THE RELATIONSHIP BETWEEN DIVERGENT AND ANALYTICAL THINKING AND HEMISPHERIC SPECIALIZATION IN MAN

A Thesis

Presented to

the Faculty of the Department of Psychology

University of Houston

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

By

Mary Ellen Hayden

December, 1973

THE RELATIONSHIP BETWEEN DIVERGENT AND ANALYTICAL THINKING AND HEMISPHERIC SPECIALIZATION IN MAN

An Abstract of a Thesis

Presented to

the Faculty of the Department of Psychology

University of Houston

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

By

Mary Ellen Hayden

December, 1973

ABSTRACT

The two cerebral hemispheres in man are specialized for processing information in diverse ways. One side analyzes input in a logical, sequential manner. The other side is more intuitive, recognizing wholes from parts and combining information to form relationships. Previous experiments have identified individuals within the normal population who have poorly lateralized hemispheric functions. In a college population this generally is manifested by suppression of the synthetic, Gestalt functioning typical of the right hemisphere. The present experiment was an attempt to assess the effect of poor lateral specialization on some higher cognitive abilities, specifically analytical and divergent thinking.

Fifty-four Ss from the Arts and Sciences Dean's List and from the Honors Program at University of Houston were screened on the Harris Test for Lateral Dominance and on Nebes' Arc-Circle Test of right hemispheric accessibility. Twenty-four of these Ss were assigned, on the basis of their test performance, to two groups: Well Lateralized Group and Poorly Lateralized Group. The two groups were then compared on two batteries of tests. The Analytic Battery included five tests: Flexibility of Closure, Planning, Concept Mastery, Arithmetic, and Reasoning. The Divergent Battery was composed of eight of Guilford's tests designed to tap

flexibility, fluency, and originality of thought. The hypothesis being evaluated was that no differences would be found between the groups on tests in the Analytic Battery because these tap left hemispheric functioning which is not affected by poor laterality in this population. The Well Lateralized Group was expected to be superior on tests in the Divergent Battery, however, because these tests require a bimodal approach for solution.

Performance on two tests in the Analytic Battery was significantly higher for the Well Lateralized Group than for the Poorly Lateralized Group. One of the tests, Flexibility of Closure ($t=2.68$, $df=22$, $p<.02$, two-tailed test), probably requires a bimodal approach for solution and, therefore, should have been included in the Divergent Battery. Differences on the second test, Planning ($t=2.26$, $df=22$, $p<.05$, two-tailed test), are more difficult to understand but may be related to the concrete nature of the test items. The only Divergent Test which resulted in significantly different performance by the two groups was Decoration ($t=1.81$, $df=22$, $p<.05$, one-tailed test), which involves spatial elements. The short time limit imposed on the Ss during the Divergent Tests may have prevented group differences on the other tests in the battery.

The primary value of the present research has been to elucidate which areas of research in this area might be most fruitful to pursue.

TABLE OF CONTENTS

CHAPTER		PAGE
I.	INTRODUCTION	1
	Functional Differences Between the Hemispheres	1
	Phylogeny and Ontogeny of Lateral Specialization	4
	Hand Dominance	8
	Handedness and Cerebral Organization . .	11
	Lateral Specialization and Higher Cognitive Processes	21
	The Experiment	25
II.	METHOD	26
	Subjects	26
	Procedure	28
	Divergent Production Battery	32
	Analytic Battery	34
III.	RESULTS	37
	Analytic Battery	37
	Divergent Battery	40
	Relationships Among the Dependent Variables	40
IV.	DISCUSSION	44
BIBLIOGRAPHY		55
APPENDIX A.	Nebes Scores, Laterality Information and Academic Major of Subjects . . .	59

LIST OF TABLES

TABLE		PAGE
1.	Statistical Summary for Analytic Battery	38
2.	Scores for Selected Subjects for Tests Having Significant Group Differences . .	39
3.	Statistical Summary for Divergent Battery	41
4.	Correlation Matrix for Selected Tests . .	42

LIST OF FIGURES

FIGURE PAGE

1. Nebes' Arc-Circle Test Stimuli 30

CHAPTER I

INTRODUCTION

The cerebral hemispheres in man have basic anatomical symmetry and serve similar sensory and motor functions. There are, however, some differences between the two sides of the brain in the manner in which they process information. One hemisphere, usually the left, is analytical, operating on input in a logical, sequential fashion. The opposite side is a synthesizer, working in a more intuitive manner and recognizing relationships. Incomplete lateralization of these two functions to separate hemispheres is believed to be associated with some deficits in specific processing abilities. The present experiment was an attempt to evaluate the effect of poor lateral specialization on performance of selected tests of analytical and divergent thinking.

Functional Differences Between the Hemispheres

Extensive studies with commissurotomy patients indicate no significant differences in the performance of the two hemispheres on the following (Gazzaniga, 1970): simple and choice reaction times; intermodal transfer from vision to touch and touch to vision; auditory tactual and auditory visual matches; ability to emote to provocative stimuli;

short-term memory tasks; and control of contralateral motor systems. However, very striking differences have been observed in the ability of the two sides to perform certain verbal and perceptual tasks. The data below were obtained from tests on commissurotomy patients who were all right handed. Recently, commissurotomies have been performed on an ambidextral and a sinistral, but detailed test results are not yet published for these individuals.

Verbal Ability. The left hemisphere is superior to the right on language-associated tasks. Spontaneous generation of speech appears to be almost entirely a left hemispheric function although the right hemisphere can repeat poems and sing the words of songs which have been well learned (Bogen, 1969b). The right brain can also comprehend both written and spoken words to some extent (Sperry, 1968). For example, a split-brain Subject who sees the word "fork" flashed to the right hemisphere can pick the object out of an array of objects available tactually to the left hand. He can also accomplish the same type of task if asked to find a "piece of silverware" with his left hand, again given only tactual access to the choices. Thus, the right hemisphere is capable of understanding some fairly advanced definitions. It can also comprehend some adjectives (e.g., rough, smooth, and round) and identify such geometric categories as cones, rectangles, cylinders, squares, and pyramids (Gazzaniga & Sperry, 1967). Working with verbs is extremely difficult for the right hemisphere, however (Levy, Nebes & Sperry, 1971).

Mathematical Ability. Arithmetic calculations are carried out primarily in the left hemisphere. However, the right brain can add and multiply numbers less than 10 if the sum or product is not greater than 20 (Sperry, 1968).

Musical Ability. The right hemisphere is more competent than the left in evaluating such musical features as tone and timbre, but understanding musical notation is almost exclusively a left hemispheric function (Bogen, 1969b).

Spatial-Perceptual Ability. The right hemisphere is superior to the left in many spatial-perceptual tasks. It is more efficient in reproducing geometric designs such as a Necker cube (Gazzaniga, Bogen & Sperry, 1965), recognizing faces and drawings of both familiar and unfamiliar objects (Levy, Trevarthen & Sperry, 1973), matching an arc with a circle of corresponding size (Nebes, 1971a), and in recognizing tactile patterns in a delayed matching-to-sample task (Milner & Taylor, 1971). The right side is also more field independent than the left (Silverman, 1973).

Right hemispheric superiority on spatial-perceptual tasks appears to be related to a general ability to process in terms of wholes. Levy-Agresti and Sperry (1968) found the left side to be more capable than the right in performing a discrimination task using blocks which could be easily processed by an analytic mode. More complex block shapes which would not be amenable to verbal-analytic descriptions could not be discriminated by the left hemisphere but could be by the right. Hemispheric specializations in verbal and musical skills also demonstrate an overall preference of the left for analysis and of the right for synthesis.

Phylogeny and Ontogeny of Lateral Specialization

Explanations of the evolutionary development and import of lateral specialization come from Bogen and Bogen (1969) and from Levy (1969, 1971). Some disagreement exists between these explanations as to whether language or lateral specialization occurred first. Bogen and Bogen suggest hemispheric asymmetry followed the usual evolutionary trend of gradual development. It probably preceded and facilitated the emergence of organized language and could be a feature of the brains of some infra-human primates. Levy, on the other hand, considers lateral specialization to be a uniquely human feature and the only essentially qualitative leap to occur in the evolution of the mammalian nervous system. She argues that the advent of language led to the lateralization of the synthetic mode to one side and of a verbal mode to the other so that synthetic processing would not be suppressed by the strong analytic propensities associated with language.

There is agreement between the Bogens and Levy on the adaptive significance of laterality, however. They suggest that two different methods of problem solving would allow for more flexible, less stimulus bound behavior than would just one method and that less competition would occur between the two methods if they were present in different hemispheres than if they both were present on each side. Several studies, which will be reviewed in a later section, lend credence to this idea.

As to the ontogeny of laterality, two recent experiments indicate differential preference of the two hemispheres for several types of information shortly after birth. Molfese (1972) measured averaged evoked potentials from the temporal cortex of the two hemispheres in response to speech and non-speech auditory stimuli. He found a greater response by the left hemisphere for speech sounds and greater response by the right hemisphere for non-speech sounds as early as a few hours after birth.

