bruner, 1967; Phillips, 1975). The "meritocracy" was confined to those individuals of high I.Q. whose brains survived the cumbersome exercises of the "Grammar School" (Young, 1958). Students who could not mold themselves in the cast of rationality and verbalism were "granted" general degrading titles. They were collectively described as retarded, slow learners, or emotionally disturbed.

It was not before the early 1960s that researchers rediscovered the neglected "reality" of the other mode of knowing and its weight in learning and behavior. During the 60's psychologists began to gain awareness of the findings then being accumulated in the neuroscience field. Consequently, the two different styles of knowing are now fully recognized and for the most part, generally accepted. They are interpreted in terms of the physical structure of the brain and attributed to the distribution of the cognitive functions in the two cerebral hemispheres (Bogen, 1977).

C. The Measurement of Hemispheric Functions

There are generally two approaches to studying the cerebral processes of the human brain. The first type of practice applies to the
patients of neurological clinics. The second type of investigation is conducted on the normal population. These two approaches are quickly reviewed in this section. In connection with the clinical research, two methods are covered. They are the brain injury studies and, as it is commonly called, the split-brain research. The review of the normal subjects studies cover three related methods. These are the dichotic listening, tachistoscopic, and electronencephalographic methods.

1. The Brain-Injury Studies

Patients with unilateral brain damage provide very good cases for understanding the distribution of function between the two hemispheres. If a person experiences noticeable deficits in certain aspects of his or her previous mental capabilities after damage to one side of his or her cortical brain, it is evident that these capabilities are subserved by the damaged hemisphere in that person. Also, damages to the right hemisphere of a group of patients, for instance, may deteriorate their performance on certain types of tasks. If injuries to the left hemisphere do not influence the performance of another group of patients on these tasks, it is concluded that they are generally processed in the right hemisphere. The same rationale applies to hemispherectomy patients—in whom one cerebral hemisphere has been removed (Benton, 1968; Dennis and Whitaker, 1977). The consequence of a right hemisphere insult has been summarized by Nebes (1977).

Early studies on unilaterally brain-damaged patients showed two major classes of cognitive deficits to be more prevalent after right- than after left-hemispheric injury. These were (1) a difficulty in perceiving,
manipulating, and remembering the spatial relationships of objects, both to one another and to the patient himself; and (2) a difficulty in perceiving and remembering visual, tactile, and auditory stimuli which are complex, fragmentary, or hard to label and describe verbally (p. 99-100).

Damages to the left cerebral hemisphere cause different forms of disorder. An important misfortune which usually accompanies most of the cases of left hemispheric insult is the loss of language, either partially or completely. An injury to the Broca's area in the left frontal lobe often entails incapability of well-articulated speech. This indicates destruction to the speech mechanism in the brain. In contrast, when an injury or a stroke hits the Wernicke's area in the left temporal lobe, the speech mechanism is not influenced. However, the speech produced is usually devoid of meaningful content (Schmidt, 1975; Tyler, 1977). Total damage to the left hemisphere usually robs the individual of both speech production and comprehension.

Damage to the left hemisphere also often causes inaccuracy in perceiving time. Carmon and Nachson (1971) find that patients with left hemispheric lesions experience significant retardation in their sequencing and time-related ordering abilities. Such retardation is not found in the normal subjects or in the cases of right hemispheric lesions.

2. Split-Brain Studies

The second clinical evidence of the distribution of the hemispheric processes comes from the split-brain research. The corpus callosum is cut through in patients who suffer from frequent epilepsy in order to confine the seizure to one side of the cortex. Such
operations appear to be successful in ending the attacks almost completely in these patients (Sperry, 1961). The operation makes the two cerebral hemispheres completely separated. This bisecting of the brain seems not to influence the normal life of the patient. However, closer examination of such patients reveals that they are left with two brains, each of which is unaware of the existence of the other. Each patient has two independent modes of thinking and learning. Studying these patients sheds light on the characteristics and capabilities of each cerebral hemisphere (Gazzaniga, 1967).

Sperry and Gazzaniga (1967) tested the linguistic abilities of the two cerebral hemispheres in their split-brain patients. They asked the patient to fix his gaze on a central point of a screen. They flashed two simultaneous visual stimuli for less than a tenth of a second. A picture of a pencil was flashed to the left-half of the patient's visual field, and a picture of a knife to the right-half. They asked the patient to tell what he had just seen. Each patient reported to have seen a picture of a knife only. When the patient was asked to write down what he had just seen, he also wrote the word "knife." Thus, it seemed that the patients could only see the stimuli which were flashed to their right hemifield, left hemisphere. The right hemisphere seemed to be blind.

However, when the patients were asked to give nonverbal responses things were different. The patient was asked to use one hand and retrieve the object he had seen on the screen from among a collection of items that were held out of sight behind a barrier. The retrieved object in this case depended upon the hand used. When a patient used his left hand, he/she drew the object that was flashed
to his/her left hemifield, the pencil. This was so despite the fact that the patient had previously denied seeing anything other than a knife. When the right hand was used, the patient retrieved the knife. Thus, the right hemisphere was not blind or deaf. The pencil had been seen, and the command to retrieve it had been heard and understood by the right hemisphere.

Moreover, Sperry and Gazzaniga (1967) had the patient hold an object in one hand without seeing it. The patient could name and describe those objects held in the right hand. Objects held in the left hand were incapable of producing any verbal response in these patients. The authors concluded that speech and writing centers in the brain of these patients were confined to their left cerebral hemispheres. The left hemisphere was then called verbal.

The right cerebral hemisphere had its own characteristic functions. It excelled the left hemisphere in such tasks as body orientation in space, face recognition, and awareness of locations and places (Gazzaniga, 1967). Besides, the split-brain patients were asked to draw some three-dimensional figures. They could do that only when they drew with their left hands, the right hemisphere. The right hand, the left hemisphere, could not produce the three dimensions. The right hemisphere was then described as visuospatial (Gazzaniga, 1967; Ornstein, 1972).

3. Studies on Normal Subjects

The clinical brain research stimulated the interest of psychologists. They hoped to extend the research to the domain of the normal population. Behavior and cognitive development were viewed possible to describe in terms of the functional potentials of the two
cerebral hemispheres. It was recognized that the clinical findings could not be generalized with validity to the normal cases. Thus, several techniques were derived for studying normal subjects. The underlying principle was to make instantaneous measurements of the involvement of one hemisphere before the interference of the other one through the intact commissures. Three of these techniques include dichotic listening, electroencephalogram, and tachistoscopic studies.

Dichotic Listening Studies: In dichotic listening, competing messages are delivered simultaneously to the subjects' ears. Kimura (1961) noticed that when the dichotic stimuli are words or digits, the right ear usually outperforms the left in perception. Nonverbal messages, in contrast, cause a left ear advantage. Kimura (1961, 1973) relates this ear preference to the cognitive processes of the two hemispheres. She recognizes the fact that contralateral neural wirings between the ears and the cerebral hemispheres are much stronger than the ipsilateral. Kimura thus argues that the ear advantage on a particular task should be a reflection of the greater involvement of the contralateral hemisphere in processing that task. Accordingly, verbal materials are said to be perceived and processed in the left hemisphere, nonverbal materials in the right.

Kimura's hypothesis received support from the clinical data. Patients who process speech in their left hemisphere, as attested by the sodium amytal method, also show right ear advantage for words and digits on the dichotic listening test. Similarly, patients with right hemisphere language have left ear advantage. The agreement between the clinical testing and the dichotic listening technique establishes a high validity for the latter. This in turn encouraged the
utilization of the dichotic listening test in more detailed experiments.

Shankweiler and Studdert-Kennedy (1967) argue that the right ear advantage which is obtained in speech is caused by particular segments of the spoken word. These are the segments that are heavily encoded. The brain is required to do substantial processing in order to sort out the intended acoustic cue. The authors find that stop consonants in general are much more encoded than vowels. Stop consonants generally produce a right ear advantage, a phenomenon not found with vowels. Thus, it is concluded that the detailed analysis is a function of the left cerebral hemisphere.

The interest in dichotic listening has developed in a different direction. Some researchers are studying the subtle factors which influence the mechanism of the test. This type of research is considered very important in that it helps in judging the validity and reliability of a particular test at hand. It also helps in understanding and reconciling the different findings of the different research efforts in the field.

Berlin (1977) and Berlin and Cullen (1977) discuss several of such factors that influence the obtained ear advantage on a dichotic listening test. They reported that the intensity of the sound in both channels should be the same. It should also be fixed at about 80db, the optimal sound pressure level for producing a reliable ear advantage. A variation of 10db between the two channels would obscure or reverse the expected ear advantage. Berlin and Cullen also note that the frequency of the sound should not vary between the two channels and should be kept within the normal frequency band width of the
human hearing ability. Another important factor that influences ear advantage is the time of onset of the paired stimuli in each channel. Berlin and Cullen (1977) state that "the largest right ear advantages for nonsense syllables occurs when signal onsets are precisely simultaneous oscilloscopically" (p. 81). A difference of 30 to 60 msec. in the onset time of the dichotic stimuli would cause the ear preference to vanish.

