COGNITIVE PROCESSING STYLE AND HANDEDNESS

By

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ABSTRACT

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This study investigated the relation between cognitive processing style and handedness in adults. Cognitive processing style was operationally defined as scores on two instruments: the 40-item Your Style of Learning and Thinking (SOLAT), and the 7-item Hemispheric Consensus Prediction Profile II (HCP). Three ipsative scores were obtained for each of these dependent variables: left, right, and integrated hemisphericity. Handedness was defined as scores on the Edinburgh Handedness Inventory. Based on these scores, left handers, ambidexters, and right handers were identified.

Subjects were 100 adult volunteers, 25 subjects each in the following sex and writing hand categories: left handed and right handed males, and left handed and right handed females. Subjects ranged in age from 23 to 63 years. In addition to the cognitive processing style and the handedness instruments, subjects completed a biographical questionnaire, a writing posture assessment, and a measure of familial sinistrality.

Right handedness was found to be associated with the right hemisphere cognitive style and left handedness was associated with the left style. All subject variables

investigated - handedness, sex, writing posture, and familial sinistrality - exerted significant effects on cognitive processing style scores.

Three major conclusions were drawn, all of which revolve around the differentiation of subgroups of left handers. The first major conclusion was that writing posture clearly affects cognitive processing style scores. Subjects with an inverted writing posture used a left hemisphere style; those with a standard posture used a right hemisphere style. The second conclusion was that inverted posture left handers with no familial sinistrality are a distinct subgroup of all left handers. This subgroup was characterized by more of an integrated and less of a left hemisphere style than their standard posture counterparts. The third conclusion was that ambidexters tend to differ among themselves. Among ambidexters (13 of 15 being left handed writers) with no familial sinistrality, those with a standard writing posture were characterized by an integrated style of thinking, while those with an inverted posture used a left hemisphere style. In addition, ambidexters with no familial sinistrality were least likely to use a right hemisphere style.

DEDICATION AND ACKNOWLEDGEMENTS

This work is dedicated to my sons, right handed Gene and left handed Drew Zande, who have learned the hard way what an achievement oriented woman is all about. While the pursuit of a Ph.D. has been an important part of my life for nine years, Gene and Drew have occupied the central position for 14 and 13 years, respectively. I am immensely proud of the young men my sons have become.

I would like to thank Dr. John Schweitzer, my dissertation director, for his computer expertise, patience, and good humor thoughout the process. Thanks are also extended to comittee members Dr. Robert Griffore, a long-time friend, and Dr. Robert Craig, my long-time academic advisor. I am grateful, too, to Dr. Robert Green for the opportunity to work as his graduate assistant. Finally, thanks are due to my parents, Mr. and Mrs. Victor Hebert, who provided many hours of child care for my sons during my graduate school years.

My acknowledgements would be incomplete without mention of the late Dr. Robert Ebel. He was a man with a rare combination of professional competence and personal wisdom which will be sorely missed as a model for graduate students and young professors.

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CHAPTER I

PROBLEM

This study is prompted by an accumulation of ten years of brain research. An intensive search is now underway for the cognitive correlates of hemispheric specialization, which refers to the localization of functions in the left or right hemisphere of the brain. One possible correlate is cognitive processing style. Cognitive processing style is defined as an individual's preferred mode of responding to a stimulus. Three styles, based on the individual's relative dependence on one or the other hemisphere of the brain, have been postulated. The left hemisphere style is characterized by a verbal, sequential, analytic mode of responding. The right hemisphere style is spatial, simultaneous, gestaltist. The integrated style is a blend of the first two styles.

Thompson and Bogen (1976) contend that

> each individual has a certain predilection for using one hemisphere more than the other. In this view, there is such a thing as individual hemisphericity; i.e., the degree to which someone tends to rely on one or the other hemisphere. (p. 93)

Drawing on Thompson and Bogen's (1976) concept, Torrance, Riegel, and Ball (1977) have developed an instrument to measure individual hemisphericity. This instrument, Your Style of Learning and Thinking (SOLAT), offers the respondent three choices for each of 40 questions: One choice represents the left hemisphere style, the second represents the right hemisphere style, and the third represents an integrated style.

Although the SOLAT is theoretically derived from research on hemispheric specialization, it has not been fully validated against the standard indices of brain functioning, one of which is handedness. One study, by Aliotti (1981), did use the SOLAT to explore cognitive processing style, handedness, and intelligence. The SOLAT and a 16-item handedness questionnaire were administered to 23 male and 37 female gifted high school students. Binet IQ scores were used as the intelligence measure.

Separate analyses for Aliotti's male and female subjects revealed that males preferred significantly more left hemisphere activities on the SOLAT and females preferred the integrated style. For males, right handedness was positively correlated with left hemisphericity. Ambidexterity correlated positively with right hemisphericity and negatively with left hemisphericity. IQ and handedness correlations were significant for the males only. Binet IQ correlated -.36 with right handedness and .34 with left handedness.

Aliotti concludes that his findings lend support to the construct validity of the SOLAT and that his results underscore the importance of controlling for handedness. The present study will extend Aliotti's research to adults and will investigate additional variables: familial sinistrality, sex, and writing posture.

Purpose and Need

The purpose of the present study is to investigate the relationship between cognitive processing style and handedness. Cognitive processing style is operationalized as hemisphericity scores on two instruments, Your Style of Learning and Thinking, and the Hemispheric Consensus Prediction Profile II (HCP). Each of these instruments provides three scores: left, right, and integrated hemisphericity. Handedness is operationalized as scores on the Edinburgh Handedness Inventory. This is a 10-item inventory which assesses both direction and degree of handedness.

The need for the present study arises from a lack of valid data on the relationship under study. What data are available fail to account for all relevant variables. Previous research has shown the need to control for sex, familial sinistrality, and writing posture, in addition to handedness.

There are few instruments specifically designed to measure cognitive processing style as a function of hemispheric specialization. Subtests of the WISC or WAIS are commonly employed, but these are ability, not preference measures. Insofar as ability is distinct from preference, then the need for a valid measure of cognitive processing style remains to be filled.

Whether or not the SOLAT and HCP do, in fact, measure anything having to do with hemispheric specialization is still an open question. The present study will attempt to answer this question by exploring the relationship between cognitive processing style and handedness.

Research Questions and General Hypothesis

The present research seeks to answer two questions: 1) Is a person's handedness associated with processing preference? and 2) What other subject variables are associated with right and left hemisphere processing preferences? More specifically, do family history of sinistrality, sex, and writing posture affect hemisphericity scores?

The general hypothesis is that handedness will be associated with cognitive processing style. Specific hypotheses are presented in Chapter III.

Implications and Applications

The educational implications of brain research have been recognized by educators and neuroscientists alike. Wittrock (1978), for example, believes that previous research implies the existence of at least two strategies employed by the brain to construct meaning, one analytic and the other holistic. Instruction to induce these strategies will vary accordingly. Wittrock believes that instruction begins with careful observation of the individual differences in cognitive processes of learners, and that the teacher is afforded new importance in understanding and facilitating their cognitive constructions.