Another newborn infant study is reported by Crowell, Jones, Kapuniai, & Nakagawa (1973) who monitored occipital EEG responses to bilateral photic stimulation in 97 Subjects. No photic driving was present in 61 of the infants; but in the remainder, 18 infants showed unilateral driving (16 on the right side and two on the left) and 18 showed bilateral driving. The experimenters consider the results to be indicative of maturational events. They hypothesize a trend from no photic driving in the least mature, unilateral driving at a later stage, and finally the bilateral driving characteristic of adults. The greater incidence of right sided activity in those individuals showing unilateral driving (16 out of 18) is an interesting finding which should be explored further. Another important finding of this experiment is the apparent lack of interhemispheric integration. This might be explained by the neuroanatomical findings of Hewitt (1962). He demonstrated that the corpus callosum in the newborn is small and poorly developed. Further development and myelinization seems to parallel that of the cortex as a whole.

Kimura (1963) studied changes in lateralization in children between four and eight years of age. Using dichotic listening techniques, she found speech functions well lateralized by the age of four. Her method involved projecting conflicting digits simultaneously to the two ears. After presentation of several pairs of digits, the subjects were asked to recall as many as possible. The number of digits reported for each ear were compared in an attempt to determine the degree of lateral specialization of language functions. Previous studies had demonstrated stronger contralateral hemispheric-auditory connections than ipsilateral connections (Kimura, 1961). Therefore, more efficient performance on material presented to the right ear would indicate superiority of the left hemisphere for language and more efficient performance by the left ear would indicate superiority of the right hemisphere. Although four-year-old boys had lower overall scores than girls, lateralization of language function was evident for both sexes. Difference scores between the two ears decreased between the ages of four and eight, suggesting a decrease in degree of lateralization. Although Kimura considers this to be an artifact of the overall general increase in performance, a second study by Molfese (1973) which will be considered later indicates a similar decrease in lateralization with increased age.

Not all of Kimura's Subjects demonstrated left hemispheric dominance for language. Of 11 left-handed girls, 10 were more efficient with the right ear and one showed no difference between ears. Of 14 left-handed boys, nine were more efficient with the right ear and the other five were more efficient with the left ear. These findings suggest some relationship between hand preference and hemispheric dominance for language as well as the possibility of a sex difference.

Molfese (1973) found evidence that Kimura's decrease in difference scores between the two ears with increasing age may not have been an artifact of her experimental method. He measured averaged evoked responses (AER's) from the temporal cortex to verbal and non-verbal stimuli. The Subjects were 10 infants (mean age = 5.8 months), 11 children (mean age = 6 years), and 10 adults (mean age = 25.9 years). Right hemispheric superiority for non-verbal stimuli decreased with age. Left hemispheric superiority for verbal stimuli, however, was greater for children than for adults and infants. Molfese suggests these results might be explained in terms of increasing communication between the hemispheres with maturation and with the development and myelinization of the various forebrain commissures.

In summary, hemispheric specialization, which is present in the human infant at birth, allows a flexibility in the organism's interaction with the environment. Individual differences in the degree of specialization, especially those associated with hand dominance, will now be considered in detail.

Hand Dominance

Annett (1964) provides a simple model for the genetic basis of hand dominance. According to her model, handedness is determined by two alleles: D, which manifests right handedness, and R, which manifests left handedness. Although D is usually dominant and R recessive, there may be partial penetrance of R in heterozygotes. Dominant homozygotes (DD) will be consistently right handed with verbal functions highly specialized in the left hemisphere. Recessive homozygotes (RR) will be consistently left handed with language functions highly specialized in the right hemisphere. Heterozygotes may become either left or right handed depending on experiential factors, and language functions may develop in either or both cerebral hemispheres. This model can account for the proportion of sinistrals and dextrals in the population by assuming the incidence of D to be 80% and that of R to be 20%. The resulting genotypes would be DD=64%, DR=32%, and RR=4%. Left handed phenotypes could range from 4% to 36%, but because of environmental pressures the incidence would probably be closer to the smaller number. This is in line with Benson and Geschwind's (1968) estimate, based on a review of several studies, that the incidence of left handedness is between 4% and 8%.

More recently Annett (1967) differentiated between persons who were consistently right or left handed and those with mixed tendencies using detailed preference questionnaires and observations. She found the incidence of these three groups occurred in the binomial proportions predicted by her model. However, second generation studies do not follow a distribution which the model would predict. Therefore, a polygenetic basis is more likely. Levy (1971) mentions a two gene, two allele per gene model she is developing which can account for subsequent generations. Unfortunately, the model has not been published at this time, so details are unavailable for evaluation.

In a more extensive study of handedness, Annett (1970a) used an association analysis method to evaluate responses to a detailed handedness questionnaire and performance on a test of manual speed. Association analysis is a statistical technique devised originally for use in plant ecology to determine which features of the environment affect the distribution of species. The terrain under consideration is divided systematically into quadrats and the presence or absence of each species is noted for each quadrat. Chi-square or phi coefficients are then calculated for all possible pairs of species. The associations are tabulated and the species with the highest count is used to dichotomize the quadrats. Each resultant sub-group is then divided again in the same way, giving a series of binary subdivisions. Annett considered each Subject as a quadrat and questionnaire responses as species. She demonstrated a continuous distribution of handedness rather than the dichotomous or three-category classification usually considered. Within this distribution she found about 8% of the Subjects appeared to be inconsistent sinistrals and about 17% appeared to be inconsistent dextrals. No tests of cerebral laterality were used in this study, but the Experimenter stressed the importance of her findings to theories of cerebral organization. Most of the experiments which have tried to correlate conditions of handedness and cerebral organization have considered handedness to be dichotomous, with sinistrals having less hemispheric specialization. This simplification may have led to erroneous conclusions about the differences between "sinistrals" and "dextrals". Any Experimenter using relatively equal numbers of Subjects in the "dextral" and "sinistral" groups would probably have many more inconsistent Subjects in the latter group for the following reason. The distribution under consideration has consistent left handedness represented on the far left and consistent right handedness represented on the far right. It is greatly skewed toward the left. Therefore, any sample of left handers taken from this distribution, particularly if the choices were not based on stringent handedness criteria, would contain more inconsistent handers than a sample of right handers of equal size. Unfortunately, most studies concerning handedness and laterality have not used stringent criteria for group assignment. Therefore, it is difficult to assess from these studies whether differences in degree of cerebral specialization exist between true left handers and true right handers or whether the differences are really betweeen consistent and inconsistent handers. Annett's theories predict that the latter is true.

Handedness and Cerebral Organization

Levy (1969) hypothesizes that incomplete lateralization of the two information processing modes to opposite hemispheres would lead to the suppression of one of the modes. She cites evidence from patients with cerebral lesions that indicates damage to either hemisphere more often leads to aphasia in sinistrals but that the aphasia is transient. This suggests language competency in both hemispheres for left handed individuals. Such bilateral language ability should result in a depression of the synthetic processing mode. She used the Wechsler Adult Intelligence Scale (WAIS) with two groups of graduate science students at the California Institute of Technology to test this idea. The verbal scale of the WAIS is considered to be a measure of the analytic mode whereas the performance scale supposedly measures synthetic processing. One group consisted of 10 sinistrals, the other of 15 dextrals. Verbal scores were not significantly different for the two groups (left mean = 142; right mean = 138; $p > .10$). Performance scores were markedly different, however (left mean = 117; right mean = 130; $p < .002$). The dextrals had a mean discrepancy between verbal and performance scores of 8 points while the sinistrals had a mean discrepancy of 25 points ($p < .0002$).

Unfortunately, Levy does not give her criteria for assignment to the handedness groups. Therefore, it is impossible to determine whether her results indicate a difference between true sinistrals and true dextrals or between "consistents" and "inconsistents".

Nebes (1971a) devised a test to measure synthetic perceptual ability which involves comparing three plexiglas circles (1 in., 1-1/4 in., and 1-1/2 in. in internal diameter) with arcs made from these same dimensions. For each circle there are four arcs of different degrees of completeness: 280°, 180°, 120°, and 80°. Three forms of the test have been used: 1) Somesthetic-Visual - The three circles are placed before the Subject in plain view, and the arcs are presented one at a time behind a curtain which obscures the view. The Subject is allowed to feel the arc with the tip of his index finger only and then must bring his hand out and point to the circle corresponding to the arc. 2) Visual-Somesthetic - The three circles are placed behind the curtain out of view while the arcs are presented one at a time visually. The Subject must feel the circles and point to the one corresponding to the arc he sees. 3) Somesthetic-Somesthetic - All stimuli are presented behind a curtain, out of view of the Subject. He must feel the arc and the circles and point out his choice.