The authors also discuss some other factors, linguistic and nonacoustical, that affect the overall dichotic performance and ear advantage. Among these factors is the scoring of the dichotic listening tests.

Underlying the interpretation of dichotic tests is the assumption that they are, in fact, testing left-hemispheric language dominance. How one scores left-hemispheric dominance is moot; as yet we know of no satisfactory way to take dichotic listening scores and project "strength of lateralization of function" onto them. Many investigators measure the absolute right-left differences for REA (right ear advantage). Others use an "index" such as right minus left divided by total performance. Yet others use the construct of the correlation coefficient in an attempt to remove performance level effects from right-left differences. All "hybrid" measures are still based on ear differences arising from the one-item correct trials, the correct item being assignable to the right or left ear. As such, transforms of the data provide no better measure or insight into left hemispheric dominance for language (Berlin and Cullin, 1977, p. 85-86).

Electroencephalogram Studies (EEG): The term electroencephalogram means electrical brain writing. It refers to the electrical activity which occurs in the brain in its relaxing or arousal states. The EEG recordings give patterns of waves which differ according to the type of task the subject is doing. Two distinct patterns are often encountered; they are referred to as alpha and beta
waves. Alpha waves are of high amplitude and have a frequency range of 8 to 13 Hz. They are usually obtained in cases of relaxation, such as lying down with eyes closed (Springer and Deutsch, 1981). Beta activity is of a distinctly low amplitude, ranging in frequency from 13 to 30 Hz or more. They are usually associated with arousal. March (1978) states that a greater amount of alpha activity usually occurs in the right cerebral hemisphere of most people.

Galin and Ornstein (1972) find that the involvement of the left hemisphere in verbal tasks, such as saying a letter, produces greater alpha activity within the right hemisphere. This indicates a relaxed right hemisphere. However, using colored blocks to build three dimensional objects enhanced a greater amount of alpha activity in the left hemisphere. In agreement with this study, Schwartz and collaborators (1974) find that speaking a word significantly lowered the level of the alpha activity in the left hemisphere. Whistling a song, however, reduced the alpha waves in the right hemisphere.

These studies on normal subjects provide parallel findings to those obtained in the dichotic listening tests. The left hemisphere is usually involved in processing verbal materials. Spatial and musical activities are subserved by the right hemisphere.

Tachistoscopic Studies: A third method of studying the cognitive functions of the two cerebral hemispheres utilizes the tachistoscope. This device makes possible the simultaneous presentation of a visual message to each half of the visual field of a subject for a very brief period of time. Tachistoscopic experiments make use of the anatomical structure of the human vision system. The neural fibers which connect the retinae of the eyes to the cerebral cortex has
distinct pathways. The right-half of the retina of each eye which receives projections from the left hemifield, is connected to the right cerebral hemisphere. The left hemifield refers to the left side of the visual field from the fixation point. The left halves of both retinae are likewise connected to the left hemisphere (see Figure 3). Thus, stimuli presented in the left hemifield are sensed directly in the right hemisphere and vice versa (Berlucchi, 1975; Spring and Deutsch, 1981).

Tachistoscopic studies reveal different hemifield superiorities in normal subjects according to the type of stimuli presented and the nature of the task required. Kimura (1969) concludes that left hemifield superiority occurs for spatial tasks, while right hemifield superiority are found for words and numerical digits. MacKeever and Hulling (1970) find that words (nouns) are better perceived in the right-half of the visual field. Similar findings are reported in several other studies done on children ranging in age from seven to 14 years (Miller and Turner, 1973; Marcel et al., 1974).

D. Lateralization of Cognitive Function

It is concluded from the review in the previous section that the two hemispheres differ in their competences for cognitive processes. Initially, neuroscientists used the term "hemispheric specialization" to imply a division of labor between the two hemispheres. The left hemisphere was viewed capable of such tasks as language, serial ordering, temporal relations, and logical inferences. The right hemisphere was considered having access only to such processes as the iconic, the kinesthetic, and the spatial representations of the world. Cognitive
Fig. 3

A schematic representation of the vision system and its neural crossed pathways
capabilities were viewed as being compartmentalized in their respective hemispheres. However, subsequent research proved that such contentions were not accurate.

Recent research has provided a more accurate view of the hemispheric distribution of function. Research has shown that the right hemisphere, for example, is capable of comprehending language to a certain level (Bogen, 1973). The left hemisphere is found to be involved in some aspects of the musical abilities of musicians (Wittrock, 1978). Many other studies indicate that cognitive functions are not distributed on the basis of all-or-none between the two hemispheres. The two hemispheres, in normal people, are in continuous interaction and communication through the intact commissures. They both work in integration and complement each other. This new awareness led neuroscientists to adopt the concept of "lateralization of hemispheric functions" to replace the idea of "dominance." Lateralization of function conveys that the difference in performance between the two hemispheres is a matter of degree. It denotes an asymmetrical competence of the two hemispheres regarding a particular function (Ornstein, 1972; Gazzaniga and LeDoux, 1978).

Language was the first higher cognitive function found to be asymmetrically represented in the two cerebral hemispheres, and it remains the best documented case of hemispheric lateralization. Even though the approaches are different, all researchers confirm the laterality of language to the left hemisphere in the majority of people (Nebes, 1978, p. 101).

1. The Origin and Development of the Lateralization of Language

There are several models to explain the developmental aspects
of the cerebral lateralization of language. Three of these models are reviewed here. First, Geschwind and Levitsky (1968) attribute lateralization of function to the anatomy of the brain. They examined in detail brains of 100 adult cases at postmortem. There was no history of any neurological pathology in any case. The authors found that the planum temporale, an area just behind the temporal lobe, of the left hemisphere was significantly larger than that of the right hemisphere. This was true for 57% of the cases. Eighteen cases showed significantly larger right planum temporale. The rest of the brains had approximately equal sized plana. Geschwind and Levitsky indicate that the planum temporale is involved in comprehending speech. They developed their conclusions accordingly, arguing that a larger planum temporale in one hemisphere means greater linguistic abilities residing in that hemisphere. It means that the concerned hemisphere is better equipped for processing language.

The second model to be discussed is presented by Kinsbourne (1970, 1978). He argues that left hemispheric lateralization for language is an innate characteristic which exists at birth. Hemispheric laterality itself does not develop at all, according to Kinsbourne. He argues that what develops is rather the individual's ability to bias his attention, usually towards the right ear. Kinsbourne builds his model on the assumption that sense receptors on the two sides of the body always have an equal potential for perceiving information from the external world. As the individual matures, he gradually learns how to activate the proper hemisphere according to his expectations or to the instructions given to him about the nature of the task being presented. This differential activation of the appropriate
hemisphere, or the attentional bias, causes the contralateral sense receptors—which have the stronger connections to the activated hemisphere—to gain advantage in perceiving the presented task (Kinsbourne and Hiscock, 1978).

A third model of the development of hemispheric lateralization for language is espoused by Eric Lenneberg. He accepts the anatomical asymmetry of the two cerebral hemispheres. However, he does not view it as the cause of the functional asymmetry (Maruszewski, 1975; Wittrock, 1978).

Lenneberg's model is developed on the analysis of some published clinical data. He finds that 50% of the infants who suffered brain injuries to either hemisphere before the age of two did not experience any delay in their acquisition of language. These same data indicate that injury to the left hemisphere during the ages from two to ten produces speech disorders in 84% of the cases. Added to this is the common observation that right hemisphere lesions seldom produce any speech impairment in right-handed adults. Lenneberg concludes from these clinical statistics that hemispheric differentiation starts to appear at age two. It is not completed, however, until puberty (Maruszewski, 1975).

Lenneberg's position received some support from other research. Satz and Associates (1975), using a multivariate analysis, find that asymmetry of language is not completed before the age of seven. Van Dyne and Sass (1979) also report that fifth graders perform better when logic problems are presented monaurally to their right ears. Third grade children, however, do not show ear differences. Heilman (1978) also states that before and during maturation
the cerebral hemispheres in man are more equipotential for language than after maturation (p. 167).

2. Individual Differences

The cerebral lateralization of language in the normal population is influenced by age, sex, and handedness (Bryden and Allard, 1978; Rudel, 1978; Springer and Deutsch, 1981).

In general, there is a consensus among researchers that the pattern of hemispheric laterality is well established after puberty, in the normal course of development. As Strack and Associates (1977) indicate, measures of ear asymmetry in general, suggest that the strength of cerebral asymmetry, at least for the processing of linguistic matter, increases with age and stabilizes around age 12. However, estimates of the age when stability is achieved vary widely from study to study, and it may well be that stability is achieved much earlier than the onset of puberty. This variance may be the result of differences in experimental measures and differences among subjects in types of language experience (p. 47).