Chall and Mirsky (1978) suggest that brain research has led to two types of inferences for education, which "deserve serious study and controlled tryout" (p. 375).

> First, there are suggestions to strengthen the "weak" left-hemisphere processes by using more the intact right hemisphere for learning of left-hemisphere processes. . . A second recommendation is that students who are weak in academic skills (based heavily on the left hemisphere) be taught music, construction, and other activities involving right-brain processing in order to provide these right-brained children with some activities in which they can excel. (p. 374)

Joseph Bogen, a neurosurgeon who performed many of the operations which led to the seminal findings on the brain's hemispheric processes, has also tackled the issue of educational implications. Bogen (1977) opens his chapter on this subject with:

> It seems that we have finally learned a fact about the brain which bears directly upon everyday pedagogical practice. We now understand that the brain is double, in the sense that each cerebral hemisphere is capable of funtioning independently, each in a manner different from the other. (pp. 133-134)

Bogen calls for an equalization of the balance between overemphasized left hemisphere processes and neglected right hemisphere thinking. He believes that recent brain research serves as scientific support for a more diversified curriculum and serves "to stimulate a new set of questions for those who will pilot the future of education" (p. 149).

Research on cognitive processing style as a function of hemispheric specialization is a relatively new but exploding field. The information amassed over the last decade as a result of many individual research efforts with normal human subjects has seemed to confuse the apparent simplicity of a dual mind. The challenge to future research is to sort out and integrate these diverse findings.

Research results to date, while varied and still seeking sure theoretical footing, nonetheless undeniably point to real and significant differences in the functioning of the brain's two hemispheres. Since such differences exist, education and psychology can hardly look away; further theorizing and a continued accumulation of research findings may someday permit well-grounded applications in the classroom.

Although such classroom applications are now considered premature by some (Hardyck and Haapanen, (1979), attempts have been made to make brain research directly relevant to classroom learning. For example, the practice, common in earlier years, of "encouraging" left handed students to switch to the right hand for writing often reflected the belief in a link beween left handedness and cognitive deficit. More recently, teaching strategies have been proposed to train the "whole" mind, i.e., the verbal, sequential, analytic half and the visuospatial, simultaneous, synthetic half (Brandwein and Ornstein, 1977; Kane and Kane, 1979; Schwartz, 1980). Another attempt at application can be seen in the new approaches to identifying intellectually gifted/ creative children (Rekdal, 1979). These approaches see traditional IQ measures as inadequate to the task of identifying creative children, and propose that identification be based on patterns of hemispheric specialization. While research on hemispheric specialization has, potentially, much to offer in terms of the educational process, it seems that a good deal of further study is required before classroom applications are justified. Research has pointed to considerable implications for education, but the state of the art does not yet permit direct application in schools.

The significance of the present line of inquiry for education lies primarily in the future development of teaching methods tailored to the individual learner. If distinguishing individual differences in cognitive processing style does not have an immediate effect on teaching strategies, research on the brain's functions can at least have the valuable effect of sensitizing teachers to the various modes of cognition employed by their students.

Preview

The next chapter will review the literature on cognitive processing style and handedness. Following an introduction to theory and research on brain functions, research on cognitive processing style - hemisphericity - will be discussed. The literature on handedness, including its correlation with other measures of hemispheric specialization, will be reviewed. Studies describing the effects of the three other subject variables used in the present study will then be reviewed: familial sinistrality, sex, and writing posture. Finally, a section on cognitive abilities will be presented.

CHAPTER II

REVIEW OF THE LITERATURE

A recognition of the mind's apparent duality spans several centuries and cultures. Experimentation with animals and with human split brain patients in the last few decades has verified this historical belief in the double mind. One fascinating line of research has been produced by Sperry and his colleagues at the California Institute of Technology. Their split brain work led to the postulation of two distinct modes of thought. According to Michael Gazzaniga (1973),

> Taken together, our studies seem to demonstrate conclusively that in a split brain situation we are really dealing with two brains, each separately capable of mental functions of a high order . . . All the evidence indicates that separation of the hemispheres creates two independent spheres of consciousness within a single cranium, that is to say, within a single organism. (pp. 98, 100)

Joseph Bogen (1977) presents a table showing the historical interest in dichotomizing human consciousness.

TABLE 1. Terms Describing the Dichotomous Theory of Intelligence*

Akhilinanda	buddi	manas
Assagioli	intellect	intuition
Austin	convergent	divergent
Bateson & Jackson	digital	analogic
Blackburn	intellectual	sensuous
Bronowski	deductive	imaginative
Bruner	rational	metaphoric
Cohen	analytic	relational
De Bono	vertical	horizontal
Deikman	active	receptive
Dieudonne	discrete	continuous
Freud	secondary	primary
Goldstein	abstract	concrete
Guilford	convergent	divergent
Hilgard	realistic	impulsive
Hobbes (per Murphy)	directed	free
Humphrey & Zangwill	propositional	imaginative
W. James	differential	existential
A. Jensen	transformational	associative
Kagan & Moss	analytic	relational
D. Lee	lineal	nonlineal
Levi-Strauss	positive	mythic
Levy & Sperry	analytic	gestalt
Lomas & Berkowitz	differentiation	integration
McFie, Piercy (from Spearman)	relations	correlates
McKellar	realistic	autistic
Maslow	rational	intuitive
Neisser	sequential	multiple
Oppenheimer	historical	timeless
Ornstein	analytic	holistic
Pavlov	second signaling	first signaling
C. S. Peirce	explicative	ampliative
Polanyi	explicit	tacit
Price	reductionist	compositionist
Radhakrishnan (per H. Smith)	rational	integral
Reusch	discursive	eidetic
Schenov (per Luria)	successive	simultaneous
Schopenhauer	objective	subjective
C. S. Smith	atomistic	gross
Wells	hierarchical	heterarchical

*From "Some Education Implications of Hemispheric Specialization" by Joseph E. Bogen in The Human Brain, by M. C. Wittrock et. al., 1977, p. 135.

The stark view of two separate minds inhabiting the cerebral hemispheres arose from historical sources, from the study of commissurotomy patients, and from animal research. Research with normal human subjects over the last ten years, however, has demonstrated the complexity of the relationship between the hemispheres, and their interdependence. For example, the processing of musical sounds, once thought to be almost exclusively the province of the right hemisphere, has been shown to vary with the musical expertise of the subject. Several studies have shown that musically naive subjects depend on the right hemisphere for processing music, while experienced musicians rely relatively more on the left hemisphere, suggesting differential processing styles based on talent or experience (Hirshkowitz, Earle, and Paley, 1978; Webster and Thurber, 1978). The state of thinking about shared or duplicated functions of the two hemispheres is expressed by Bradshaw, Gates and Nettleton (1977), who contend that no one hemisphere is exclusively specialized for any one function. Rather, the right and left hemisphere cognitive processes are integrated and sometimes seem to be duplicated, or bilaterally represented, in each hemisphere.