Nebes (1971a) validated his test with five right handed commissurotomy patients. On all three forms of the test the Subjects performed significantly better using their left hand (right hemisphere) than they did using their right hand. The Somesthetic-Visual portion of the test has subsequently been used to compare sinistrals and dextrals (Nebes, 1971b). One set of Subjects consisted of 10 right handed and 10 left handed male graduate students and postdoctoral fellows in Biology at the California Institute of Technology. The second set was composed of 32 Duke University freshmen, half of whom were sinistrals and half dextrals. Half of each Duke sub-group was female, half was male. For both sets he found sinistrals to be inferior to dextrals in their performance ($p < .001$). Mean scores for the Biology students were 36.4/48 (S.D.=2.4) for dextrals and 27.8/48 (S.D.=4.1) for sinistrals. Right handed Duke University freshmen averaged 16.8/24

(S.D.=1.8) as compared with 13.2/24 (S.D.=1.4) for their left handed peers.

Assignment to handedness groups was based on the 10 questions on hand preference included in the Harris Test for Lateral Dominance. The Subject is asked which hand he prefers to use to: write, throw, hold a knife, erase, hold a toothbrush, turn a door knob, comb his hair, use scissors, wind a watch, and hold a hammer. Dextrals from Cal Tech answered "right hand" to 9.6 of these questions, sinistrals to 4.4. Duke University right handers answered "right hand" to 9.8 of the activities, sinistrals to 3.4. Of the Cal Tech sinistrals, three had been converted to writing with their right hand. None of the Duke University students had been successfully converted from their initial hand preference. No objective tests of manual skill differences were administered.

Nebes used two Somesthetic-Visual control tests with all three sets of Subjects. In one control test Subjects were required to pick the circle identical to a sample circle from a group of three. The second test was similar but involved arcs. There were no significant differences between performance on these tests by the right and left hemispheres of commissurotomy patients nor by the two handedness conditions from the college population. These results are consistent with Nebes' assumption that, whereas the arc-circle task requires right hemispheric solution, the control tests can be solved by either processing mode.

A pilot study was conducted by the present Experimenter at the University of Houston to evaluate the possibility of using Nebes' test as a device for determining the degree of hemispheric specialization in a college population. Although good performance on the test is probably indicative of a high degree of specialization when stringent controls are maintained to prevent left hemispheric strategies, poor performance may come from several sources. First, college students must rely on analytical solutions for most of the problems they encounter in the academic situation. Almost every test they take in school taps verbal and mathematical ability predominantly. Even when the purpose of Nebes' test is explained and the student is told not to employ verbal or other left hemispheric strategies, the temptation to do so may be strong. Therefore, poor performance may result from experiential sets even in cases where cerebral organization is such that the Subject has good access to both processing modes.

A second source of poor performance may result from kinesthetic figural aftereffects (KFAE). Petrie (1967) found some individuals who consistently augmented and some who consistently reduced on tests of KFAE. The augmenter tended subjectively to increase the perceived size of objects as stimulation continued over time, whereas the reducer subjectively decreased the perceived size of objects with stimulation over time. Several subjects in the Nebes pilot study were very accurate during the first phase of testing in any testing session, but as the session progressed performance changed in an interesting way. Some Subjects chose the medium sized circle when the small arcs or circle were presented and the large circle when the medium or large arcs and circles were presented. Others chose the medium circle when the large arcs or circle were presented and the small circle when either the medium or small arcs and circles were presented. Evaluating the degree of hemispheric specialization may, therefore, be impossible using Nebes' test with augmenters and reducers because of the severe confounding by KFAE. Fortunately, most individuals are moderate in that they do not augment or reduce to a large degree on perceptual tasks.

The third source of poor performance on the Nebes test is, of course, cerebral organization which leads to suppression of synthetic problem solutions. Unfortunately, it is difficult on the basis of the Nebes test alone to determine which of the three alternatives causes low scores for any individual.

Silverman, Adevai, and McGough (1966) studied performance on several perceptual tasks by Subjects in two handedness groups. They call the two groups right handed and left handed, respectively, but their criteria for group membership is illustrative of the greater number of "inconsistents" usually included in "left handed" groups. A group of Rutgers

University students (N=93) was screened using a questionnaire which requested information on hand preference for several everyday activities. Possible scores on the questionnaire ranged from 14 (extreme right hander) to 70 (extreme left hander). The initial plans were to use the 10 Subjects with the highest scores and the 10 with the lowest scores. However, 12 persons fell within the range from 14 to 16, so the right handed group contained 12 Subjects. Scores for the 10 left handers ranged from 35 to 65. They were all sinistral writers and referred to themselves as left handed people. These two groups were tested on the following:

1) Rod and Frame Test - The Subject in a dark room was confronted with a luminous tilted frame within which was a tilted rod. His task was to orient the rod to the true vertical.

2) Gottschaldt Embedded Figures - Subject was required to locate a simple geometric design which he had previously seen with another complex geometrical design. Latency was measured.

3) Mirror Tracing - The Subject was required to trace a path around a double-ruled six-pointed star, guided only by the mirror reflection of the star. An error score was obtained.

4) Traced Letter Identification - Subject was required to identify letters traced on his forehead and on the backs of his hands. An accuracy score was obtained.

5) Two-Point Discrimination - Subjects were required to judge whether one or two points were stimulated on the back of his left hand.

6) Tactile Localization - Subject was required to place a mark on a drawing of a hand to correspond with the point on the ventral surface of his own hand which was stimulated. Stimulation to his hand occurred outside his visual field.

7) Laterality Orientation - Subject was required to identify sidedness of pictures of body parts.

Significant differences were found between the groups on the rod and frame test ($z=2.04$, $p<.05$), mirror tracing ($z=2.11$, $p<.05$), laterality orientation ($z=1.98$, $p<.05$), and tactile localization on the right hand ($z=1.78$, $p<.08$) and the dominant hand ($p<.02$) but not on the left hand.

Silverman (1973) has tied performance on the rod and frame test more directly to the special abilities of the two hemispheres. Using patients who had received unilateral electroconvulsive shock, he tested one hemisphere while the other was still recovering from the therapy. He found the left hemisphere to be more field dependent than the right in these Subjects.

Levy is interested in hand position used in writing as well as in which hand is dominant. She observed (Levy, 1971) an individual who writes with his right hand in an inverted position (pencil above the line of writing, pointing toward the body). This Subject had a 34 point difference between his Verbal and his Performance IQ as measured by the WAIS, suggestive of perceptual deficits similar to those of sinistrals. Based on this observation and on preliminary results of perceptual tests on left handers who write normally, Levy hypothesizes differences in cerebral organization based on whether an inverted or normal method of writing is used for both sinistrals and dextrals. She suggests normal writers use hands controlled by the language-dominant contralateral hemisphere, but that inverted writers use hands controlled indirectly by the hemisphere not dominant for language. This theory is currently being investigated by Levy and associates.

At this point a brief summary might be useful. Annett (1964, 1967, 1970a) proposes a genetic basis for hand preference which conforms with the incidence of handedness manifested in the population. According to her theory, homozygotes for either right handedness or left handedness would have hemispheres well specialized for the two opposing functions. Heterozygotes, who could be either right or left handed phenotypically, would be less well specialized in terms of cerebral organization. Since handedness can be conceptualized as a continuum, only those individuals at the extreme ends would have highly specialized hemispheres. Levy (1969, 1971) hypothesizes deficits in one of the processing modes in individuals with poor cerebral lateralization.

Several studies (Levy, 1969, 1971; Nebes, 1971b; Silverman, Adevai & McGough, 1966) demonstrate perceptual deficits in persons usually referred to as sinistrals but who are, more probably, inconsistent handers.

For all the studies cited above which show perceptual deficits in certain groups, university students were Subjects. Because logical, analytical functioning of a relatively high degree is usually necessary for admission to a university, no generalization should be made from this group to poorly lateralized individuals at large. The possibility should be explored that in some poorly lateralized individuals analytical abilities suffer while spatial perceptual abilities are well developed. Such individuals would be characterized by low verbal and mathematical intelligence and would, of course, not be found in a college population. Annett (1970b) conducted a study which has interesting implications within this context. She tested a random sample of 219 children aged 3-1/2 to 15 years for hand preference and for manual dexterity for each hand. She found no change in handedness during this age period, but she did find some interesting differences in scores on the Peabody Picture Vocabulary Test between groups classified as right handers, left handers, and mixed handers. Mean scores for mixed handers were lower than those of consistent handers, whereas the mean scores of consistent left handers were higher than those of mixed and right handers. However, scores for mixed handers varied much more than those of consistent handers so that what actually occurred was a bimodal distribution of mixed handers with most of them at the lower end (IQ below 70), very few in the middle, and more at the extreme high end (IQ above 130).