Gender has been shown to affect the pattern of language lateralization. Buffery (1977) finds that boys do not develop their hemispheric lateralization for language as early as do girls, dealing with right-handed subjects only. Similarly, Rudel (1978) argues that the rate of neurophysiological maturation is different for males and females. Language functions develop earlier in girls than in boys. Levy and Gur (1980) also state that there is sufficient evidence to conclude that there is considerable variation in the direction and degree of hemispheric lateralization. Such variations are functions of sex and handedness, among other factors (p. 206). Harris (1978) in
his extensive review states that females are neurologically disposed to be better in linguistics than visuospatial skills and acquire language earlier than males. Thus, females ultimately come to depend on linguistic modes more than males do and in more situations (p. 481).

A third variable which affects cerebral lateralization of language is handedness. Hand preference has not gained a consensus of definition. Different investigators set different definitions. They adopt different criteria for differentiating between left- and right-handedness. This yields different techniques for assessing handedness (Barnsley and Rabinovitch, 1970; Kinsbourne and Hiscock, 1978). Some authors rely on hands used in performing several activities as an indication of hand preference. Others consider the speed of performance as an index. Some other authors regard the efficiency of each hand as a measure. Still others rely on questionnaires (Crovitz and Zener, 1962; Oldfield, 1971; Annett, 1972; Briggs and Nebes, 1975). In addition, the scoring of handedness often depends upon the researcher's choice. This may lead to conflicting results among the different approaches. Differences in the way subjects are classified may account for some or all of the conflict (Springer and Deutsch, 1981, p. 107).

Studies from several parts of the world support the generalization that the normal population is largely right-handed (Hicks and Kinsbourne, 1978). Left handedness represents about 10% of the population. It is observed that left handedness occurs much more often among epileptics, mentally retarded and learning disabled subjects. Twins—who usually are susceptible to neurological deficiencies because of the twinning process—also show a higher incidence rate of left handedness. Such observations caused scientists to relate left
handedness to pathology (Satz, 1972; Springer and Searleman, 1980).

One point of view takes the position that "all" left handedness is essentially pathological in origin and that trauma occurring at birth can account for most of it. According to this view, which stands on empirical basis, the tendency of left handedness to run in families is a consequence of a genetically based increase in the risk of birth trauma in such families (Springer and Deutsch, 1981, p. 111).

Satz (1972), however, allows for some instances of non-pathological left handedness. He calls it natural left handedness. Considering the equal probability of lesions to the right and left hemispheres, Satz (1972) develops his model in an effort to account for the logically possible-to-exist cases of pathological right handedness.

Hand preference has also been associated with the anatomical asymmetry of some parts of the two hemispheres and with some neurophysiological processes. A few studies have reported such an association. Witelson (1980) reviews several of these studies. He concludes that:

Hand preference was correlated (sinistrals showed less or reversed asymmetry compared to dextrals) with right-left asymmetry in the parietal aperculum, prefrontal region, occipital regions (of the brain), venous drainage pattern, and blood volume supply. In four reports, speech lateralization as determined by the sodium amytal test or inferred by ear asymmetry on dichotic stimulation tasks was observed to be correlated with measures of neuroanatomical asymmetry. Neuroanatomical asymmetry is associated with, and may be a substrate of functional asymmetry (p. 108-109).

The origin and nature of left handedness may be explained differently. However, the relationship between handedness and the cerebral lateralization of language is well documented (Milner, 1975;
Boklage, 1980; Corballis, 1980; Mebert and Michel, 1980; Witelson, 1980). The relationship between handedness and language lateralization is an association rather than a cause-and-effect. It is known that left handedness is associated with a pattern of cerebral language which deviates markedly from the pattern usually observed in the right-handed population. This is confirmed by both sodium amytal\(^1\) testing of patients and by the dichotic listening test.

The sodium amytal test reveals that 96% of the right-handed patients have left hemispheric lateralization for language. Rossi and Rosadini (1967) obtained even higher figures. They find 98.6% of the right-handed patients to be left-brained for language. Dichotic listening, which has the advantage of being applicable safely to normal populations, reveals that some 80 to 85% of normal right-handed people have right ear superiority (Bryden and Allard, 1978; Kinsbourne and Hiscock, 1978). This is a reflection of left hemispheric lateralization for language. Lishman and McMeekan (1977) have 86% of their right-handed group showing right ear advantage for verbal tasks. Still, Satz and Associates (1967) find that 87% of the right-handed subjects have right ear advantage.

Left-handers in general show a variable pattern of cerebral lateralization for language, as compared to right-handers (Corballis and Beale, 1976; Restak, 1979; Witelson, 1980). They form a heterogeneous group with respect to cerebral language. The sodium amytal test on patients shows that 70% of left-handers have their language

\(^1\)This is an anesthetic which is injected rapidly into the common carotid artery of one side in order to determine the hemisphere most concerned with language, in patients who are awaiting neurosurgery.
processed in the left hemisphere as do right-handers (Satz, 1980). Rossi and Rosadini (1967) report that some 71% of the left-handers have left cerebral language; however, their sample contains only a very small number of left-handers. Fifteen percent of the left-handers show right cerebral speech, while 15% have language processed in both hemispheres (Satz, 1980).

Satz and co-authors (1967) had 60% of left-handers classified as left-brained for language. Forty percent revealed right cerebral laterality. Sixty-five percent of the left-handers in another study had right ear superiority; 35% had reversed ear advantage (Lishman and McMeekan, 1977). In general, left-handers who are left lateralized for language possess a lower degree of laterality as compared to their right-handed counterparts (Corballis and Beale, 1976; Gur and Gur, 1980; Kinsbourne, 1980).

3. Learning Disabilities and Cerebral Language

A relationship between learning disabilities and cerebral laterality of language was recognized by Orton (1937). He differentiated between several forms of learning disabilities. He contended that reading and writing difficulties are the result of incomplete cerebral dominance. Learning disabilities would result from the case that some cognitive or motor functions were not under the full control of the dominant hemisphere. This abnormality, Orton argued, weakened the coordination among the several perceptual processes which made reading and writing possible. Hence, learning difficulties appeared. Orton's hypothesis received some support from Zangwill (1960). The latter argued that incomplete lateralization of language in the left hemisphere, or ambilaterality for language, would cause learning
problems. He assumed that this ambilaterality of language might be a basic handicap in maturation and learning (p. 24). Furthermore, he found that "speech ambilaterality" was more frequent among left-handers than among right-handers.

Orton's hypothesis was supported by several recent studies. Pirozzola and Rayner (1979) concluded from their tachistoscopic presentation of words and letters to 12 year-olds that the disabled readers revealed severe inadequacy in their left hemisphere processing of linguistic information. Similar results were obtained by Tomlinson-Keasey and Kelly (1979) concerning seventh grade students. Good achievers in mathematics and in reading showed left hemisphere specialization. All subjects were right-handers. Observing lateral eye movement, Stein and Associates (1980) found that disabled learners lacked coordination between handedness and cerebral laterality for speech.

The emergence of the dichotic listening technique made possible a new approach for testing the relationship between learning disabilities and laterality of language. Three contentions are being increasingly supported by research in this area. First, the majority of poor readers reveal right ear superiority, a pattern similar to the normal population's. Second, the degree of right ear advantage in good readers is significantly greater than that in poor readers. Third, the between group difference appears only after a certain age. This is the age after which language functions become more fully lateralized in normal children (Satz, 1976, p. 278-279). These three points were hypothesized by Satz and Sparrow in 1970 (Satz, 1967). They found that at age nine, good and poor readers had right ear
advantage, and at age 13, the ear advantage for the poor readers was significantly lower than that of their matched normal readers.

Bryden (1970) worked with children whose ages were eight-to-twelve years. He found that the majority of good and poor readers have a right ear advantage for digits. However, the number of children having ipsilateral hand and ear preference tended to be higher among the good readers. Zurif and Carson (1970) also found no significant ear difference between groups. Poor readers tended to show a slight left ear advantage. Even though these two studies suffer from some methodological and technical shortcomings (Satz, 1976), they drew conclusions about a possible developmental factor in the relationship between learning disabilities and lateralization of language.

Witelson (1976) administered, among other things, a dichotic listening digits test to a group of 85 right-handed dyslexic boys and a group of 165 normal boys. He divided them into age groups of six-to-fourteen years. The groups were matched for I.Q., handedness, and socioeconomic status. The results indicated that both normal and dyslexics in each age group had a right ear superiority. However, the dyslexics showed a markedly lower number of the total digits recalled correctly. Witelson then concluded that the normal pattern of left hemisphere specialization for language did not rule out the possibility that left hemisphere functioning per se may be deficient in dyslexics even though it is mediating the typical cognitive process (p. 251).