Much of the recent lateralization research has been aimed at describing the psychological functions specific to each half-brain in normal subjects. Work on the integration or duplication of functions is still in its infancy. However, after a ten year long flurry of research, the literature on handedness and cerebral specialization is now considerable. Much has been learned about the psychological characteristics which reflect the brain's organization. What has been learned with any certainty, however, is about dextrals, especially dextral males. The typical conclusion is that the left hemisphere of dextrals is specialized for verbal, sequential, analytic processing, and the right hemisphere is specialized for visuospatial, simultaneous, synthetic processing.

The cerebral organization of left handers, who represent a sizable minority of the population, is less clear. Estimates of the incidence of left handedness in the population vary. Hardyck and Petrinovich (1977) believe that a population estimate of 8-10% is most appropriate, with a higher incidence being likely among certain impaired populations. Annett (1973) records estimates of left handedness between 4% and 35%, depending on sex, age of the sample, and criterion for sinistrality. More males are sinistrals; a higher percentage of younger persons are left handed, presumably due to fewer social pressures for right handedness in recent years; and the incidence of sinistrality increases as the number of items to determine laterality increases.

Sinistrals are more heterogeneous than dextrals with respect to hemispheric specialization, and their cerebral organization is not always directly opposite to that of right handers. While over 90% of right handers have right hemisphere specialization for visuospatial, synthetic functions, most studies agree that only 50% to 70% of sinistrals share this organization (Geffen and Traub, 1980; Herron et. al., 1979). There is less agreement about the amount of right hemisphere participation in the verbal aspects of language in the remaining 30% to 50% of sinistrals, and this subgroup is usually considered to have either bilateral or reversed representation.

Cognitive Processing Style: Hemisphericity

The purpose of the present study is to investigate the relationship between cognitive processing style and handedness. The literature reviewed in this section defines cognitive processing style as hemisphericity, describes research on cultural differences in hemisphericity, and reviews those studies which have used the SOLAT, which is the measure of hemisphericity in the present study.

Cognitive processing style - hermisphericity - is an individual's preference for activating one or the other hemisphere in response to task and internal demands. Reminiscent of the executive control function in information processing models, Rapaczynski and Ehrlichman (1979) say that which hemisphere predominates in a given task might be determined by the "choice" of process to be used by the individual. Such a choice is a cognitive style or strategy. Subjects with different styles or strategies might be expected to show different laterality patterns, and this is the underlying expectation of research on hemisphericity.

In the present study, these different laterality patterns are expected to be reflected in handedness differences.

The results of studies on hemispheric specialization are thought to be influenced by individual differences in cognitive processing style, "the suggestion being that stimulus presentation and mode, together with task requirements and subject variables, may influence hemispheric modes of processing" (Moore, 1979, p. 325). To say that individuals differ in cognitive processing styles does not necessarily mean that each individual habitually uses the same style, right, left, or integrated. Rather, the hemispheres operate flexibly, in a complimentary fashion. Characteristic styles or strategies are important, nonetheless, as attested to by Webster and Thurber (1978). These researchers, using a tactual shape recognition task, trained subjects to learn the shapes in one of two ways, with instructions designed to induce a sequential, left hemisphere strategy, or with instructons to use a Gestalt, right hemisphere strategy.

The instructions were found effective in biasing subjects toward approaching the task in one way or another. On questioning subjects after the experiment, however, it was revealed that 23% of those instructed to use the Gestalt strategy stated that they had actually used words to help them learn, and 37% of those instructed to use a sequential strategy said they had <u>not</u> used words. These remarks "may reflect the difficulty of altering strategies with which <u>S</u>s come predisposed to use (at least in the absence of prolonged training)" (p. 482).

Webster and Thurber's results indicate that

> brain lateralization must be defined, not strictly by tasks, but by the strategies used by subjects to perform the tasks used to detect and study that lateralization. It is this which immensely complicates the issue of interpreting the origin and basis of individual and group differences in lateralized performance effects. (p. 483)

Hardyck (1977) describes the ways in which different processing styles are used to achieve similarly successful outcomes.

> It is argued that the bilaterally organized individual - the familial left-handed individual - achieves exactly the same range of quality of solutions to problems as does the highly lateralized and specialized right-handed individual, despite the lack of extreme hemispheric specialization . . . by employing both hemispheres to work on problems in a parallel manner and then combining the two efforts in order to reach a solution equivalent to one that a single, highly specialized hemisphere could produce. The process can be characterized as follows: Individuals with a highly lateralized form of cerebral organization will solve a given type of problem by processing it in the hemisphere specialized for that type of problem, checking it and rechecking it until a satisfactory answer is reached. An individual with a bilateralized type of cerebral organization will solve a problem by having the two hemispheres do overlapping parts of the problem in parallel, sharing data and cross-checking until a satisfactory answer is reached. Measures of outcome, in terms of successful solutions, for both lateralized and bilateralized individuals will be identical. (pp. 239-240)

Cultural Hemisphericity. Cognitive processing style was examined in a series of articles initiated by Bogen, DeZure, ten Houten and Marsh (1972), who hold that there are two distinct modes of human thought, the propositional and appositional. These modes are thought to be methods of information processing typical of the left and right hemisphere, respectively, of well-lateralized right handers. Thompson and Bogen (1976) describe the thinking behind their research:

> It was next supposed that these two kinds of cognition are differentially suited to various tasks, so that the proportion of involvement of the two hemispheres varies according to the situation. We can therefore speak of a particular task as having a certain hemisphericity.
>
> Not only can one speak of hemisphericity varying from task to task, but we can suppose that each individual has a certain predilection for using one hemisphere more than the other. In this view, there is such a thing as individual hemisphericity; i.e., the degree to which someone tends to rely on one or the other hemisphere. Although Zook and Dwyer raise no objection to the concept of individual hemisphericity, we wish to make clear that this intermediate step in our argument remains unproven. There is now an abundance of EEG evidence for task hemisphericity, whereas similar evidence for individual hemisphericity is much harder to come by. (p. 93)

Bogen et. al. had earlier speculated that individual hemisphericity either reflects or gives rise to certain cultural differences, and this hypothesis was later tested by Thompson and Bogen. Subjects were 1,220 rural and urban Hopi, black, and white men and women. Scores on the Street Gestalt Completion test (measuring right hemisphere specialization) and the Similarities subtest of the WAIS (left hemisphere) were computed as ratios of Street/Sim, or Appositional/Propositional. Blacks and Hopis scored relatively higher on appositional, right hemisphere thought. This was explained in terms of the belief that subdominant cultural groups are given less access to propositionalizing and thus rely more on the appositional mode of thought.

Zook and Dwyer (1976) critique these findings by asserting that the right hemisphere seems "to develop similar levels of ability in radically different cultural groups while development of the left hemisphere is depressed by lack of educational opportunity" (p. 88). Zook and Dwyer contend that the group differences found by Bogen really only reflect group differences in the Similarities scores. They see the data as consistent with an abilities model which has right hemisphere abilities as more independent of cultural influence and left hemisphere abilities as more dependent.

Marsh's (1976) article on cultural hemisphericity confesses confusion over Zook and Dwyer's reasoning that only left hemisphere capabilities will vary as a function of education: "We are puzzled by a theory which would ascribe one-half of the cortical higher functions to a heritable origin but not the other" (p. 92).