The argument might be made that the Peabody Picture Vocabulary Test measures spatial perceptual ability more than verbal ability. However, the Peabody generally correlates more highly with verbal than with performance intelligence as measured by other tests (Anastasi, 1971). Annett's findings suggest further research in which scores on well chosen verbal intelligence and spatial perceptual tests are compared for children in the three handedness conditions. An overall negative correlation between verbal and spatial ability in ambidextrals would be very interesting. Unfortunately, the possibility that both the poor analytic ability and mixed handedness resulted from neurological damage would be difficult to rule out.

Lateral Specialization and Higher Cognitive Processes

Experiments on the effects of decreased laterality in the college population have dealt primarily with lower level processes such as perception, but higher order deficits might also be expected. Bogen and Bogen (1969) believe the flexibility inherent in two well-developed processing modes is necessary for insightful problem solving. Several quotations from individuals noted for their intellectual productivity show how the two processes might interact to facilitate original thought. Albert Einstein, when asked to describe his creativity in action, replied:

> The physical entities which seem to serve as elements in thought are certain signs and more or less clear images . . . (in) combinatory play . . . The above mentioned elements are, in my case, of visual and some of muscular type. Conventional words or other signs have to be sought for laboriously only in a secondary stage, when the above mentioned associative play is sufficiently established and can be reproduced at will.[1]

Stephen Spender, the English poet, described the origin of one of his poems as follows: "a dim cloud of an idea which I feel must be condensed into a shower of words."[2] Poincare, the French mathematician, observes:

> Most striking at first is this appearance of sudden illumination, a manifest sign of long, unconscious prior work. The role of this unconscious work in mathematical invention appears to me incontestable . . . it never happens that the unconscious work gives us the result of a somewhat long calculation all made, where we have only to apply fixed rules . . . All one may hope from these inspirations, fruits of unconscious work, is a point of departure for such calculations. As for the calculations themselves . . . They require discipline, attention, will and therefore consciousness. In the subliminal self, on the contrary, reigns what I should call liberty, if we might give this name to the simple absence of discipline and to the disorder born of chance. Only, this disorder itself permits unexpected combinations . . . we vaguely comprehend what distinguishes the two mechanisms or, if you wish, the working methods of the two egos . . .[3]

---

1. Hadamard, J. <u>An essay on the psychology of invention in the mathematical field</u>. New York: Dover, 1954.
2. Spender, S. The making of a poem. In Ghiselin, B., Ed. <u>The creative process: A symposium</u>. New York: New American Library, 1952.
3. Poincare, H. <u>Science and method</u>. New York: Dover, 1952.

The recurrent theme throughout these quotations is the use of a bimodal approach to problems. One approach, suggestive of synthetic processing, involves non-verbal perception of relationships. It is "combinatory" or "associative", not analytic. It is intuitive, not disciplined. But this approach is only the initial step; words or symbols must be found and manipulated to express the impressions. Hard work of an analytic nature must follow the inspiration.

Deikman (1971) also talks about a bimodal consciousness which is important for problem solving. He considers an active mode which is organized to manipulate the environment and a passive mode which involves taking in the environment. The active mode is object oriented, associated with focused attention. The passive mode involves a more diffuse attention, paralogical thought, and dominance of the sensory over the formal. Creative problem solving requires interaction of the two modes in the following manner: The active mode stages a directed intellectual attack on the problem until a state of impasse is reached. A passive, unfocused period ensues during which the answer is found in an "Aha!" or "Eureka!" experience. The active mode reasserts itself and the answer is analyzed to assess its validity.

Guilford (1967), in his model of human intelligence, describes an operation he calls divergent thinking which is also suggestive of a bimodal approach to problem solving.

Divergent thinking involves flexibility, fluency, and originality, abilities concerned with the ready flow of ideas and with a capacity to change the direction of thought. Guilford has found the following relationship between analytic ability, as measured on tests of verbal and mathematical intelligence, and divergent thinking, as measured by a battery of tests he devised. At the lower end of the intelligence continuum divergent production scores are uniformly low, but with increasing intelligence there is an increase in the range of divergent scores. Very high intelligence is associated with divergent thinking ability varying over a wide range from very low to very high. Therefore, although divergent thinking is dependent upon at least a minimum of analytic ability, analytic solutions do not seem to require the ability to think divergently.

All of these discussions strongly suggest accessibility to the different modes of thought resident in the two hemispheres is necessary for creative or divergent thinking or insightful problem solving. The right side must contribute the intuitive, associative talents required for these tasks while the left analyzes and expresses the impressions formed. Therefore, poor lateral specialization should preclude optimal performance on problems requiring divergent strategies even in individuals of high analytic ability. The following experiment was conducted to test this hypothesis.

The Experiment

Subjects were solicited from the Dean's List for the College of Arts and Sciences and from the Honors Program at the University of Houston. This source was used in an attempt to obtain individuals of relatively equal intelligence so that any group differences on divergent tests would not be attributable to differences in analytic ability. Each Subject was tested using Harris' Test for Lateral Dominance (Harris, 1945) and Nebes' Arc-Circle Test (Nebes, 1971a). Strict criteria based on the results of these two tests were used to assign 12 Subjects to each of two groups: Well Lateralized and Poorly Lateralized. Subjects were given eight tests from Guilford's Divergent Production Battery and five analytic tests including verbal, mathematical, reasoning and sequencing items. The hypothesis tested was that scores on the Analytic Battery would not be significantly different for the two groups, but that those on the Divergent Battery would be lower for the Poorly Lateralized Group than for the Well Lateralized Group.

CHAPTER II

METHOD

<u>Subjects</u>

Subjects were solicited from the 1973 Spring Dean's List for the College of Arts and Sciences at the University of Houston and from the Honors Program. Fifty-four Subjects agreed to come for the initial screening which consisted of the Harris Test for Lateral Dominance and the Somesthetic-Visual form of Nebes' Arc-Circle Test. From this group 24 Subjects were selected for inclusion in the experimental groups based on the following criteria.

<u>Well Lateralized Group</u>. Members of this group were either consistently right handed or consistently left handed. All sinistrals had a family history of left handedness, and no Subject was included who had been converted from left to right handedness. Each Subject had a score of 33/48 or above on Nebes' Arc-Circle Test.

<u>Poorly Lateralized Group</u>. Subjects in this group were inconsistent handers, scoring in the mid range of the Harris Test for Lateral Dominance. No Subject with a tendency to left handedness was included if he had a family history of sinistrality, but all Subjects with right handed tendencies had sinistrals or ambidextrals in their family. Nebes scores for this group were 29/48 or less. Control for poor performance due to KFAE factors consisted of rejecting any

Subject who did not select each circle at least twice for any set of twelve presentations.

There were two exceptions made to the handedness criteria for this group. One male Subject and one female Subject were dextrals who had no sinistrals in their families, but both wrote with their right hand inverted. As was mentioned earlier, inverted dextrals have been associated with poor hemispheric lateralization by Levy (1971). Both Subjects had low scores (26 and 25, respectively) on the Arc-Circle Test but average to high scores (41 and 34, respectively) on the Circle-Circle Test.

The two groups which resulted from the above criteria had the following characteristics. The Well Lateralized Group contained six males (three dextrals, three sinistrals) and six females (five dextrals and one sinistral). Mean score on the Arc-Circle Test for this group was 35.00 and that on the Circle-Circle Test was 37.42. The Poorly Lateralized Group consisted of six males (four inconsistent dextrals, one inconsistent sinistral, and one without any discernible preference) and six females (all inconsistent dextrals). Mean score on the Arc-Circle Test was 26.25 and that on the Circle-Circle Test was 36.25. Scores of the two groups on the Circle-Circle Control Test were not significantly different ($t=0.48$, $df=22$). Appendix A contains a list of each Subject's Nebes scores, handedness, eyedness, footedness, family handedness, and academic area.

Procedure

Subjects were contacted initially by telephone or by notices posted on the Honor's Program bulletin board. A brief description of the nature of the experiment was given, but no specific hypothesis or discussion of expected results was provided. On their first visit each Subject completed a short form giving name, address, telephone number, age and academic major. He was then given the Harris Test for Lateral Dominance. This test consists of the following sections:

1) Knowledge of Right and Left - The ability to discriminate right and left is tapped.

2) Hand Preference - The Subject is asked to indicate which hand he would use to perform the following tasks: brush his teeth, comb his hair, hold an eraser, turn a door knob, throw a ball,hammer a nail, cut with scissors, cut with a knife, wind a watch, and write.

3) Skills - The relative dexterity of each of the hands is ascertained using the following tasks: simultaneous writing, signing name, tapping and dealing cards.

Tests for eye and foot dominance were also administered to each Subject; but, because the relevance of these measures to the subject of cerebral dominance is not known, they were not used as criteria for group membership in this experiment. A complete family history of handedness was solicited.