E. **Summary**

The structure and function of the human brain has been discussed
in this chapter. Cognitive functions are found to be asymmetrically distributed between the two cerebral hemispheres. Language, logical thinking, and awareness of time are found to be lateralized to the left hemisphere in the majority of people. Musical, artistic, and visuospatial abilities are lateralized to the right hemisphere, by and large. Five methods of measuring hemispheric functional asymmetry have been reviewed. The chapter then discussed three major factors which influence the pattern of hemispheric asymmetry in normal populations. The relationship between language lateralization and learning disabilities has also been reviewed.
III. PROCEDURE AND DESIGN

A. Sampling

All public secondary schools in the city of Jeddah were considered. Two schools were selected at random using a random numbers table. Five 11th grade classes were also randomly drawn from each school. As indicated in the previous section, the 11th grade level consisted of two sections, the science and letters sections. The selected classes in each school were drawn from the field of all classes in both sections. The overall number of students was initially 308. Eleven of them were excluded because of incomplete or unavailable school records.

B. Medical Examination

A general physician examined the ears and the hearing ability of each individual student. It was not feasible to do a thorough audiometric scanning for such a large group. Seventeen students were excluded from the study after this preliminary examination because of either temporary ear pain or an achronic abnormality in their hearing.

C. Handedness

Students handedness was measured by means of a questionnaire. This is a generally accepted practice (see for example, Annett, 1970; Miller, 1971; Newcombe and Ratcliff, 1973; Dimond and Beaumont, 1974; Sampling matrices are shown in Tables 3 and 6 in Chapter IV.
Bryden, 1977; Satz and Associates, 1979). "Many investigators of hemispheric asymmetry use a questionnaire to screen their subjects for handedness as a matter of course" (Bryden, 1977, p. 617). The questionnaire used in this study consisted of ten items, selected from several tests available in the United States (Crovitz and Zener, 1962; Annett, 1970; Oldfield, 1971; White and Ashton, 1976). The ten selected items were considered culturally appropriate for Saudi Arabian students. For instance, the questionnaire did not ask about the hand by which a student ate because Muslims are required by their religion to eat with their right hand. Also, a question like "by which hand do you hold a fork?" was not asked. Muslim Arabs do not eat with forks.

The questionnaire was delivered to all students of the same school in the same class period. It was distributed and administered in both schools on the same day. Students were allowed ten minutes to fill out the questionnaire. See Appendices A and B for the Arabic and English versions of the test.

For each item, students were given two alternatives to choose from, left or right. They were instructed to choose one answer that represented their own case most accurately. Those who said that they do from three to seven items with their left-hand were later asked to perform the ten activities listed in the questionnaire. Two handedness indices were then computed for each of those students. The mean value was taken as the representative handedness index. This precaution was necessary, because in earlier investigations left-handers were less consistent in responding to questionnaires than were right-handers (Satz and Associates, 1967; Hardyck and Petrinovich, 1977).
D. Classification of Handedness

Students answers on the questionnaire were scored as follows:

\[
\text{Handedness Index (HI)} = \frac{R - L}{R + L} \times 100.
\]

The letter R represents the number of items the students said they did with their right-hand. The letter L represents the number of items the students said they did with their left-hand. A common research practice has been to assign in advance at least three intervals on the expected range of scores. They represented left-handedness, ambidexterity, right-handedness, and other characteristics (see as examples Crovitz and Zener, 1962; Annett, 1967; Teng and Associates, 1979).

However, as Satz and Associates (1967) argued, such methods of classification might not be sound because of the apriori determination of unjustified cutoff points. Besides, the term "ambidexterity" was inadequate. "Classification should be based on some ratio difference score derived from qualitative measures" (Satz and Associates, 1967, p. 298).

A different approach to classification was used in this study. The average handedness index, $\overline{HI}$, for the whole group was computed. According to Hicks and Kinsbourne (1978), about 90% of the population was supposed to be right-handed. The concept of $\overline{HI}$ was then expected to represent the average state in which the performance of the right-hand would outscore that of the left-hand. Scores of $HI > \overline{HI}$ were taken to represent right-handedness. $HI < \overline{HI}$ represented non-right-handedness and, therefore, was said to be left-handedness. This approach seemed logical in that it compared each student to the samples mean. The distribution of handedness is shown in Appendix C.
E. The Dichotic Listening Test

Dichotic listening is considered a valid and reliable technique for measuring hemispheric asymmetry of auditory and language functions (Richardson and Firlej, 1979; Springer and Deutsch, 1981). Hemispheric asymmetry for verbal materials which is inferred from ear advantage of the dichotic test has been shown by Kimura (1961) to agree very well with the results of the sodium amytal test. In dichotic listening tests, two auditory stimuli are presented simultaneously, one stimulus to each ear. After presenting a set of pairs, usually from two to four, the subject is asked to recall as many words as he can. The number of correct words recalled from each ear is counted. A laterality score is then assigned to each subject.

The dichotic listening tape for this study was developed in the Haskins Laboratory in New Haven, Connecticut. It consisted of 114 monosyllabic Arabic words. An Arabic and English copy of these words are presented in Appendices E and F. The same standard procedure that was usually used in the laboratory was also applied in developing the Arabic tape. The words were entered into the computer. Each word was carefully scrutinized on a monitor and confined to one-half of a second. The words were then divided into pairs on the condition that no two words in a pair started or ended with the same consonant. No word was repeated or paired with itself. The vowels of the two words in the pairs were kept mostly distinct. The total of pairs was 57.

The computer shuffled these pairs and randomly clustered them into groups of three pairs of words. There were 19 groups of three pairs of words. Each set constituted one trial and occurred in
exactly one- and one-half a second. There was no time-lag between any two successive pairs in the same set. The sets were kept 10 seconds apart. A high fidelity, dual-channel, reel-to-reel tape recorder was then used for recording the sets of words on a tape.

The first four sets of three pairs of words were recorded on the tape. One word of each pair was recorded on one channel, and its mate on the other. These four sets were the introductory trials. They were recorded again on the same tape. After one minute of silence on the tape, the remaining 15 sets of three pairs were recorded in a similar manner. This was the first half of the test. The computer then repeated the randomization of these 15 sets. Different clusters of three pairs were constructed. Each specific word, however, was still paired with its old mate. These 15 sets were then recorded on the tape after two minutes of silence following the first half. The output channels of the computer were reversed so that each word which was recorded on one channel in the first half occurred then on the other channel. Thus, there was no need for the subject later to reverse the headphone after the first half of the test.

F. Reliability of the Test

The reliability of the dichotic listening test was measured by the consistency of ear preference on retesting. The class with the least number of students was used for this purpose. There were 20 students in this class. They took the dichotic listening test twice. They were classified into left- and right-eared groups each time, according to the classification procedure used in the study. Only 19 students, however, were available for the retest. Table 1 indicates
the results of the two tests.

Table 1. The mean laterality index, $\bar{LI}^{1}$ and the number of right-eared (Re) and left-eared (Le) students in a reliability testing.

<table>
<thead>
<tr>
<th>Test</th>
<th>$\bar{LI}$</th>
<th>Re</th>
<th>Le</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>46</td>
<td>12</td>
<td>8</td>
</tr>
<tr>
<td>2nd</td>
<td>49</td>
<td>13</td>
<td>6</td>
</tr>
</tbody>
</table>

$^{1}$See classification of the cerebral speech, p. 48.

The table shows that two students shifted their ear preference on retesting. They both were classified as left-eared the first time. They showed right-ear preference in the second test. Thus, 89% of the students retained their ear preference on retesting.

G. Administering The Test

A Pioneer RT 909 reel-to-reel stereo deck and an SE-650 stereo headphones were used to administer the dichotic listening test to 280 students. The test was given to each student individually. Each student was given the following instructions: you are going to hear a list of words recorded in a somehow strange way; you will hear one-syllable, meaningful words; different words will come to each ear simultaneously; in each trial you will hear three different words in each ear; you will then be given enough time to repeat the words you heard; don't be concerned about order and repeat as many as you can; remember, this test has nothing to do with your school or teachers; you will be given the first four trials as an introduction, and
they will be repeated for you again before the experiment starts.

Each student then took the four introductory trials twice. The first half of the test was then presented; it contained 15 trials of three pairs of words. Ten seconds were given between trials for free recall. After two minutes of resting, the student listened to the second half of the dichotic tape. This contained the same 45 pairs arranged differently into sets of three. Also, each ear then received the words that it did not hear in the first half of the test. Each ear thus heard 90 different words in total.

H. Classification of the Cerebral Speech

There are different methods for scoring dichotic listening tests (Kuhn, 1973; Berlin and Cullen, 1977). Among these methods is a laterality index (or laterality quotient) which is used by several researchers. The laterality index is stated as follows:

$$LI = \frac{R_c - L_c}{R_c + L_c} \times 100$$

Rc is the number of words recalled correctly by the right ear. Lc is the number of correctly recalled words from the left ear.

The scale of this index extends from -100 to +100. A common research practice has been to divide this range into three regions, representing left, mixed, and right ear preferences. The cut-off points of these regions are usually not justified on an empirical basis. They may not represent real differences on the continuum of ear preference.