In yet another article on the topic, ten Houten et. al. (1976) reanalyzed the original data and confirmed the relative appositionality of Hopis and blacks compared to whites and of rurals compared to urbans. The reanalysis also revealed sex differences which were not found in the original study.

Several years later, Thompson, Bogen, and Marsh (1979) tested the discriminability of the Street test for right hemisphere processing among cultural groups. The Street test was given to 145 right handed black and white males and females. Findings showed blacks to be superior to whites on this test. Several manipulations of the test (change of background color, for instance) showed that both absolute and relative levels of performance can be affected by modifications of the test. Thompson et. al. conclude that "more sophisticated testing may reveal variation in appositional abilities as large as the variation in propositional abilities" (p. 42).

Based on the research cited above on cultural differences in hemisphericity, the sample for the present study was confined to whites.

Studies Using Your Style of Learning and Thinking. Research using the SOLAT as a measure of hemisphericity has tended to focus on giftedness or creative functioning. Torrance, Reynolds, Riegel, and Ball (1977) report on eight studies of adolescents and adults who have taken Form A or B of the SOLAT. Aliotti (1981) notes that:

> A persistent trend in these studies has been the relative higher percentage of right hemispheric scores among gifted adolescents. For example, the distribution of cerebral dominance on this test among 200 adolescents

> was as follows: Right (33%), Left (24%), Integrated (27%), and Mixed (16%). These are in contrast with figures for the general population of Right (10%), Left (60%), Integrated (15%), and Mixed (15%). (p. 36)

Torrance (1982) reviews a series of research efforts using 198 graduate students enrolled in one of six offerings of his course in creative thinking. He administered the SOLAT and one or more measure of creativity to all students. The 12 creativity instruments were of two kinds, those assessing creative style or personality (What Kind of Person Are You; Something About Myself; Stein's Physiognomic Cue Test; Welsh Figure Preference Test; Adaptation-Innovation Inventory; Transaction Ability Inventory; Creative Motivation; and Rorschach Inkblot Movement and Originality) and those assessing creative ability or level (Torrance Tests of Creative Thinking; Remote Associates Test; Sounds and Images; and Test of Creative Potential).

Torrance summarizes the results of these studies as follows:

> The results reveal that there is a rather consistent tendency for the measures of creative style to be positively and significantly related to the right hemisphere style of information processing and negatively and significantly related to the left hemisphere style. The results for the integrative style are inconsistent and generally rather low. Results for the creative ability measures are much less consistent. There is a more consistent tendency for the left hemisphere style to be negatively related to measures of creative ability than for positive relations between right and integrative styles and measures of creative ability. (p. 36)

The mean test-retest reliability for the SOLAT is reported to be .85 (Torrance and Sato, 1979). Alternate forms reliabilities range from .63 to .85, which "seem to be satisfactory. Since new areas of behavior were sampled, it is not surprising that the coefficients of correlation were not higher" (Torrance and Reynolds, undated Preliminary Norms-Technical Manual, p. 2).

Cross-cultural research using the SOLAT has also been conducted. Torrance and Sato (1979) tested 4,000 Japanese and United States students, and reported on a random sample of 200 Japanese and 200 United States college students. Torrance and Sato found that the Japanese scored significantly higher on both the right and left hemisphere scales of the SOLAT and lower on the integrated scale than their American counterparts.

The SOLAT has been chosen for use in the present study as the primary measure of cognitive processing style. The reason for this choice was, largely, based on availability of such measures. The SOLAT and the Hemispheric Consensus Prediction Profile II (HCP) developed by Loye (1982) were the only two measures available, and both were used. The literature on the HCP is scanty and presented in Chapter 3 where instrumentation for the present study is described.

Handedness

Hicks and Kinsbourne (1978) provide a thorough review of three aspects of human handedness: its correlation with other laterality dimensions, its causes, and its measurement and definition. They find that: Left handers are more variable than right handers in terms of the hemisphere that is superior for linguistic functions; right handers are more strongly lateralized than left handers; substantial evidence exists for a genetic cause of handedness, although the appropriate model is still unclear; some left handedness is pathological; and handedness and most other laterality dimensions are related.

Hardyck and Petrinovich (1977) hold that

> the relationship between handedness and cerebral organization seems definite, though far from precise . . . The few studies that have assessed family history of handedness have, in general, increased the precision of the relationship under study. (p. 398)

Hardyck and Petrinovich suggest a classification of individual differences in handedness and cerebral function along a continuum, with

> those individuals who are strongly right-handed and have no family history of left-handedness being more highly lateralized for speech and visual functions, the verbal functions being left-hemisphere lateralized and the spatial functions right-hemisphere lateralized. At the opposite end of the continuum are the left-handed with a positive family history of left-handedness who have both speech and visual functions bilaterally localized. Bridging these two groups are the right-handed with a family history of left-handedness, whom one would expect to show greater lateralization of function than do the right-handed with negative family history, but less than do the familial left-handed.
>
> One group remains unaccounted for - the left-handed with no family history of left-handedess. Since the available evidence suggests that localization of function is identical with that of the right-handed with no family history of left-handedness, this group will be classified as identical with the right-handed. (p. 398)

Because self-report handedness inventories provide an easy gauge of cerebral specialization, they have been liberally used. Such inventories have been scrutinized for reliability and validity. Raczkowski, Kalat and Nebes (1974) studied 47 college undergraduates. On two occasions one month apart, subjects completed a 23-item handedness questionnnaire, adapted from surveys developed by Hull (1936) and Oldfield (1971). Individual performance tests were also administered. Item analysis permitted 17 items to be retained, including one item on footedness. Fourteen items showed better than 90% agreement between questionnaire responses and performance test. The remaining three items showed over 80% agreement, with some right hand preference among sinistrals included to measure varying degrees of left handedness. Reliability was ascertained by using percent agreement between the first and second questionnaire responses on each item. The 17 items retained showed agreements of 89% or more.

Reliability was also an issue for Bryden (1977). Bryden measured the handedness of 620 male and 487 female Canadian undergraduates using two standard questionnaires, the Crovitz-Zener and the Oldfield. The former test has 14 items, the latter has 10. Five items were overlapping and their correlations were used as rough measures of test-retest reliability. These correlations ranged between .80 and .90.

Discrepancies in defining and measuring handedness have undoubtedly contributed to some inconsistent results in the laterality literature. Thompson and Marsh (1976) point out that much early research classified handedness dichotomously, making no allowance for an ambilateral group. Not only is one intermediate classification needed, but it has also been considered desirable to have two ambilateral groups, moderately left handed and moderately right handed (Deutsch, 1978). Failure to account for a separate group of ambilaterals resulted in an increase in the number of sinistrals in early research. A more important difficulty relates to the choice of a proper criterion for handedness.