Nebes' Arc-Circle Test was given twice. The stimuli for this test were made from plexiglas, 1/8 in. thick and 1/8 in. high (see Figure 1). Each form was painted a flat black and mounted on a 4x4 in. white card. The set of stimuli for the Arc-Circle portion included three circles with internal diameters of 1-1/2 in., 1-1/4 in., and 1 in. For each circle there were four arcs of 280°, 180°, 120°, and 80° of completeness, respectively. The stimuli for the Circle-Circle Control Test consisted of the original three circles and a second identical set. In addition, a practice set contained two circles 1-3/4 in. and 2-1/4 in. internal diameter, respectively, and four arcs for each circle. These stimuli were also painted black but were not mounted on the white cards.

On his first visit the subject was given the practice set to manipulate as the purpose and method of the test were explained. He was told that the test was designed to tap right hemispheric functions, which were briefly described to him. He was cautioned against using left hemispheric strategies such as measuring across an arc or running his finger across the opening in the arc to describe a complete circle. He then picked a card which indicated which hand he used first in the test. The three test circles were presented, and the Subject was allowed to feel the inside surface of each circle with the tip of the index finger of the hand to be used. Each of the twelve arcs was then

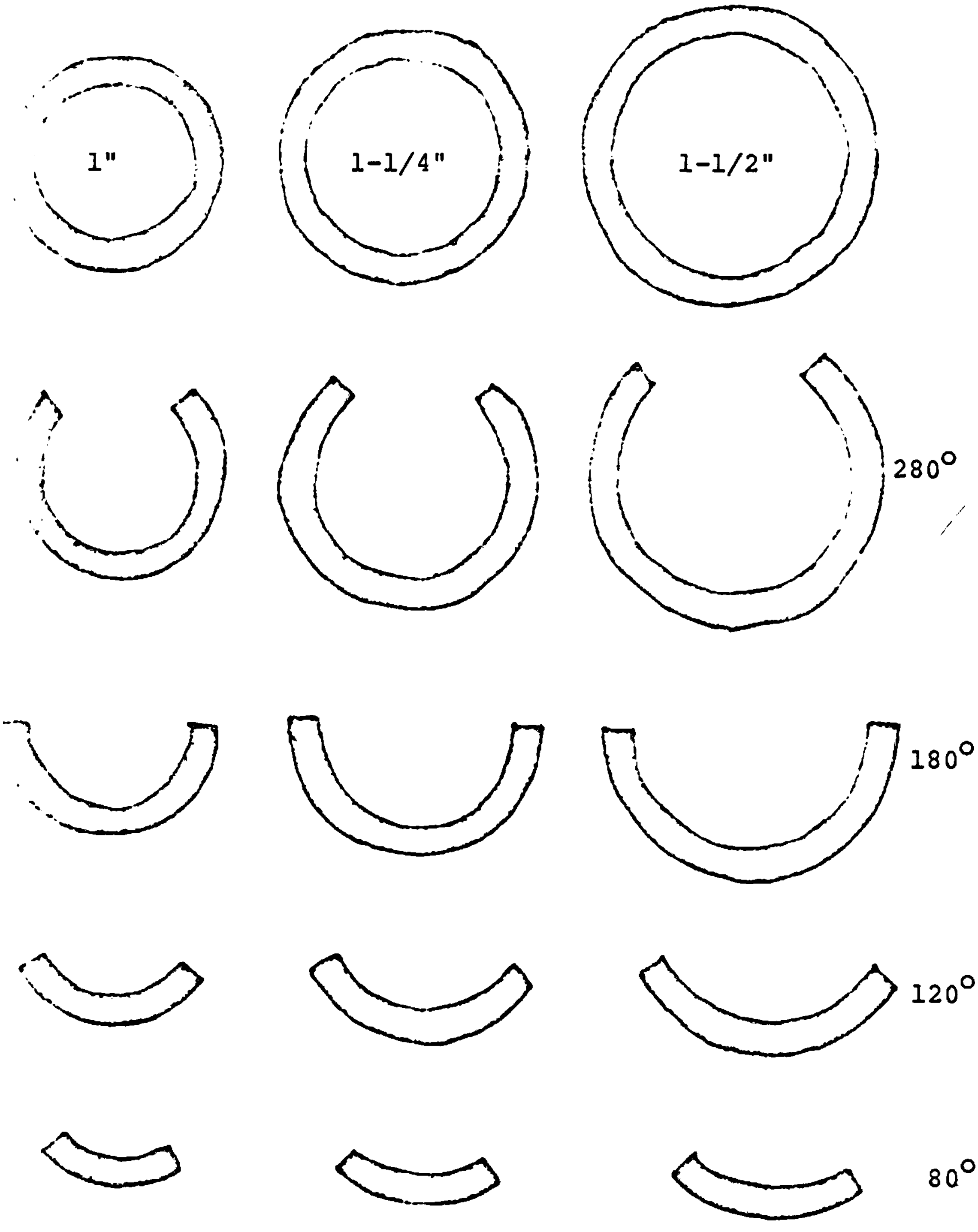

FIGURE 1

NEBES' ARC-CIRCLE TEST STIMULI

presented in random order behind the screen, one at a time. The Subject felt each arc with the tip of his index finger and then pointed to the matching circle. After all 12 stimuli had been presented, the Subject was allowed to feel the three circles with the tip of the index finger of his other hand. The arcs were then presented to that hand in the same random order. No feedback on performance was given to the Subject.

The Circle-Circle Control Test was also administered. The procedure for this test was identical to that of the experimental test except that 12 random presentations of the circles were given to each hand.

A second session for the Nebes Test was given at least 24 hours after the first. The purpose of the delay was to minimize possible KFAE effects. The second session was identical to the first except a different random order was used for presentation of both arcs and circles. Also, the Subject began with the hand opposite the one he used first in the initial session.

Subjects who qualified for one of the two groups returned for Guilford's Convergent Production Battery and for an Analytic Battery. In order to avoid confounding due to solution sets, the two batteries were given in different sessions.

Divergent Production Battery

The Divergent Production Battery consisted of the following paper and pencil tests, all of which were timed.

1) Making Objects - This test of visual-figural expressional fluency requires the Subjects to construct specified objects from simple figural elements. Three minutes were provided for construction of nine figures. Scores are based on a simple count of the number of different figural elements used to make each figure.

2) Possible Jobs - This test taps the ability to elaborate upon given information or to suggest alternative deductions or extensions. Subjects are given three emblems and are asked to suggest jobs associated with them. Five minutes are provided for the test, and scores consist of a simple count of acceptable responses.

3) Seeing Problems - The ability to see implications of a meaningful kind such as being aware of consequences or making predictions is measured. Subjects are given the names of six objects and are asked to write different problems specific to each of them. Four minutes are provided for solution, and scores are based on a simple count of acceptable responses.

4) Plot Titles - Two factors are measured by this test: ideational fluency and originality. Subjects are given two short stories to read and are then asked to write titles applicable to the stories. Six minutes are

provided for solution. Scoring for fluency involves counting total number of responses. Originality scores are obtained by counting the number of "clever" responses. For this experiment, all titles were submitted to a class in Experimental Psychology for determination of "clever" and "non-clever". Any title which was rated "clever" five times or more (total possible = 16) was counted toward the originality score.

5) Decorations - The purpose of this test is to tap the ability to elaborate or to add meaningful details to what is given. Subjects are given outlines of well-known articles of furnishings and are asked to decorate them. Artistic quality is not important but figural ideas are. Six minutes are provided for this test, and scores are based on a simple count of the number of different types of decorations used for any picture.

6) Simile Interpretations - This test measures the ability to produce efficiently appropriate verbal expressions of organized thought. Subjects are given statements such as "A is like B, it ________", and are asked to complete the simile. Eight such statements are given, and Subjects have six minutes to provide answers. Scores are based on a simple count of acceptable responses.

7) Word Fluency - Subjects are required to produce rapidly words which contain a certain letter. Two letters are given and two minutes are allowed to list words for each

letter. Scores are based on a simple count of acceptable responses.

8) Utility Test - Subjects are required to conceive of new and unusual uses for familiar objects based on a wide variety of attributes. The names of two objects are provided, and Subjects are allowed five minutes to list uses for each object. Scores are based on a simple count of the number of acceptable responses (fluency score) and a count of the number of times categories are changed (flexibility score).

Analytic Battery

The Analytic Battery contained the following tests:

1) Concept Mastery Test, Form T (Terman, 1956) - This test is a measure of the ability to deal with abstract ideas verbally at a high level. It was included because it has a high ceiling, which was considered necessary for the population being sampled. Only Part I, which requires Subjects to indicate whether pairs of words are antonyms or synonyms, was used. Subjects were given unlimited time to respond to 115 items. Scores represent the number correct minus the number incorrect.