For this study a different approach was used in applying the above laterality index. As indicated in the classification of
handedness, the overall average index, $\bar{LI}$, is computed for the 280 students involved. This value was taken to represent the average state in which the right ear outscored the left. This average value was thus considered to represent the minimum index for right-earedness. Any score, $LI$, equal to or greater than $\bar{LI}$ was regarded as an indication of right ear preference. This reflects a left cerebral lateralization for speech and language (Kimura, 1961). Values of $LI$ less than $\bar{LI}$ were considered as an indication of non-right ear preference. It was called left-earedness, a reflection of right hemisphere laterality. The distribution of the ear preference is shown in Appendix D.

I. Achievement Scores

Science achievement was assessed by the results of the final examination in science courses. Students final scores in the science courses which have been taken during the last two years were obtained from the schools records. An average score on these finals was computed for each student to represent his achievement in science. The courses were as follows:

1. The ninth grade "general science and health,"
2. the first and second semester of 10th grade physics,
3. the first and second semester of 10th grade chemistry,
4. the first and second semester of 10th grade biology.

The final examination in "general science and health" was a national test that was taken by every ninth grade student in the country. The test was written by science education personnel in the Ministry of Education. The rest of the tests were local. They were
written by the group of science teachers in each school. These tests are usually approved by the testing division at the Department of Education for the Western Region. All of the tests were of the paper-and-pencil type. They consisted mainly of essay questions measuring for cognitive recall. The scale on all of these tests ranged from 0 to 100 points.

J. Analysis of Data

The one-way analysis of variance, fixed model, was utilized for comparing the mean achievement scores of the different groups involved. The Pearson's r-correlation coefficient was also used to give further evidence on the nature of the relationship between achievement in science and the degree of cerebral lateralization of the Arabic language. Table 2 shows the analysis of variance design.
Table 2. A summary of a method for computing F in the one-way ANOVA, fixed model.

<table>
<thead>
<tr>
<th>Source of Variance</th>
<th>Sum of Squares (SS)</th>
<th>df</th>
<th>Mean Squares</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between-Groups</td>
<td>( g \left( \sum_{j=1}^{g} \frac{n_j}{N} \right)^2 - \frac{g (\sum_{j=1}^{g} \sum_{i=1}^{n_j} x_{ij})^2}{N} )</td>
<td>g-1</td>
<td>SS(_b)</td>
<td>( \frac{MS_b}{MS_w} )</td>
</tr>
<tr>
<td>Within-Groups</td>
<td>( g \sum_{j=1}^{g} \sum_{i=1}^{n_j} x_{ij}^2 - g \sum_{j=1}^{g} \left( \frac{n_j}{N} \right)^2 )</td>
<td>N-g</td>
<td>SS(_w)</td>
<td>( \frac{MS_b}{MS_w} )</td>
</tr>
<tr>
<td>Total</td>
<td>( g \sum_{j=1}^{g} \sum_{i=1}^{n_j} x_{ij}^2 - \frac{g (\sum_{j=1}^{g} \sum_{i=1}^{n_j} x_{ij})^2}{N} )</td>
<td>N-1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\( MS_b \) is the between-groups mean square; \( MS_w \) is the within-groups mean square.

In analyzing the major objectives, the 280 students were classified into right- and left-eared groups according to their laterality indices on the dichotic listening test. The ANOVA was then used for contrasting the mean achievement scores of the two groups. In analyzing the secondary objective, students in each of the two ear groups were divided into left- and right-handed groups according to the results of the handedness questionnaire. The ANOVA was utilized in searching for significant differences between the mean achievement score of the four ear-by-hand groups.

In addition, the correlation between cerebral laterality of language and achievement in science was investigated. Correlation was considered useful in that it would provide more information about the strength and direction of the relationship between the two variables.
The Pearson's r correlation coefficient between the degree of language lateralization and science achievement for the whole sample of 280 students was computed. The same coefficient was also computed for the four ear-by-hand groups.

K. The Mathematical Model

The mathematical model for the ANOVA is: \[ X_{ij} = \mu + \alpha_j + \epsilon_{ij} \].

Where: \( X_{ij} \) is the mean achievement score for the \( i \)(th) student in the \( j \)(th) group. \( \mu \) is a constant; it is the overall population average of achievement scores. The between-group effect is \( \alpha_j \). It is a constant for all scores in a particular group, and it varies across groups. In other words, \( \alpha_j \) reflects the effect that a particular person is classified under the corresponding group to which he belongs. The error term is \( \epsilon_{ij} \). This is a random element that cannot be explained by the experiment. It reflects the variation of an \( i \)(th) score within its \( j \)(th) group.

The model then indicates that each achievement score \( X(ij) \) is composed of the sum of three numbers. The first one is the population grand mean. The second one is the deviation of the mean of group \( j \) from the grand mean. The third number represents the deviation of the score \( X(ij) \) itself from the mean of the group to which it belongs.

The mathematical formula for the Pearson's r-correlation coefficient is as follows:

\[
 r = \frac{\sum (X-X) (LI-LI)}{\sqrt{\sum (X-X) (LI-LI)}}
\]

Where \( X \) is the average achievement score in science for each student
in a particular group, \( \bar{x} \) is the mean achievement score for that group, \( LI \) is the laterality index of a student in a group, \( \bar{LI} \) is the average laterality index for the group.

I. Power of the Test

The level of significance was set at \( \alpha = 0.05 \). This means that the probability of Type I error was 5%. A related concept that should be indicated in this regard is the probability of Type II error. This is determined by the power of the F-statistic. A power level of 0.80 was selected for this research. Type II error is thus fixed at the probability level of 0.20.

Usually a power level of 80% is considered as the convention for most problems. This level provides at least an 80% probability that a null hypothesis will be rejected. This level is consistent with the idea that the general seriousness of Type I and Type II errors is of the order of .20/.05. Type I errors are considered as being four (4) times more serious than Type II errors, when \( \alpha \) is set at 0.05 (Courtney, 1983).

Once the power of the test is determined, it is possible to determine the effect size (Cohen, 1969). The latter is "the degree to which the phenomenon exists in the population, or the degree to which the null hypothesis is false" (Courtney, 1983). The effect size dictates the minimum sample size required for the stated power of the test and the degrees of freedom involved. Other things being equal, larger sample size is required for smaller effect size. In this study, the effect size is 0.25 for the major problem and 0.40 for the secondary problem.
M. Summary

To recapitulate, this chapter presented the procedure and design of the study. Ten 11th grade classes were randomly selected from two schools in the city of Jeddah, Saudi Arabia. The number of the participating students was 280, after removing those with hearing problems or incomplete school records. Handedness was determined by a ten-item questionnaire. A dichotic listening test of monosyllabic Arabic words was used for assessing hemispheric lateralization of language. Hand and ear preference were judged in terms of the group's norms. Science achievement was represented by the average score of the final examinations in science which had been taken during the last two school years. In this study, the one-way ANOVA, fixed model, and the Pearson's r-correlation coefficient were utilized in testing the stated hypotheses. The application of these statistical measures is presented in the next chapter.
IV. PRESENTATION AND INTERPRETATION OF THE DATA

A. The Major Problem

The major purpose of the study was to examine the relationship between achievement in science and lateralization of cerebral language in male Saudi Arabian students. A laterality index was computed for the 280 students involved according to the results of the dichotic listening test. The total index was summed up. The average laterality index (LI) for the whole sample was found to be 39.98, a positive value. This meant that 39.98% of the time, the performance of the students right ears excelled that of their left ears in hearing the dichotically presented words. The right ear heard, on the average, 39.98% more words than did the left ear. This 39.98 value was then taken to represent the minimum index of right-earedness, or of left cerebral lateralization for Arabic language. Right and left lateralization of language was thus judged in terms of the groups mean.

The whole sample was then divided into left and right lateralized for language. Those students who obtained laterality indices greater than or equal to 39.98 were classified as right-eared. Students with LI < 39.98 were considered having left ear preference. Table 3 shows the number of students in each category and the corresponding percentage.
Table 3. The numbers and percentages of right-eared (Re) and left-eared (Le) students.

<table>
<thead>
<tr>
<th></th>
<th>Re</th>
<th>Le</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students</td>
<td>188</td>
<td>92</td>
<td>280</td>
</tr>
<tr>
<td>Percentage</td>
<td>67</td>
<td>33</td>
<td>100</td>
</tr>
</tbody>
</table>

One-hundred and eighty-eight students achieved laterality indices above the mean and were considered as right-eared. According to Kimura (1961) these students processed Arabic speech mainly in their left cerebral hemisphere. They represented 67% of the population at hand. The remaining 33% achieved laterality indices below the mean. They were regarded as left-eared students. They utilized their right hemisphere in processing Arabic speech more than 39.98% of the time rather than their left hemisphere.