> Writing hand alone will not suffice as it is subject to the greatest cultural pressure. . . . hand dominance should be defined in terms of several (but only a few) basic manual activities, such as using objects or tools which are symmetrical (unlike scissors). This includes such acts as throwing a ball, swinging a hammer, etc. (Thompson and Marsh, 1976, p. 217)

Thompson and Marsh believe that "the best tests for hand preference are those in which only one hand is used, and in which spontaneous use is observed" (p. 218), as opposed to tests involving strength of grip or a timed performance with each hand. One-question handedness assessments are inadequate because further questioning usually reveals that not all self-professed dextrals are completely lateralized to the right; the same may be said of sinistrals. Individual observations of subjects to determine handedness are thought by Thompson and Marsh to be inordinately time-consuming and unnecessary, given reported reliabilities of at least 95% and validities of at least 90% for paper and pencil inventories.

The literature reviewed in this section on handedness has led to a decision to use the 10-item paper and pencil Edinburgh Handedness Inventory in the present study. Given the accepted reliability and validity of such inventories, direct observations of hand preferences were not required. The handedness inventory chosen has the advantage of providing for degree, as well as direction, of handedness.

Correlations with Other Measures. A variety of measures of hemispheric specialization have been devised, ranging from simple self-reports of handedness through measures of eye dominance (tachistoscopic tests) and ear dominance (dichotic listening) to the sophisticated techniques of brain wave analysis in EEGs. The search for reliable and valid measures of cerebral specialization has left few stones unturned. Data has been gathered from a wide range of sources - from observations of commissurotomy patients to measurements of thumbnail appearance (Block, 1975).

The present study uses handedness as a measure of hemispheric specialization. A review of research correlating handedness with one or more of the other dimensions of laterality is presented in this section. The research reviewed has produced mixed results. Several studies have shown a significant correlation between ear and hand laterality (Hicks and Kinsbourne, 1978; Lewandowski, 1982).

Some evidence shows the correlation between handedness and eyedness to be very poor (Clark, 1957; Gronwall and Sampson, 1971; McKinney, 1967). Hardyck and Petrinovich (1977) state that handedness and eyedness correlate only about .53.

The laterality dimension of footedness has also been linked with handedness. Footedness is usually assessed by asking the subject which foot is used to kick a ball, or which foot a shoe is put on first. Levy and Levy (1978) have studied footedness from another angle - differences in the size of the right versus the left foot. Noting that 75% of their subjects had feet of unequal size, Levy and Levy found that size asymmetries were strongly related to handedness and sex. Right handed males had larger right feet than left, and right handed females had larger left feet. Nondextrals showed the opposite pattern.

Hicks and Kinsbourne (1978) conclude their review on human handedness by stating that "handedness is related to most other laterality dimensions" (p. 539), and that sinistrals are more heterogeneous than dextrals on most dimensions. For this reason, "different indexes of laterality are more likely to intercorrelate with each other in groups of right-handers than in groups of left-handers" (p. 540).

Johnstone, Galin and Herron (1979) divided 90 subjects into handedness groups according to preference (12-item questionnaire), performance (speed, strength, dexterity), and preference plus performance to determine which method yielded the greatest group differences on EEG and dichotic listening measures. The handedness measures were found to be significantly intercorrelated and were significantly correlated with dichotic listening results as well. Correlations between handedness and EEG were significant only for females. Johnstone et. al. summarize:

> In summary, the questionnaire is a more comprehensive measure of handedness than any single performance measure. The relation of handedness to EEG asymmetry may lie in that part of the questionnaire which is unrelated to the performance tests. In contrast, the dichotic test seems to relate to performance as well as to the preference questionnaire. Ambidexters have been shown to be a distinct group; combining ambidexters with "pure" left-handers simply because they use the same hand for writing may be confounding. Finally, attempts should be made to score degree of handedness where possible rather than dividing subjects into discrete groups. (p. 79)

Studies correlating handedness with other measures of hemispheric specialization have been reviewed. It was observed that handedness correlates positively with most other measures of hemispheric specialization, particularly for right handers. The studies reviewed provide data on the validity of handedness as a measure of hemispheric specialization.

Subject Variables

In addition to handedness, three subject variables were explored in the present study - familial sinistrality, sex, and writing posture. The literature addressing these variables is reviewed in this section.

Familial Sinistrality. Results from several lines of research support the heterogeneity of left handers in terms of their underlying cerebral specialization. Familial sinistrality is one factor which contributes to this heterogeneity.

A family history of sinistrality is associated with moderate rather than strong left handedness. The non-familial left handed tend to be more strongly lateralized and probably have the same verbal organization as right handers. The left handed with no family history of sinistrality may use their left hands because of an early brain insult, because of an unspecified environmental effect, or even because of extreme negativism (Hardyck and Petrinovich, 1977).

Most sources agree with Annett (1973) that laterality is continuous rather than dichotomous. Although dichotomizing human thought has been appealing historically, a simple dichotomy of left or right cognitive processes is now considered insufficient, since left handers are heterogeneous and even right handers are somewhat variable in terms of laterality. Handedness, sex, and familial sinistrality have all been shown to contribute to one's resting point on the laterality continuum.

Lake and Bryden (1976) found that three factors - handedness, sex, and familial sinistrality - moderate ear laterality on a dichotic listening task, such that 1) males with familial sinistrality showed a strong right ear and left hemisphere superiority, while females with familial sinistrality showed an atypical left ear and right hemisphere superiority, regardless of handedness; and 2) males and females without familial sinistrality were similar to each other, with left handers showing a left ear and right hemisphere superiority.

A study by Piazza (1980) also describes a continuum of laterality. Piazza found that right handers without familial sinistrality are most strongly lateralized for right handedness; left handers with familial sinistrality show the weakest lateralization and are most likely to show atypical brain organization. Occupying mid-points on the continuum are sinistrals without familial sinistrality and dextrals with familial sinistrality.

A similar pattern was discovered by Varney and Benton (1975) who tested tactile perception of direction by stimulating the palms of subjects' hands. They found a significant familial sinistrality effect, such that 1) right handers without familial sinistrality showed clear superiority on the left hand; 2) left handers with familial sinistrality were superior on the right hand; and 3) both dextrals with familial sinistrality and sinistrals without familial sinistrality showed no lateral asymmetry.

Because of the influence of familial sinistrality on both left and right handed subjects, Varney and Benton recommend that information on this factor be obtained from all subjects, regardless of avowed handedness, in laterality research. Andrews (1977) leads to the same conclusion when he notes that, regardless of hand preference, a family history of left handedness has been associated with an attenuated dependence of language functions on the left hemisphere in EEG, dichotic listening, and tachistoscopic research.

The genetics of handedness, like so many other human charcteristics, has aroused spirited scientific debate. Levy and Nagylaki (1972) have proposed a model of the genetics of handedness which assumes a dichotomous distribution. Annett's (1973) model, on the other hand, has handedness as a continuously distributed function, with right handedness inherited and left handedness not. Most of the genetic models propose that left handedness is carried as a Mendelian recessive (Hardyck and Petrinovich, 1977).

Accused by Hudson (1975) of failing to take into account cultural influences on handedness, Levy (1977) asserts that she doesn't underestimate these influences. Levy states that sinistrality has increased in the United States from 2.2% in 1932 to 11.1% in 1972, ostensibly because of a relaxation in the culture's attitude toward sinistrality.