2) Flanagan Aptitude Classification Tests, Parts 4, 9 and 10 (Flanagan, 1958) - Part 4 tests the ability to reason and to express problems in simple form using conventional mathematical symbols. Twenty-four items are included; and testing time, which is usually 24 minutes, was cut to 20

minutes for this experiment because of the ability level of the Subjects. Part 9 tests the ability to plan and organize. It was included in this battery because it appeared to be a good method for measuring sequential processing which is considered to be a major feature of the analytic mode. Each problem contains an outline of steps necessary to accomplish an aim or purpose. Subjects must reorganize the outline so that the proper sequential method results. Four problems are included, and testing time was again cut from 24 to 20 minutes for this experiment. Part 10 tests Subjects' ability to add, subtract, multiply and divide quickly and correctly. There is also a section which requires Subjects to add the number of X's in boxes. Five minutes are provided for 60 addition and subtraction problems, two minutes for 15 problems requiring the addition of X's, and three minutes for 45 multiplication and division problems. Corrections are made for incorrect answers when scoring these tests.

3) Closure Flexibility, Form A (Thurstone & Jeffrey, 1956) - This test was chosen as an analytic spatial task because it is labeled as such by Guilford (1967), who includes it in his Convergent Production Battery. Each problem requires Subjects to look at a sample figure and then to indicate whether the sample is concealed in each of four other figures. The figures are sometimes very complex and require considerable analysis. Ten minutes are

allowed for completing this test, and scores reflect the number correct minus the number incorrect.

CHAPTER III

RESULTS

Analytic Battery

Each of the tests in the Analytic Battery was analyzed using Student's t, and the results are displayed in Table 1. Contrary to the original hypothesis, significant differences occurred between the groups on two tests in this series, Flexibility of Closure ($t=2.68$, $df=22$, $p<.02$) and Planning ($t=2.26$, $df=22$, $p<.05$). In both cases the Well Lateralized Group was superior. The Poorly Lateralized Group scored slightly higher, although not significantly so, on Concept Mastery and on all the mathematics tests.

Because handedness criteria were somewhat different in this experiment from the usual comparison of sinistrals and dextrals, an examination of the performance of some selected Subjects is required. Of particular interest are the scores of sinistrals, the one true ambidextral, and the inverted dextrals on the two tests in which significant differences were found. These data are provided in Table 2. All four sinistrals in the Well Lateralized Group scored below the group mean on Flexibility of Closure; one subject (WLF5) scored particularly low (60). Therefore, a Randomization Test for Two Independent Samples (Siegel, 1956) was performed on the Closure scores within the Well Lateralized

TABLE 1

STATISTICAL SUMMARY

FOR ANALYTIC BATTERY

	Well Lateralized Group		Poorly Lateralized Group			
	$\overline{X}$	S.D.	$\overline{X}$	S.D.	t	p*
Concept Mastery	42.50	5.35	45.67	4.84	-0.43	NS
Flexibility of Closure	99.67	5.90	76.75	6.66	2.68	$<.02$
Mathematics Total	50.75	8.52	57.83	12.47	-1.62	$<.20$
Add, Subtract	26.58	4.29	30.00	6.03	-1.60	<20
Addition of X's	7.75	2.09	8.42	2.28	-0.75	NS
Multiply, Divide	16.42	4.23	19.42	5.65	-1.47	<20
Reasoning	16.17	6.12	14.50	5.99	0.67	NS
Planning	27.25	3.11	22.00	7.44	2.26	<05

*df=22, two-tailed test

TABLE 2

SCORES FOR SELECTED SS FOR TESTS HAVING SIGNIFICANT GROUP DIFFERENCES

	Nebes	Closure	Planning	Decorations	Handedness	Family History
WLM1*	33	93	26	26	Left	Maternal GF & uncle, paternal GF & aunt left.
WLM3	39	96	28	28	Left	Maternal & paternal GMs, numerous cousins left.
WLM5	36	89	30	17	Left	Of 10 siblings, 3 left & one ambidextral.
WLF5	33	60	26	23	Left	Paternal GM & numerous cousins both maternal & paternal left.
WL $\bar{X}$	35	99.67	27.25	29.17		
PLM2**	26	80	20	16	Right, Inverted	Ambidextral sister.
PLM4	28	82	16	34	Left tendencies	All right.
PLM5	23	76	20	21	Ambidexter	Father & both his parents left. No maternal sinistrals.
PLF1	23	60	30	16	Right, Inverted	All right.
PL $\bar{X}$	26.25	73.67	22.33	23.24		

*WL = Well Lateralized; ** PL - Poorly Lateralized; M or F refers to sex.

Group to determine whether the consistent dextrals were significantly better than the consistent sinistrals on this task. Differences between these two sub-groups were significant at the .05 level ($t=2.07$, $df=10$, one-tailed test). Planning scores for consistent sinistrals were distributed both above and below the group mean. Scores for the selected Subjects from the Poorly Lateralized Group were found on both sides of the means for both the Closure and Planning Tests.

Divergent Battery

Each test on the Divergent Battery was analyzed using Student's t, and the results are displayed in Table 3. The only test that resulted in significantly different performances for the two groups was Decorations. Scores on this test are listed in Table 2 for the same eight selected Subjects. Again, all the sinistrals in the Well Lateralized Group scored below the mean. However, consistent dextrals were not significantly better than consistent sinistrals on this task as determined by the Randomization Test for Two Independent Samples ($t=1.44$, $df=10$, $p<.10$). Again, the selected Subjects within the Poorly Lateralized Group appear both above and below the group mean.

Relationships Among the Dependent Variables

Pearson product moment correlations among scores on the Nebes Arc-Circle Test and eleven of the dependent variables were ascertained. As can be seen from Table 4, performance

TABLE 3

STATISTICAL SUMMARY

FOR DIVERGENT BATTERY

	Well Lateralized Group		Poorly Lateralized Group			
	$\bar{X}$	S.D.	$\bar{X}$	S.D.	*t*	*p**
Making Objects	19.33	3.80	19.92	4.27	-0.35	NS
Possible Jobs	15.08	2.28	14.00	2.73	1.06	NS
Seeing Problems	16.08	2.58	15.92	4.50	0.11	NS
Plot Titles Fluency	14.17	3.81	14.92	3.96	-0.47	NS
Originality	3.75	0.29	3.33	0.39	0.55	NS
Decorations	29.17	9.82	23.24	5.66	1.81	$<.05$
Similes	16.25	4.98	17.33	4.44	-0.56	NS
Word Fluency	46.50	10.47	40.17	8.10	1.66	$<.10$
Utility Fluency	30.67	7.06	30.17	7.84	0.16	NS
Flexibility	22.83	6.36	20.00	2.19	0.97	NS

*df=22, one-tailed test

TABLE 4

CORRELATION MATRIX FOR SELECTED TESTS

	Nebes	Concept Mastery	Closure	Mathematics	Reasoning	Planning	Word Fluency	Possible Jobs	Similes	Decorations	Utility
Concept Mastery	-.11										
Flexibility of Closure	.50**	.01									
Mathematics	-.32	.34	-.01								
Reasoning	.24	.20	.34	.26							
Planning	.36*	.13	.29	-.05	.30						
Word Fluency	.26	.07	.18	.25	-.14	.33					
Jobs (Fluency)	.16	-.05	.10	-.27	-.43+	.22	.34				
Similes (Fluency)	-.00	.16	.36	.06	-.05	.02	.29	.27			
Decorations	.28	-.20	.37*	.09	-.07	.22	.40*	.39*	.47°		
Utility (Fluency)	-.07	-.02	-.10	-.25	-.33	.09	.34	.36*	.27	.33	
Plot Titles (Fluency)	-.09	.06	.05	.22	-.04	.12	.21	.64**	.37*	.47°	.22

*p<.05
+p<.02
°p<.01
**p<.002

on the Nebes correlates most highly with Flexibility of Closure ($r=.501$, $p<.002$). A significant correlation was also found between the Nebes and Planning ($r=.36$, $p<.05$). Negative relationships were found between the Nebes and both Mathematics and Concept Mastery, but neither correlation was significant. Nebes scores did not correlate significantly with any of the items from the Divergent Battery. Tests within the Analytic Battery did not correlate significantly with other tests in the battery, but a significant relationship was found between Flexibility of Closure and Decorations ($r=.37$, $p<.05$). Both of these tests involve spatial elements. There was also a significant correlation between Reasoning and Possible Jobs, but in a negative direction ($r=.43$, $p<.02$). Among the Divergent Tests several significant correlations exist.

CHAPTER IV

DISCUSSION

Subjects in the Well Lateralized and the Poorly Lateralized Groups did not differ significantly in their performance on tests of verbal intelligence (Concept Mastery), simple mathematical ability (Flanagan Part 10) and mathematical reasoning (Flanagan Part 9). These abilities are usually categorized as "verbal IQ" on most intelligence tests. Significant differences did occur, however, between the groups on two tests in the Analytic Battery, Flexibility of Closure and Planning. Reconsideration of the optimal strategy for solution of the Closure task leads to the conclusion that it should have been included in the Divergent Battery instead of the Analytic Battery. Even though analytical processing is a necessary component of the test, a bimodal approach is probably required. Confronted with this timed test, an individual would be most efficient if he could obtain and shift Gestalts rapidly. He could get closure on a portion of a figure, analyze it to be sure it contained the sample, and then go to another figure. A poorly lateralized individual would not be able to accomplish the Gestalt closure as rapidly and efficiently and would, therefore, be inferior to the well lateralized Subject. The title of this test should have been heeded!