The percentage of right ear advantage among adult English speaking populations was found to be higher than 67%. Lake and Bryden (1976) concluded that right ear advantage occurred on the average in 73.6% of the males in the general population. There are several sources for this difference in results between this study and others, including language (Arabic vs English), the type of verbal stimuli (words, digits, or consonant-vowel syllables), the rate of presentation of stimuli, and the method of developing the test itself. In addition, the cultural difference and the method of classification may also be major sources of variation between this study and other English language experiments.
To test the main hypothesis, these two groups were contrasted with each other on the basis of their achievement in science curricula. An achievement score was computed for each student by averaging his grades in seven science classes that he had taken during the previous two school years. One-way analysis of variance, fixed model, was applied in order to test for variation in achievement between the two groups. The computation of $F$ is summarized in Table 4.

Table 4. The calculations for ANOVA, the difference in achievement between left and right lateralized students.

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>Degrees of Freedom</th>
<th>Mean Squares</th>
<th>$F$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>6840.02</td>
<td>1</td>
<td>6840.02</td>
<td>33.17</td>
</tr>
<tr>
<td>Within Groups</td>
<td>57317.14</td>
<td>278</td>
<td>206.18</td>
<td></td>
</tr>
<tr>
<td>Totals</td>
<td>64157.16</td>
<td>279</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

As indicated in Table 4, the computed $F$-value was 33.17. Significance between mean achievements at the 5% level with degrees of freedom of 1 (numerator) and 278 (denominator) required an $F$-value of 3.89 or higher. Thus, the null hypothesis of the major problem was rejected. There was a significant difference in achievement in science between the two groups.

Students who demonstrated right-earedness or left lateralization for the Arabic language with respect to the average group's performance on the dichotic test were better achievers in science than their left-eared counterparts. This finding was not unexpected. Right-eared
students may have utilized the appropriate language centers of their brains. These are usually in the left cerebral hemisphere. Right-eared students were more adequately equipped with the cerebral tools which enabled them to reach an optimal level of the understanding of speech and verbal interaction (Friedman and Associates, 1976). Assuming this to be true, students with right-ear preference would find verbal instruction in science easy to assimilate.

In addition, science is a rational enterprise. It deals with quantitative measurements, mathematical models, and logical inferences. Sequentiality and order are important. Laws, principles and generalizations are presented in algebraic equations. Activities like these are generally perceived and processed in the left cerebral hemisphere. Being a good achiever in science thus usually requires an adequate performance of the left cerebral hemisphere (Bogen, 1977). Accordingly, the findings of this study support the position that right-eared students, who were also better achievers, seemed to rely on left hemisphere strategies in learning science.

B. The Secondary Problem

The secondary problem of the research was to test whether handedness was a factor in the relationship between lateralization of cerebral speech and achievement in science. Right- and left-eared students were classified as right- or left-handed according to their scores on the handedness test. Four groups were differentiated. Their achievement scores were contrasted by means of the one-way analysis of variance.

A handedness index was computed for each student. The indices
were summed and divided by the total number of students (280). The mean value ($\bar{HI}$) for the handedness index was found to be 79.72. Similar to the classification of the cerebral speech, students were divided into right- and left-handed groups. Those who obtained an $HI \geq 79.72$ were regarded as right-handers. Students with an $HI < 79.72$ were called left-handers. The number and percentage of students in each category are presented in Table 5.

Table 5. Numbers and percentages of right-handed (Rh) and left-handed (Lh) students.

<table>
<thead>
<tr>
<th></th>
<th>Rh</th>
<th>Lh</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of</td>
<td>240</td>
<td>40</td>
<td>280</td>
</tr>
<tr>
<td>Students</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage</td>
<td>86</td>
<td>14</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 5 indicates that 240 students obtained handedness indices equal to or greater than 79.72. They were classified as right-handers. They represented 86% of the 280 subjects. The remaining 14% were classified as left-handers because their handedness indices were less than 79.72. The number of those left-handers was 40.

Left- and right-handed students were subsequently divided into left- and right-eared groups according to their scores on the dichotic listening test. Table 6 indicates the resulting four different groups.
Table 6. Numbers and percentages of the students in each ear-hand group.

<table>
<thead>
<tr>
<th></th>
<th>LeLh</th>
<th>ReLh</th>
<th>LeRh</th>
<th>ReRh</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Students</td>
<td>19</td>
<td>21</td>
<td>73</td>
<td>167</td>
<td>280</td>
</tr>
<tr>
<td>Percentage</td>
<td>6.8</td>
<td>7.5</td>
<td>26.1</td>
<td>59.6</td>
<td>100</td>
</tr>
</tbody>
</table>

As Table 6 indicates, 6.8% of the total sample were classified as left-eared and left-handed. 7.5% were right-eared and left-handed. Students classified as left-eared and right-handed formed 26.1% of the whole sample of 280 students. The remaining 59.6% were found to be right-eared and right-handed.

The analysis of variance was used to test the secondary hypothesis. The mean achievement scores in science for each of the four groups were compared. Table 7 summarizes the computations for the ANOVA.

Table 7. The calculation for ANOVA, differences in achievement among the four ear-hand groups.

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Squares</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between</td>
<td>7667.27</td>
<td>3</td>
<td>2555.76</td>
<td>12.49</td>
</tr>
<tr>
<td>Within</td>
<td>56489.85</td>
<td>276</td>
<td>204.67</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>64157.12</td>
<td>279</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The computed F-values shown in Table 7 is 12.49. This number exceeded the tabulated value of 2.65 for $\alpha = 0.05$ and df = 3,276. The
secondary null hypothesis was therefore rejected. There was a signif-
icant difference between the four ear-hand groups.

The procedure of the least significant difference (LSD) was ap-
plied for a detailed comparison between the groups. The computations
are summarized in Table 8.

Table 8. The decision table for the LSD comparisons

<table>
<thead>
<tr>
<th>Groups</th>
<th>N_i</th>
<th>(\bar{X}_i)</th>
<th>(\bar{X}<em>i - \bar{X}</em>{i+1})</th>
<th>LSD at (\alpha=.05)</th>
<th>Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>ReRh</td>
<td>167</td>
<td>77.89</td>
<td>10.64</td>
<td>5.02</td>
<td>Significant</td>
</tr>
<tr>
<td>ReLh</td>
<td>21</td>
<td>67.25</td>
<td>3.36</td>
<td>5.02</td>
<td>Not Significant</td>
</tr>
<tr>
<td>LeRh</td>
<td>73</td>
<td>63.89</td>
<td>1.81</td>
<td>5.02</td>
<td>Not Significant</td>
</tr>
<tr>
<td>LeLh</td>
<td>19</td>
<td>62.08</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The mean achievement scores of the four groups are presented in the
\(\bar{X}_i\) column in a decreasing order. \(N_i\) is the number of subjects in each
group; \(\bar{X}_i - \bar{X}_{i+1}\) is the difference between successive means. LSD for
unequal cell size is computed from the equation:

\[
LSD = t_{.025} \sqrt{\left(\frac{1}{n_1} + \frac{1}{n_2} + \frac{1}{n_3} \frac{1}{n_4}\right)S^2}
\]

Where \(t_{.025}\) is the tabulated value of the t-distribution at 0.025 con-
fidence level and 276 degrees of freedom, \(MS_w\) the value of the With-
in-group mean square was used to estimate \(S^2\) (see Table 7).

Table 8 shows that a difference of 5.02 or more between two
groups means is required for significance. The difference between the
first two groups exceeded 5.02. Therefore, the mean achievement score
of the group of right-handers with right ear preference was
significantly higher than that of the group of right-eared, left-handed students. Consequently, the first group achieved in a significantly higher level than any of the other three groups.

Recalling the conclusion of the previous section, students with right ear preference in general were found to have an achievement mean score in science which was significantly higher than that of the left-eared group. When the right-eared group was broken down into left- and right-handers, the above analysis showed that the group of left-handers and right ear preference achieved least. Combining the two findings, one concludes that achievement in science may be influenced by an interaction between handedness and language lateralization, rather than by the latter alone. Thus, most of the variance in the first analysis may have come from the subgroup of right-handers within the right-eared group.

In conclusion, handedness was shown to be a factor in the relationship between language lateralization and science achievement. The effect of handedness had a particular pattern. Right-handedness was associated with the highest achievement level when it was combined with right-earedness, left hemisphere language. This was not true for left-earedness. Right-handers with left ear preference, right hemisphere language, did not achieve as high. Left-handedness, in contrast, was associated with lower achievement in science in the case of right-ear preference. These conclusions are further supported by the correlation coefficients which are computed and discussed below.

C. Correlation

The correlational computations were accomplished as an additional
examination of the relationship between the degree of cerebral lateralization for Arabic language and achievement in science. Pearson's \( r \)-correlation coefficients were computed for the whole sample and for the several subgroups. The values of \( r \) are presented in Table 9.