In discussing the genetic transmission of handedness, Annett (1973) and Hudson (1975) point to a clear association between a mother's handedness and that of her children, especially daughters, and a weak paternal link, especially evident in sons. Annett also notes a strong association between sisters. In spite of these findings, though, she claims that present evidence is insufficient to demonstrate a genetic cause of handedness. Genetics may influence handedness, she says, but it plays no major role, since 84% of sinistral children have two dextral parents and 72% of the children of sinistral mothers are dextral.

The debate goes on. Although there are proponents of a completely nongenetic view of handedness (Collins, 1968), the weight of the evidence is in favor of a genetic mechanism. Hardyck and Petrinovich (1977) summarize their review of genetic theories.

> In summarizing this area, the most appropriate conclusion seems to be that a genetic model is a more probable explanation. Such a conclusion has to be based more on the cumulative body of data on the left-handed than on the strictly genetic evidence. The most compelling evidence is the systematic behavioral differences in hemispheric specialization that have been reported on the left-handed. (pp. 389-390)

The literature on familial sinistrality reveals it to be an important variable in laterality studies. Familial sinistrality is associated with moderate or weak lateralization for both left and right handed subjects. These findings suggest a more integrated cognitive processing style among subjects with a family history of sinistrality.

Sex. Several consistent findings of sex differences in laterality have emerged from the research. Many studies have found males to be more highly specialized than females

(Lake and Bryden, 1976; Tucker, 1976; Bradshaw, Gates and Nettleton, 1977). Females and sinistral males are generally considered to be less strongly lateralized than right handed males.

It has been suggested (Bradshaw, Gates and Nettleton, 1977; Bradshaw and Gates, 1978; Johnson and Harley, 1980) that greater hemispheric equipotentiality for language in females and in sinistral males may stem from a relatively greater invasion of right hemisphere space otherwise reserved for visuospatial processing. This would account, then, for male superiority on visuospatial tasks and female superiority on verbal tasks. Left handed males are like left handed females: Both obtain elevated verbal and depressed spatial scores.

Stronger specialization in males for right hemisphere visuospatial functions is a common research finding. Even in young children this difference has been reported. Witelson (1976) studied the development of spatial processing by the right hemisphere. She found that, in boys, the right hemisphere is specialized for nonlinguistic spatial processing by at least six years of age. In girls, the right hemisphere is not so specialized even by thirteen years; girls evidence bilateral representation.

Maccoby and Jacklin (1974) reviewed the literature on sex differences and concluded that, by adolescence, sex differences in verbal and spatial abilities are well-documented. Stronger lateralization of the right hemisphere in males is thought to account for their superior performance on spatial tasks, but this strength of lateralization is not confined to the right hemisphere. Kail and Siegel (1978), for example, found a stronger specialization for verbal processes of the left hemisphere in males.

In addition to findings of consistent sex differences in cognitive functioning, obvious sex differences in handedness exist. There are typically more males than females counted among the left handed. Peters and Pederson (1978), for example, found 11.9% left handed males and 10% left handed females in a sample of 5,910 Canadian students. Part of this difference may reflect the greater number of males victimized by early brain damage, which can result in left handedness.

McKeever and VanDeventer (1977) state that both sex and familial sinistrality may moderate the degree of cerebral specialization for language processing, and that failure to assess these variables accounts for conflicting results in the research literature. Ray, Morell, Frediani and Tucker (1976) suggest that the finding of sex differences in brain functioning is so pervasive that closely controlled experimental procedures are not really required to demonstrate these differences. Piazza (1980) believes that laterality researchers must investigate sex differences as well as handedness and familial sinistrality, which operate together to produce various effects.

The literature pertaining to sex differences in cognitive functioning and in handedness was reviewed. Typical findings include the relatively stronger specialization of males, and the greater number of left handers among males. These findings suggest that females would be more integrated on a measure of cognitive processing style.

Writing Posture. The systematic study of hand position during writing began with Levy (1974) and Levy and Reid (1976). Levy and Reid classified 73 undergraduate subjects by sex, handedness, and writing posture, and administered two tachistoscopic tests of cerebral lateralization, one for visuospatial, one for language specialization. Their results indicated that direction of cerebral lateralization can be indexed from a subject's writing posture, either inverted or noninverted, with posture determined by direction of the pencil and by whether the hand is above or below the writing line. Subjects with a noninverted, standard writing posture were found to have the linguistically specialized hemisphere contralateral to the dominant hand; the reverse was true for inverteds. Females and inverteds were less strongly lateralized than males or noninverteds.

Other researchers have attempted to replicate Levy and Reid's findings, with mixed results. Moscovitch and Smith (1979) tested the Levy and Reid results by designing a reaction time experiment in three modalities: visual, auditory, and tactual. They found that while subjects with a noninverted writing posture responded fastest to stimuli on the same side as the responding hand in all three modalities, this was true for the inverteds only in the auditory and tactual modes. Moscovitch and Smith's results showed definite differences in neural organization between inverteds and noninverteds, primarily in the visual/ visuomotor systems.

Another study by these authors (Smith and Moscovitch, 1979) yielded partial support for Levy and Reid's hypothesis. Results of dichotic listening and tachistoscopic tests were equivocal; performance on the visual/verbal test, though, did lend support to Levy and Reid. Smith and Moscovitch point to an anomolous visual information processing system in inverted sinistrals to explain the discrepancy between their findings and those of Levy and Reid.

Herron, Galin, Johnstone, and Ornstein (1979) disagree with Levy and Reid's contention that hand position is an index of the linguistic hemisphere. They conclude that the right hemisphere is strongly engaged during sinistral writing, regardless of writing posture or hemispheric specialization for speech. Herron et. al. offer modest support for Levy and Reid's and Moscovitch and Smith's inferences that the two hand postures reveal different patterns of brain organization among sinsistrals. They disagree, however, that hand posture indexes the language hemisphere, on the grounds that language is not a unitary ability for sinistrals. The concept of a language hemisphere, they believe, may be useful only for typical right handers.

Peters and Pedersen (1978) surveyed 5,910 Canadian elementary school children for the incidence of the inverted writing position, and found a significant increase, especially for males, in the use of this position between grades one and six. In grades one through four, the inverted position was used by 31% of the males and 22% of the females; in grades five and six, use of this inverted position increased to 59% of the males and 43% of the females. While Levy suggests that most sinistrals use the inverted writing style, Peters and Pedersen find that this is true only for males. The development of an inverted handwriting posture over the elementary school years may be accounted for by sex differences in the human brain, by differences in conformity to social pressure to use the "appropriate" hand, or as a response to pressures for handwriting speed with increased volume of school work.

Allen and Wellman (1980), similarly, studied hand position in elementary school students and found it to be a function of age, with girls being closer to the eventual standard adult position at all ages than boys. Allen and Wellman also found that the closer the child to the standard writing position, the better his/her reading scores, and suggest that bilateralization leads to depressed scores.

Research investigating writing posture has been reviewed. This literature suggests that those who use an inverted writing posture will be more integrated and less strongly lateralized in cognitive processing style.