Superiority of the Well Lateralized Group on Planning was quite surprising and is difficult to evaluate. Sequential processing, which is a major component of this task, is attributed throughout the laterality literature to the left hemisphere. However, Picture Arrangement, a test which requires a similar approach, is included in the Performance Scale of the WAIS. As Levy (1969) has shown, differences between the verbal and performance scales of the WAIS are larger for sinistrals than for dextrals. But a very important basic difference exists between Picture Arrangement and Planning in that the former is strictly non-verbal whereas the latter is presented verbally. However, the subject matter of Planning is very concrete. Subjects are asked to order the steps in baking a cake, building a patio, writing a paper, and conducting a research project. In all cases the elements in the outline are concrete enough to be imagined. Some examples are: mixing ingredients for concrete, setting wooden frame for concrete, scanning notes on reading, typing final form of paper, getting approval from school authorities, etc. Perhaps the ability to imagine oneself in such a situation is advantageous in solving these problems. The individual with access to the non-verbal mode for processing this information would then have an advantage over someone who was more or less constrained to working in the verbal mode.

Associated with this idea is evidence reviewed by Milner (1971) which suggests sequential processing of non-verbal material occurs in the right hemisphere. Thirteen Subjects with right frontal lobe lesions showed a deficit in their ability to judge the recency of presentation of art reproductions although they showed normal recognition. Nine patients with left frontal lobe lesions showed no deficit when performing this non-verbal task, but they could not judge the recency of verbal material. These findings suggest that a task which involves sequential processing is not necessarily a left hemispheric task.

An interesting follow-up to the present finding would be to compare two groups similar to those used in this experiment on the following four tasks: 1) a test of purely spatial sequencing similar to that reported by Milner (1971), 2) the Picture Arrangement test from the WAIS, 3) the Flanagan Planning Test, and 3) a purely abstract sequencing task. The second and third tests can be considered to be combinations of spatial and verbal components. If the present results are due to the concrete nature of the Planning task, greater differences between the groups should appear on the first test than on subsequent ones, and no differences should be found on the purely abstract task.

The only significant difference in performance between the groups on the Divergent Battery was on Decoration, a spatial or figural test. This finding is in line with the general deficit of poorly lateralized individuals in performing spatial-perceptual tasks. The absence of a difference on Making Objects, another figural test, is surprising. The overall failure to obtain differences between groups on the tests in this battery may be the result of the rigid time constraints imposed. Perhaps the time was so short that only the relatively obvious responses could be made, responses which were equally available to both well lateralized and poorly lateralized individuals. If this were the case, extending the time available should result in exhaustion of these obvious answers and eventually to group differences. Another problem with timed tests for divergent thinking relates to the almost universal idea that truly original or innovative thoughts must be incubated and cannot generally be produced at will (Bogen & Bogen, 1969; Deikman, 1971).

Of course, the possibility exists that failure to find significant differences results from the absence of such differences. However, the bias of this Experimenter is that differences do exist but, because of the tests used or the administration procedures, they were not tapped. Possibly a better method of evaluating higher cognitive flexibility would be to use some of the tasks devised to measure functional fixedness. Adamson (1959) presented Subjects with a few thumbtacks, three small pasteboard boxes, three candles, and some matches and asked them to mount the candles in burning position on a wall. Whether or not the Subject could do so depended upon his ability to think of various ways to use the objects presented. Tasks similar to this would be interesting for comparing the divergent thinking abilities of well lateralized and poorly lateralized individuals. Measures of success and failure and of solution time required could be analyzed.

Performance on the Nebes Arc-Circle Test correlated significantly with only two other tests, Flexibility of Closure and Planning. Concept Mastery and Mathematics scores were not significantly related to each other or to any of the other tests given. Mathematical reasoning correlated positively, but non-significantly, with every other test in the Analytic Battery. Not surprisingly, however, it was negatively correlated with every test in the Divergent Battery although only the negative correlation with Possible Jobs was significant. Successful performance on the Reasoning test would necessitate a critical analysis of any solution the Subject derives; but critical evaluation of potential answers on the Divergent Battery would not be beneficial because Divergent scores are based on number of answers, not quality of answers. Therefore, evaluation would decrease scores on the Divergent Battery in two ways: 1) it would slow the Subject down and 2) it would lead to rejection of potential answers. The correlations revealed among the tests within the Divergent Battery were expected because the tests were devised to measure similar abilities.

In violation of the rule that results which do not strictly meet a set significance level must be attributed to chance, a few speculative remarks will be made about the negative correlation between Mathematics and the Nebes ($r=.3?$, $df=22$, $p<.10$). An individual with poor access to a synthetic mode of processing might compensate for this deficit by fully developing his analytic capacities. The ability to perform rote mathematical calculations very rapidly would give the poorly lateralized individual more time to attend to other aspects of problems requiring insight. He could, therefore, make up for decreased flexibility to some extent by becoming extremely proficient at strictly analytic tasks. Further evaluation of this speculation should be made.

One remaining consideration in this paper is Subject assignment. Previous studies of laterality in normals have compared poorly defined groups labeled "sinistrals" and "dextrals". In the present study the Well Lateralized Group contained four sinistrals, a direct violation of previous methodology. Similarly, the Poorly Lateralized Group was composed predominantly of individuals with inconsistent dextral tendencies. Based solely on the results of Nebes' test, the consistent sinistrals seem to have as good an access to right hemispheric abilities as do the consistent dextrals. However, the results on Flexibility of Closure do not at first seem to support such a conclusion. If right hemispheric availability is not diminished in these individuals, why do they have lower Flexibility scores? A possible explanation for these results comes from James, Mefferd, and Wieland (1967). They administered a battery of three tests to several groups of right and left handed Subjects. The battery included Spatial Orientation, Speed of Closure, and Flexibility of Closure. This battery initially correlated with handedness at a very low level. However, when the forms were relabeled and turned upside-down for the sinistrals so that the sample figure was not obscured by the left hand in writing position, these differences disappeared. This finding suggests that features of the testing situation rather than inherent abilities of the sinistrals might account for poor performance on Flexibility of Closure. Further evaluation of this possibility is important. If poor Closure scores in these individuals can be accounted for by extraneous variables, this test might be used as an initial screening tool for laterality. The Nebes is very time consuming, requiring about an hour for two sessions. Closure requires only ten minutes and can be administered in groups. Considerable economy would, therefore, be gained if this test were a good enough predictor of lateral specialization to be used as an initial screening device.

Some anecdotal observation on two of the Subjects who participated in the initial screening but did not qualify for assignment to an experimental group might also be of interest. One male and one female ambidextral were screened but were rejected because their Nebes scores were above the critical score. The most consistent difference between these Subjects and others was the length of time spent per session on the Nebes. Unfortunately, session length was not monitored during this study because a pilot study had shown fairly uniform times of between 15 and 20 minutes. The female ambidextral spent close to an hour in her first session and scored 18/24 on the Arc-Circle Test. She commented repeatedly about the difficulty of the task and spontaneously reported the strategies she tried. One interesting tactic she employed was attempting to move her eyes the same speed and at the same angle as her obscured finger was moving over the arc and comparing this movement with the visually available circles. During her second session she decided to use a "more intuitive" approach, spent about 20 minutes, and scored 13/24. This same Subject insisted on giving verbal responses to this task although she was repeatedly asked to point to the correct choice.

The male ambidextral was also particularly interesting. He stated he was ambidextrous with right handed tendencies as a young child, but he broke his right arm at age four.

While that arm was in a sling he started to use his left hand and has continued to do so for many activities including writing. His first session was also very long, and he scored 15/24 on the Arc-Circle Test. When he appeared for his second session he commented that he did not believe he could solve another problem that day. He had just come from a Chemistry examination for which he had studied for the preceding 24 hours. He then sat down and in 10 minutes scored 18/24 on the Arc-Circle Test. The temptation is strong to question whether poorly lateralized individuals can, by "fatiguing" one mode of processing, free the subordinate mode. Of course, this is a giant speculative leap, but so little is known about the interaction of the two modes of processing in normal individuals that no clues should be discarded without examination.

In summary, performance on two tests in the Analytic Battery was significantly higher for the Well Lateralized Group than for the Poorly Lateralized Group. One of the tests, Flexibility of Closure, probably requires a bimodal approach for solution and, therefore, should have been placed in the Divergent Battery. Differences on the second test, Planning, are more difficult to understand but may be related to the concrete nature of the test items. The only Divergent Test which resulted in significantly different performance by the two groups was Decorations, which involves spatial elements. The short time limit imposed on the Subjects dur .g these tests may have prevented group differences. The rimary value of the present research has been to elucidat which areas of research concerning higher cognitive fun. . ions and laterality in normal individuals might be mos fruitful to pursue.