**Table 9.** The correlation coefficients between achievement in science and the degree of laterality for language.

<table>
<thead>
<tr>
<th>The Group</th>
<th>Number of Students</th>
<th>( r )</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Students</td>
<td>280</td>
<td>0.45</td>
</tr>
<tr>
<td>Right-eared Students</td>
<td>188</td>
<td>0.50</td>
</tr>
<tr>
<td>Left-eared Students</td>
<td>92</td>
<td>-0.02</td>
</tr>
<tr>
<td>Right-eared/right-handed</td>
<td>167</td>
<td>0.75</td>
</tr>
<tr>
<td>Right-eared/left-handed</td>
<td>21</td>
<td>-0.01</td>
</tr>
<tr>
<td>Left-eared/right-handed</td>
<td>73</td>
<td>-0.03</td>
</tr>
<tr>
<td>Left-eared/left-handed</td>
<td>19</td>
<td>-0.15</td>
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</table>

A medium positive correlation, \( r = 0.45 \), was found between the degree of cerebral lateralization and science achievement. This value jumped to be of a relatively higher magnitude when the right-eared students were considered separately, \( r = 0.50 \). The value of \( r \) was even higher, \( r = 0.75 \), for the right-eared students with right hand preference.

These conclusions were in agreement with the findings reported in the previous sections, i.e., right-sidedness of both the preferred ear and hand associated with the highest correlation level between the degree of language lateralization and achievement in science. Thus, the
findings support the position that right-handers with right ear preference (or left hemisphere language) may have a better neurological makeup for perceiving, processing and assimilating scientific information that is conveyed mainly in a verbal mode, as indicated by a significantly higher score of achievement in science. These students may be viewed as having a higher level of neurological readiness for science education which is heavily loaded with verbalism.

Table 9 also shows that the correlation coefficient was of a negligible value for the group of left-eared students in general, \( r = -0.02 \). The values of \( r \) were also negligible in the two cases of crossed hand and ear preference, \(-0.01\) and \(-0.03\). For the group of left-handers who also had left ear preference, \( r \) was of a weak negative value, \(-0.15\). Reconciling these values with the value of 0.45 which was found for the whole sample, it was concluded that left-earedness and/or left-handedness are associated with lower achievement in science. Left-handedness and left-earedness (or right hemispheric laterality for language) may be viewed as disturbing factors which hindered students conceptualization of spoken language and written materials upon which science curricula depended heavily.

Such conclusions, however, should be received in the light of the limitations of the study. Some of these limitations should be recalled. First, the research was confined to male students ranging in age from 16 to 18, in grade 11. Sex and age were not considered as variables in the study. The notions of mixed-ear preference and ambidexterity were not given full recognition in the study. Also, psychological and environmental variables were not investigated; it was assumed that randomization should have minimized their effects.
D. Summary

The chapter presented the data and findings of the study. Thirty-three percent of the 280 students were found to have non-right ear preference, left earedness. Of the total group, 14% were left-handers. Right-eared students as a group achieved at a significantly higher level in science than did the left-eared. The achievement level of the right-eared students who were also right-handers was significantly higher than that of the other three hand-by-ear groups. Correlation between the degree of language lateralization and science achievement supported these findings. The Pearson's r-correlation coefficient was highest, +0.75, in the case of right-handedness and right-earedness combined.
V. SUMMARY, CONCLUSIONS, IMPLICATIONS AND RECOMMENDATIONS

A. Summary

The major objective of the study was to investigate the relationship between cerebral lateralization for Arabic language and achievement in science. A secondary purpose was to examine the relationship between language laterality and science achievement by students who were left- and right-handed. The study was conducted in Jeddah, Saudi Arabia where ten classes were randomly selected from the 11th grade level in two boys schools.

A dichotic listening test of Arabic monosyllabic words was devised for measuring hemispheric laterality. Stimuli were grouped in sets of three pairs of words occurring in one and one-half seconds. Handedness was measured by a ten-item questionnaire. Right ear or hand preference was assigned to a student when his corresponding index was equal to or greater than the mean index for the whole sample.

Out of the 280 students involved in the study, 67% were classified as having right ear preference, left hemisphere lateralization for language. This group obtained a mean achievement score in science which was significantly higher than that of the 33% left-eared subjects, α = 0.05. Among the right-eared group, right-handed students showed a significantly higher level of science achievement. The mean achievement score for the right-eared, right-handed students was even higher than that of any other subgroup.

There was a positive correlation, r = 0.45, between achievement in science and the degree of cerebral lateralization for language.
The correlation coefficient was higher, $r = 0.50$, when the left-eared students were not included. The value of $r$ was even higher (0.75, the highest among subgroups) when only right-handers with right ear preference were considered. In the case of left-earedness and left-handedness, the correlation was of a weak negative value, $r = -0.15$. All of the remaining subgroups showed negligible correlation between the degree of language laterality and science achievement.

B. Conclusions

The conclusions drawn from the study were as follows:

1. Like other scriptive languages, the Arabic language was in general perceived and processed in the left cerebral hemisphere in the majority of the native speakers.

2. Achievement in science depends upon the organization of linguistic functions in the cerebral hemisphere and the corresponding pattern of language lateralization.

3. Left hemispheric lateralization of language furnishes a more adequate substrate for a higher level of achievement in science than does right hemispheric lateralization.

4. The degree of left hemispheric lateralization of language also correlates positively with science achievement.

5. Handedness is a factor in the relationship between science achievement and language lateralization.

6. Right-handedness and left cerebral lateralization of language together, provide a high level of neurological readiness for learning science.

7. Left-handedness and/or right hemispheric language can be
viewed as distracting elements which may hinder or reduce the level of achievement in science.

A remark is viewed necessary here. The elevated level of science achievement in the case of right-handers with left cerebral lateralization of language may be because these students have an optimal neurological setup for understanding scientific knowledge itself. For example, these students may be capable of utilizing cognitive strategies which are suitable for assimilating and conceptualizing the content of science subject matter. An alternative explanation, however, is that the higher level of achievement in these students may stem from a greater proficiency in understanding verbalism and didactic teaching which prevailed in science classrooms in the Saudi schools. In addition, it is possible that those students who are capable of understanding scientific content or assimilating verbal instruction have attained a developed self concept which in turn may also contribute to their higher level of achievement.

C. Implications for Science Education

The findings of this study indicate that differences in achievement in science are associated with neurological differences. Specifically, low achievement level is related to incomplete hemispheric lateralization of language. Right cerebral lateralization for language may be creating difficulties in comprehending verbal instruction, or it may be hindering students assimilation of rational and analytical subject matter in science. This implies that the level of achievement by those students may be elevated by introducing them to modes of science instruction which depend less on verbalism and/or by
teaching them the nonanalytic and wholistic aspects of science. Both suggestions imply genuine involvement of the right cerebral hemisphere in addition to the left. Science education as a whole, with all its components such as curriculum development, instruction, and evaluation, should be oriented towards a balanced concern of both cerebral hemispheres.

Bogen (1977) indicates that even though some anatomical asymmetry underlies the potential for hemispheric lateralization, the level to which hemispheric capacities are developed depends upon environmental exposure (p. 144). Bogen then indicates that we need to "learn to live within nature as bilaterally educated, whole persons" (p. 146).

Nebes (1977) also argues in favor of the bilateral development of the individual. He writes:

If the right hemisphere does indeed process data in a manner different from the left, we may be short-changing ourselves when we educate only left-sided talents in basic schooling. Perhaps when people speculate about an inverse relationship between scholastic achievement and creativity, they are really talking about the effect of overtraining for verbal skills at the expense of nonverbal capacities. Many problems can be solved either by analysis or synthesis; but if people are taught to habitually examine only one approach, their ability to choose the most effective and efficient answer is diminished. Increased understanding of how the minor hemisphere works will hopefully lead to better training in how to choose between and to use the skills of both hemispheres of the human brain (p. 105).

The call for bilateral education in this study then is not unprecedented. Several neuroscientists, such as Bogen, Nebes and others, by working with neurological patients, have perceived the necessity of the development of the right hemisphere. Their
recommendations may sound theoretical in the sense that they seem to be interpolations from clinical data to the normal populations. In this study, however, the importance of bilateral hemispheric development comes as logical implications of a research experiment which has been conducted in the field of education and within the school environment.

The concept of right hemispheric instruction in science may not be easily appreciated by some science educators. It conflicts with the assumptions of objectivity, rationality, sequentiality, and precision, which are taken for granted as intrinsic to science. Dewey (1930) argues that "logical order is not a form imposed upon what is known; it is the proper form of knowledge as perfected" (p. 256). He argues that the only means by which science progresses is the "scientific method" which he deliberately articulates in five precise and mandatory steps, "the method by which alone science is science." He states:

Science represents the office of intelligence, in projection and control of new experiences, pursued systematically, intentionally, and on a scale due to freedom from limitations of habit. It is the sole instrumentality of conscious, as distinct from accidental, progress. And if its generality, its remoteness from individual conditions, confer upon it a certain technicality and aloofness, these qualities are very different from those of merely speculative theorizing (p. 266).

Such assertions about science from influential thinkers like Dewey and others have been inculcated in the mind of some science educators so deeply that they could not see science otherwise.