Cognitive Abilities

Whether hemispheric specialization is related to intelligence, academic achievement, or special abilities is of considerable interest to educators. The literature reviewed up to this point is directly relevant to the study reported here. The review contained in the remainder of this chapter is being presented to acquaint the reader with other laterality research areas in which education has a stake. Under the general heading of cognitive abilities, research on the following topics will be reviewed: cognitive deficit, sinistral advantages, verbal and performance IG discrepancies, academic achievement, and special abilities in music, architecture, and art.

Cognitive Deficit. The relation between intelligence and laterality has historically focused on cognitive deficits. In one study examining this relationship, Hardyck, Petrinovich and Goldman (1976) analyzed handedness, eyedness, intelligence, and achievement measures taken on 7,688 California children in grades one through six. No meaningful relationships were found which could support a link between handedness and cognitive ability. The literature postulating such a link was reviewed and summarized as follows:

> Of 14 studies concerned with reading ability, 13 found no differences betwen the right-

> and left-handed and one found the left-handed to be superior. In eight studies of intelligence, seven found no difference and one found the left-handed to be lower in intelligence. In four studies of retarded and mentally defective children, three found a larger percentage of left-handed children among the mentally defective and one study found no difference. Three studies report that the perceptual performance of the left-handed is lower than the right-handed. One study reports the left-handed to show a higher incidence of alcoholism, one says the left-handed show more emotional instability, and one finds the left-handed report that more stressful conditions were associated with their births. (p. 273)

Hicks and Beveridge (1978) dispute the conclusion of Hardyck et. al. that sinistrality is not related to cognitive deficit. What is sampling error for Hardyck et. al. may be meaningful group differences in crystallized and fluid intelligence for Hicks and Beveridge, who suggest that sinistrals may show a fluid intelligence deficit: "The available relevant results uniformly suggest that left-handers may have a fluid intelligence deficit" (p. 305); Hicks and Beveridge acknowledge, however, the limited data base (three studies) and conducted their own test of the hypothesis. Subjects were 37 right and 30 left handed college students who were given The Cooperative Vocabulary Test, a measure of crystallized intelligence, and the Culture Fair Intelligence Test, a measure of fluid intelligence. As predicted, Hicks and Beveridge found that left handers' performance was inferior to right handers' on the fluid intelligence test. They state that "it may be an error to conclude, as Hardyck et. al. (1976) have, that there are no handedness related differences in human abilities" (p. 306). Hicks and Beveridge do not suggest that all sinistrals are fluid-intelligence deficient, but that a subgroup of left handers may be so characterized.

Bishop (1980a) comes to a similar conclusion:

> Clearly the claim that left-handers in general do not differ from right-handers does not rule out the possibility that sinistrality may be associated with various abnormal conditions. (p. 569)

<u>Sinistral Advantages</u>. In some cases left handedness has been found to confer advantages. Aliotti (1981), for example, suggests that his results, as well as other research, show that "intellectual giftedness may be associated with 'nonright handedness' which is expressed either as left-handedness or ambidexterity" (p. 39).

Deutsch (1978) conducted research based on the observation that an unexpectedly high proportion of subjects selected for superior pitch memory were left handed. Deutsch studied 76 dextral and 53 sinistral undergraduates and found that the moderately left handed performed better than any other group. Deutsch interprets these findings

> in terms of a duplication of storage of pitch information by the moderately left-handed. If the efficiency of storage and retrieval at one locus is identical for all populations, then the retrieval of this information from two separate loci should significantly increase the overall probability of correct judgment. We can further hypothesize that such duplication of representation occurs in parallel with the duplication of representation of speech functions in the two hemispheres. (p. 560)

Beaumont (1974) also points to certain sinistral advantages. His model of brain organization is one in which left handers would be at "a disadvantage for rapid simple communication, but an advantage for complex integrative activity" (p. 113). His results showed

> a relative incapacity of the left hander to sustain performance over a protracted period, as well as the possibility of a superiority in learning of the left handed. (p. 113)

In a justification for the study of left handedness, Hardyck and Petrinovich (1977) note the fact that "the left handed of high ability are usually conveniently forgotten in discussions of handedness and deficit" (p. 387), naming as examples Michelangelo, DaVinci, Benjamin Franklin, and Pablo Picasso. Hardyck and Petrinovich also cite evidence suggesting that sinistral children may be more creative than dextrals.

Other strengths of sinistrals include their ability to recover from the effects of cerebral lesions more quickly and with fewer long-term effects than the right handed. Even having a left handed sibling is an advantage. Subirana (1969) states that "the aphasics with a left-handed sibling are nearly always the champions of the language rehabilitation division" (p. 268).

<u>Verbal and Performance IQ Discrepancies</u>. Research relating verbal and performance IQ discrepancies to handedness grew out of the general finding of female superiority in verbal skills and male superiority in spatial (Maccoby and Jacklin, 1974). Levy and Nagylaki (1972) suggest that

hemispheric specialization is the mechanism underlying these sex differences and that spatial ability is facilitated by strong cerebral specialization. Females and left handed males are thought to have poor spatial ability because their language functions are more diffusely localized, resulting in less cerebral space available for spatial functions.

Strength of laterality has not always been associated with accuracy on a task. Although Levy and Nagylaki (1972) argue that strong cerebral specialization facilitates performance on spatial tasks, other researchers have not consistently found this to be the case. Witelson (1976), e.g., studied spatial processing in 200 right handed six to thirteen year old children. She found that although boys had stronger right hemisphere specialization, there was no difference in overall accuracy between boys and girls. Piazza (1980) also discovered no association between strength of specialization for auditory tasks and superior performance.

Harris (1978) presents an exhaustive review of the literature on sex differences in spatial ability, saying:

> The fact of the male's superior spatial ability is not in dispute; but the explanation is. In light of evidence implicating a critical role for the right cerebral hemisphere - particularly the temporal, parietal, and occipital areas - in spatial perception, the most pertinent question to raise, in the context of the present book, is whether sex differences in cerebral organization and functioning underlie the male's greater spatial ability. (p. 406)

After reviewing the evidence, Harris finds "a reasonable degree of support" (p. 466) for Levy's hypothesis.

In a test of Levy's hypothesis that bilateral representation is more common among females and left handed males, Johnson and Harley (1980) compared the performance of left and right handed males and females (120 university students) on a short form of the WAIS. Partial support was obtained: A handedness effect was found but a sex effect was not. Strongly left handed subjects showed significantly elevated verbal scores and depressed spatial scores, as compared with other groups and with their own scores on the other test.

On the basis of their results, Johnson and Harley believe that handedness predicts spatial ability better than sex, and that assessment of degree of handedness is critical in such research. They also suggest that the large verbal-performance IQ discrepancy found by Levy may have been due to the high IQs of her Caltech student subjects: mean verbal IQ of 142 for sinistrals and 138 for dextrals; mean performance IQ of 130 for dextrals and 117 for sinistrals. When Johnson and Harley divided their 30 left handed male subjects into two groups according to IQ, they obtained a 12.17 verbal-performance discrepancy for those with IQs between 120 and 139, and a discrepancy of less than one point for those with IQs between 94 and 118.