BIBLIOGRAPHY

BIBLIOGRAPHY

Adamson, R. E. Functional fixedness as related to problem-solving: A repetition of three experiments. *Journal of Experimental Psychology*, 1959, *44*, 228-291.

Anastasi, A. *Psychological testing* (3rd Ed.). London: MacMillan Co., 1971.

Annett, M. A model of the inheritance of handedness and cerebral dominance. *Nature*, 1964, *204*, 59-60.

Annett, M. The binomial distribution of right, mixed and left handedness. *Quarterly Journal of Experimental Psychology*, 1967, *29*, 327-333.

Annett, M. A classification of hand preference by association analysis. *British Journal of Psychology*, 1970a, *61*, 303-321.

Annett, M. The growth of manual preference and speed. *British Journal of Psychology*, 1970b, *61*, 543-558.

Benson, F. D. & Geschwind, N. Cerebral dominance and its disturbance. *Pediatric Clinics of North America*, 1968, *15*(3), 759-769.

Bogen, J. E. The other side of the brain I: Dysgraphia and dyscopia following cerebral commissurotomy. *Bulletin of the Los Angeles Neurological Societies*, 1969a, *34*(2), 73-105.

Bogen, J. E. The other side of the brain II: An appositional mind. *Bulletin of the Los Angeles Neurological Societies*, 1969b, *34*(3), 135-162.

Bogen, J. E. & Bogen, G. M. The other side of the brain III: The corpus callosum and creativity. *Bulletin of the Los Angeles Neurological Societies*, 1969, *34*(4), 191-220.

Crowell, D. H., Jones, R. H., Kapuniai, L. E., & Nakagawa, J. K. Unilateral cortical activity in newborn humans: An early index of cerebral dominance? *Science*, 1973, *180*, 205-208.

Deikman, A. J. Bimodal consciousness. *Archives of General Psychiatry*, 1971, *25*, 481-489.

Flanagan, J. D. Flanagan aptitude classification tests. Chicago: Science Research Associates, Inc., 1958.

Gazzaniga, M. S. The bisected brain. New York: Appleton, 1970.

Gazzaniga, M. S., Bogen, J. E. & Sperry, R. W. Observations on visual perception after disconnexion of the cerebral hemispheres in man. Brain, 1965, 88(2), 221-236.

Gazzaniga, M. S. & Sperry, R. W. Language after section of the cerebral commissures. Brain, 1967, 90, 131-148.

Guilford, J. P. The nature of human intelligence. New York: McGraw-Hill Book Co., 1967.

Hewitt, W. The development of the human corpus callosum. Journal of Anatomy, 1962, 96(3), 355-358.

James, W. E., Mefferd, R. B., & Wieland, B. A. Repetitive psychometric measures: Handedness and performance. Perceptual and Motor Skills, 1967, 25, 209-212.

Kimura, D. Cerebral dominance and the perception of verbal stimuli. Canadian Journal of Psychology, 1961, 15(3), 166-171.

Kimura, D. Speech lateralization in young children as determined by an auditory test. Journal of Comparative and Physiological Psychology, 1963, 56(5), 899-902.

Levy, J. Possible basis for the evolution of lateral specialization of the human brain. Nature, 1969, 224, 614-615.

Levy, J. Lateral specialization of the human brain: Behavioral manifestations and possible evolutionary basis. In John A. Kiger, Jr., (Ed.), Biology of Behavior. Corvallis: Oregon State University Press, 1971.

Levy, J., Trevarthen, C., & Sperry, R. W. Perception of bilateral chimeric figures following hemispheric deconnexion. Brain, 1972, 95, 61-78.

Levy-Agresti, J. & Sperry, R. W. Differential perceptual capacities in major and minor hemispheres. Proceedings N.A.S., 61:1151 (abstract). Reviewed in Levy, J. chapter in Kiger's Biology of Behavior, cited above.

Mil 'r, B. Interhemispheric differences in the localization of psychological processes in man. *British Medical Bulletin*, 1971, *27*(3), 272-277.

Mil 'r, B. & Taylor, L. Right hemisphere superiority in tactile pattern-recognition after cerebral commissurotomy: Evidence for non-verbal memory. *Neuropsychologia*, 1972, *10*, 1-15.

Mol 'se, D. L. Cerebral asymmetry in infants, children and adults: Auditory evoked responses to speech and music stimuli. Paper presented to the Acoustical Society of America, Miami, 1972.

Mol 'se, D. L. Cerebral asymmetry: The development of speech perception in the human brain. Paper presented at Midwest Psychological Association, 1973.

Nel s, R. D. Superiority of the minor hemisphere in commissurotomized man for the perception of part-whole relations. *Cortex*, 1971a, *7*, 333-349.

Nel s, R. D. Handedness and the perception of part-whole relationships. *Cortex*, 1971b, *7*, 349-356.

Pet ie, A. *Individuality in pain and suffering*. Chicago: University of Chicago Press, 1967.

Sie el, S. *Nonparametric statistics for the behavioral sciences*. New York: McGraw-Hill, 1956.

Silverman, A. J. Unpublished lecture at Texas Research in Mental Science, April, 1973.

Silverman, A. J., Adevai, G., & McGough, E. Some relationships between handedness and perception. *Journal of Psychosomatic Research*, 1966, *10*, 151-158.

Sperry, R. W. Hemispheric deconnexion and unity in conscious awareness. *American Psychologist*, 1968, *23*, 723-733.

Ter an, L. M. Concept Mastery Test, Form T. New York: The Psychological Corporation, 1956.

Thurstone, T. G. & Jeffrey, T. E. Closure Flexibility, Form A. Chicago: Industrial Relations Center, The University of Chicago, 1956.

APPENDIX A

NEBES SCORES, LATERALITY INFORMATION AND ACADEMIC MAJOR OF SUBJECTS

	Nebes						
	Arc-Circle	Circle-Circle	Hand	Eye	Foot	Family History	Academic Major
WLM1*	33	41	Left	Mixed	Right	Maternal GF & uncle, paternal GF & aunt left.	Mathematics
WLM2	35	31	Right	Right	Right	All right.	Physics
WLM3	39	47	Left	Left	Left	Maternal & paternal GMs, numerous cousins left.	Sociology
WLM4	34	34	Right	Mixed	Right	All right.	Physics
WLM5	36	43	Left	Right Amblyopia	Left	Of 10 siblings, 3 left & one ambi-dextral.	Geology & Biology
WLM6	36	40	Right	Right	Right	All right.	Political Science
WLF1	39	23	Right	Right	Right	All right.	English
WLF2	33	42	Right	Right	Right	All right.	Art History
WLF3	33	40	Right	Right	Right	All right.	Art & Spanish
WLF4	35	36	Right	Right	Right	All right.	Mathematics

*WL - Well Lateralized; M and F refer to male and female, respectively.

NEBES SCORES, LATERALITY INFORMATION AND ACADEMIC MAJOR OF SUBJECTS (Continued)

	Nebes Arc-Circle	Nebes Circle-Circle	Hand	Eye	Foot	Family History	Academic Major
WLF5	33	39	Left	Mixed	Right	Paternal GM & numerous cousins, both maternal & paternal, left.	English
WLF6	34	33	Right	Right	Right	All right.	Speech Audiology
PLM1*	28	30	Right**	Right	Right	Father & paternal relatives ambidextrous.	Economics
PLM2	26	41	Right, Inverted	Right	Right	Only sibling ambidextrous.	Radio-TV
PLM3	26	40	Right**	Right	Right	All male members of family ambidextrous.	English
PLM4	28	38	Left+	Mixed	Left	All right.	Political Science
PLM5	23	39	Mixed	Right	Right	Father, paternal GF & GM left. No maternal sinistrals.	Psychology
PLM6	21	23	Right**	Right	Right	Only sibling & numerous cousins left.	Psychology

*PL - Poorly Lateralized; M and F refer to male and female, respectively.
**Inconsistent right.
+Inconsistent left.

NEBES SCORES, LATERALITY INFORMATION AND ACADEMIC MAJOR OF SUBJECTS (Continued)

	Nebes						
	Arc-Circle	Circle-Circle	Hand	Eye	Foot	Family History	Academic Major
PLF1	23	34	Right, Inverted	Mixed	Right	All right.	Mathematics
PLF2	25	33	Right**	Right	Right	Father & sister left.	Political Science
PLF3	29	42	Right**	Right	Right	Sibling & cousins left; 2/4 children ambidextrous. No sinistrals in husband's family.	English
PLF4	26	36	Right**	Mixed	Right	Sibling left; 1/2 children left. No sinistrals in husband's family.	Geography
PLF5	28	39	Right**	Right	Right	Father & one maternal cousin left.	Mathematics
PLF6	29	40	Right**	Right	Right	Son left.	Economics

**Inconsistent right.