However, several philosophers and historians of science recently began to differentiate between textbook science and science as it is
viewed by scientists. They acknowledged the subjective, arational, and wholistic aspects of science as well. Kuhn (1970) indicates that logical presentations and precise terminology are generally characteristic of textbook science, of the final produce which is neatly recorded by scientists in order to transmit it to the interested and specialized students. Kuhn (1970) sees in science a field of practice in which observations are restricted by the psychological states of the observer. Inquiry is never free. It is controlled by the prevailing "paradigm" at a particular period of time.

The role of the wholistic, intuitive, and imagery types of thinking, which are supposedly right hemispheric processes, in the development of science is also recognized by eminent scientists. For example, KeKulé, the discoverer of the benzene ring, describes the role of imagination in his puzzling discovery. He writes:

I sat in this room and wrote on my textbook, but could make no progress - my mind was on other things. I turned my chair to the fire and sank into a doze. Again the atoms were gamboling before my eyes. Little groups kept modestly in the background. My mind's eye, trained by the observation of similar forms, could now distinguish more complex structures of various kinds. Long chains here and there more firmly joined; all winding and turning with snake-like motion. Suddenly one of the serpents caught its own tail and the ring thus formed whirled exasperatingly before my eyes. I woke as by lightning, and spent the rest of the night working out the logical consequences of my hypothesis (cited by Leatherdale, 1974, p. 20).

Kuhn (1970) cites evidence that science does not progress through gradual accumulation of knowledge. Rather, advancement in a field comes about when a practitioner suddenly experiences a shift in his perception, in his "visual-conceptual" views of the world. Several variables are intuitively seen in a new integrated pattern; a
new "paradigm" is then born. Analogy and metaphores are consistently used by scientists in their research. Analogy is considered by Oppenheimer as "an indispensable instrument of science." Analogy, for example, helped La- volisier understand the mechanism of combustion. He drew analogy between respiration and the combustion of carbon (Leatherdale, 1974). Most of the scientific terms and expressions are of metaphoric origin. For instance, the term "travel" is applied to light, "fluid" is applied to air, "waves" and "rays" are applied to matter. Even the terms force, motion and power, are intrinsically metaphoric expressions; however, such terms seem "so natural that they become, in a sense, invisible metaphors and pass for straightforward descriptive terms" (Leatherdale, 1974, p. 233).

Thus, claiming for right hemispheric instruction in science along with the left hemispheric types does not conflict with the nature of science. As Sagan (1977) argues, science advances through the cooperation of both hemispheres. The right hemisphere feels and sees patterns in nature. The left hemisphere tests these patterns to see whether or not they fit the data.

The findings of this study have implications for research in the field of science education as well. Bilaterally balanced education in science requires substantial research efforts and diverse field work. It is appropriate in this regard to recall John Dewey's concept of the interaction between means and ends. Dewey (1930) would argue that educational research should start with a broad unspecified objective. Observations then take place "for surveying the possible means and hindrances." An appropriate mean or set of means are then
selected, at the same time the aim is gradually focused and starts to take shape. "Aims are thus outgrowth of existing conditions." The means are then utilized in order to achieve the aims. However, these aims are only temporarily valid. They are not finalities or ends in themselves. Because the education process is continuous, it is impossible to state permanently valid objectives. Mobility and dynamism of the process should grant instability to the stated objectives (Dewey, 1930).

Differences in achievement in science are associated with the hemispheric distribution of language as a cognitive function and to handedness. The hemispheric distribution of cognitive functions and handedness should be viewed as variable in learning science. This may not always be true for singular cases, however, educational research is seldom concerned with individual cases. The patterns of hemispheric lateralization of cognitive functions and handedness may then be determined and utilized as a basis of differentiating between experimental and control groups in future research concerning science learning.

Currently existing research findings may also be re-examined. Conclusions concerning differences in science achievement between groups may be revised for extended explanations in terms of the possible effect of handedness and cerebral lateralization of cognitive functions.

An important relevant topic of research is teacher effectiveness. Instruction for a balanced growth of the function of the two cerebral hemispheres would depend heavily upon the effectiveness of the science teacher. Research on teacher effectiveness in the past
had adopted a process-product scheme in which teacher performance (as the process) was correlated with some measures of teacher effectiveness (as the product). Medley (1982) reviews the early research on teacher effectiveness and indicates its weaknesses. He develops a new scheme in which teacher interaction and pupil characteristics are introduced as variables influencing teacher effectiveness. Medley's concept of pupil's characteristics should be widened to encompass neurological characteristics such as handedness and the pattern of lateralization of language and other cognitive functions.

D. Recommendations

Several recommendations were considered useful for future research. This study should be replicated on a similar population, using a similar dichotic listening test and methodology. Similar studies should be conducted in Saudi girls schools as well. This would provide evidence concerning the internal validity of the current study. The sex differences in the pattern of cerebral lateralization of language and its relation to science achievement would also be clarified in such replications.

It would be appropriate to conduct studies like this one in other Arabic speaking countries. This would test the applicability of the findings reported in this study in other social and environmental settings within the Arabic world. These studies may also investigate the influence of the social and traditional factors on the relationship between science achievement and Arabic language lateralization.

A massive nationwide survey of handedness should be made in the Saudi schools. Male and female schools should be included. This
would provide unprecedented data base which is a primary requirement for the progress of the neurological research in the country. The percentage of left-handedness in the Saudi population at large would not be known without such a comprehensive survey. Questionnaires would be a convenient device for this large-scale survey.

The relationship between cerebral lateralization of language and achievement in other school subject-matter should be studied. This would be one of the first steps to be taken in order to create what Chall and Mirsky (1978) call the "educational neuroscience" discipline. Studies like these may widen the scope of applicability of the neuroscientific findings in the actual school environment.

It would be informative to devise studies which would investigate the cause of the higher level of achievement in science in the case of right-handedness and left cerebral lateralization of language. Such studies may explain whether or not the higher achievement level is caused by elevated linguistic capabilities. Similar studies may be conducted in other subject-matter areas if differences in achievement are found.

Several professionals should collaborate and devise various types of dichotic listening tests, both verbal and non-verbal. Standardized procedures for utilizing these tests should be developed and made available to researchers. Practice like this would provide a variety of valid and reliable instruments which would be very important for the advancement of the expected field of "educational neuroscience."
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APPENDICES
APPENDIX A

The handedness questionnaire written in Arabic

حب التعليمات والأمثلة التي في الصفحة السابقة، ضع علامة تجاه
في الخانة التي تمثل حالتك بصورة عامه لكل فقرة من الفقرات العشيرة
التالية:

المواضيع

الجواب

بيني

1- بأي يد تكتب؟

2- بأي يد ترسم الحجر أو الكره؟

3- بأي يد تمسك مشرب تنس الطاولة " بنج بونج "؟

4- بأي يد تمسك عود الكبري عند اجعلاه؟

5- بأي يد تمسك النقش عند استعماله؟

6- بأي يد تعفك مرة أحسن أنما تتعوك؟

7- بأي يد توزع ورق اللعب " في البلوت أو الباصرة "؟

8- بأي يد تعفك غلاة العلبة عندما تفتحها؟

9- بأي يد تعفك عندما تربط مسرا " برغبا "

في الخشب؟

10- بأي يد تعفك المطرقة عند استعمالها؟
APPENDIX B

The English Translation of the Handedness Questionnaire

According to the instructions and examples given on the previous page, answer the questions below by marking left or right. Give one answer which best represents your own case.

<table>
<thead>
<tr>
<th>QUESTIONS</th>
<th>ANSWERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Which hand do you write with?</td>
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<tr>
<td>2. With which hand do you throw a ball?</td>
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<tr>
<td>3. With which hand do you hold the racket when playing table tennis?</td>
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<td>4. With which hand do you strike a match?</td>
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<td>5. Which hand do you use when cutting with scissors?</td>
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<td>6. With which hand do you brush your teeth?</td>
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<td>7. With which hand do you deal playing cards?</td>
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<td>8. With which hand do you hold the lid when you open a jar?</td>
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<tr>
<td>9. With which hand do you hold a screwdriver?</td>
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<tr>
<td>10. With which hand do you hold a hammer?</td>
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</tbody>
</table>

1 Students were given an introductory sheet on which was indicated the purpose of the questionnaire and some examples on how to answer the questions.
APPENDIX C

The frequency distribution of handedness, number of students (f) versus handedness index (HI)
APPENDIX D

The frequency distribution of cerebral laterality, number of students \( (f) \) versus laterality index \( (LI) \)
APPENDIX E

A list of the Arabic words which were used on the dichotic listening tape, written in Arabic

<table>
<thead>
<tr>
<th>Arabic Word</th>
<th>Translation</th>
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<tbody>
<tr>
<td>ابتدأ</td>
<td>Start</td>
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<tr>
<td>لا هو الا أن</td>
<td>There is nothing but</td>
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APPENDIX F

A list of the Arabic words which were used on the dichotic listening tape, written in Latin letters.

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