Mascie-Taylor discusses these results in terms of other research (Levy, 1969; Miller, 1971) which also found that sinistrals obtained lower scores on performance (visuo-spatial) tests than dextrals. Unlike Mascie-Taylor's finding, however, no difference between groups was found by

Levy or Miller for verbal IQ. Small sample sizes and method of classifying handedness may have been responsible for the discrepancy between Levy's and Miller's findings and those of Mascie-Taylor. Mascie-Taylor concludes with:

> Clearly the relationship between sex, handedness and ability requires further study, using larger sample sizes, more specific ability data, and with enhanced knowledge of handedness patterns and of hemispheric dominance. (p. 247)

Academic Achievement. Academic achievement has also been studied for its relation to laterality. Richardson and Firlej (1979), for example, studied various laterality indicators as predictors of reading achievement in normal readers. They review the literature on developmental dyslexia and suggest that theories explaining reading retardation in terms of abnormal or incomplete cerebral dominance are also applicable to the normal population.

Citing methodological problems of laterality assessment in previous research, Richardson and Firlej examined the interrelationships among four behavioral and two experimental measures of cerebral specialization. Behavioral measures (preferred hand for writing, preferred hand for a variety of manual tasks, preferred eye, and preferred foot) and experimental measures (dichotic listening and simultaneous tachistoscopic presentations) were obtained for 131 boys, 10-15 years of age.

The investigators found "no evidence that left-handedness, right cerebral dominance, or inconsistencies in laterality were correlated with reading retardation" (p. 593).

They do allow for the possibility, however, that "impairment in reading and spelling is attributable rather to the use of inappropriate spatial strategies encouraged by a bilateral representation of nonlinguistic capacities" (p. 593), and note the need for further research in this area.

Tomlinson-Keasey and Kelly (1979) also asked whether hemispheric specialization is important to academic achievement, specifically reading and math achievement. These researchers tested the hypothesis that older subjects who rely on the right hemisphere for word processing are less skilled at reading. Subjects were 84 right handed third and seventh graders. Specialization was assessed through visually presented pairs of words or pictures for which reaction time in matching the pairs was calculated. Achievement scores were obtained from the Stanford Achievement (seventh graders) and the Metropolitan Achievement (third graders) tests.

Data showed that a lack of specialization for words was related to higher reading achievement for both age groups. Right hemisphere specialization for words was associated with less reading skill, and younger subjects were twice as likely to show right hemisphere specialization for words. Specialization for words changed markedly from third to seventh grade. Forty percent of the third graders showed left hemisphere specialization for words; by the seventh grade, this percentage increased to 69%. A similar developmental change for pictures was not found.

Tomlinson-Keasey and Kelly's analysis of achievement data showed that a lack of specialization for words in third graders was associated with higher achievement in the language skills of word knowledge, language, and spelling. For seventh graders, lack of specialization was associated with superior achievement in math concepts. These results were contrary to the expectation that left hemisphere specialization for words would be associated with higher achievement scores.

With regard to processing of pictures, right hemisphere specialization was associated with higher math skills, as expected, but only for third graders. The investigators suggest that different requirements for math success in the seventh grade require the combined participation of both hemispheres. Among the seventh graders, those who processed pictures in the left hemisphere were significantly disadvantaged in reading comprehension scores.

Tomlinson-Keasey and Kelly conclude that studies of hemispheric specialization must account for developmental changes. They suggest that "researchers might be able to isolate patterns of hemispheric information processing that are coupled with optimal achievement in various areas" (p. 105). They outline a path for future research:

> A variety of age groups should be investigated, with attention focused on the whole continuum of specialization which includes clear preference for processing information in one hemisphere; a minimal specialization; and a clear pattern of processing information in the other hemisphere. Finally, age group differences and patterns of specialization

> must be related to a variety of skills that underlie adequate performance in today's society. This is not to deny the importance of reading but rather to acknowledge the role of other skills. The conclusion of such a detailed description of the developing patterns of hemispheric specialization should invite interventions that match human preferences and abilities with optimal achievement. (p. 106)

The effect of cerebral specialization on the achievement of college students was studied by Bracken, Ledford and McCallum (1979). Your Style of Learning and Thinking was administered to 41 undergraduates to assess hemisphericity, and scores were compared with multiple choice test grades on course content. Results indicated that the left hemisphericity students scored significantly higher on the course tests than the right hemisphericity students. Bracken et. al. suggest that "right-hemisphere dominant individuals may be penalized in instructional situations where multiple-choice measures are used exclusively" (p. 446).

Special Abilities: Music. Abilities in the area of music perception and performance have been extensively studied. Because music was early accorded a processing niche in the right hemisphere, it has been an area of considerable interest to laterality researchers. A case study of Maurice Ravel, the French composer (Cytowic, 1976), demonstrated the tragic consequences of a later brain assault:

> At 58, Ravel was struck with aphasia, which quelled any further artistic output. Most strikingly, he was able to think musically but unable to express his ideas in either writing or performance. Hemispheric

> lateralization for verbal (linguistic) and musical thinking offers an explanation for the dissociation of Ravel's ability to conceive and to create. (p. 109)

Bever and Chiarello (1974) upset the then-prevailing notion of left ear and right hemisphere superiority for processing of melodies when they reported that trained musicians evidenced a left hemisphere superiority. Only musically naive subjects showed the expected right hemisphere superiority. Their interpretation was in terms of the effect of musical training on brain functioning, by which analytic left hemisphere processes were brought into play.

Further evidence of the complexity of musical processing was supplied by Gordon (1975), who pointed out that musically sophisticated subjects showed left hemisphere specialization for melodies, as Bever and Chiarello found, but not for chords.

Trained musicians were also the subjects of a study by Goodglass and Calderon (1977). Sixteen dextral subjects (nine women and seven men), mean age of 23 years, who had demonstrated a left ear, right hemisphere advantage for tones, were selected to participate. Goodglass and Calderon found that the left ear advantage for tones was maintained even when competing stimuli (digits) were presented simultaneously. They conclude that "the two hemispheres concurrently and independently process that component of a complex stimulus for which each is dominant" (p. 397), and that "the present study is in accord with the bulk of prior experimental work which identifies music as primarily a right hemisphere function" (p. 404).

A further test of Bever and Chiarello's findings was provided by Gaede, Parsons and Bertera (1978), who found that subjects with low musical aptitude show significant ear differences on musical tasks, while high aptitude subjects had minimal ear differences. Gaede et. al. found no effect of experience on these ear differences, which contradicts Bever and Chiarello's interpretation. Gaede et. al. summarize as follows:

> In our experiment we successfully disentangled aptitude and experience and demonstrated that while both variables affected general level of performance, it was only aptitude which related to ear or hemispheric differences. (p. 371)

Gates and Bradshaw (1977), following a thorough review of the literature on the role of the cerebral hemispheres in music, also question the impact of musical training on musical processing: "It may not be musical training as such which determines hemispheric specialization, but rather the way in which the music is processed" (p. 422). Because of the demands in music perception on both hemispheres, neither hemisphere should be considered dominant; rather the hemispheres interact, each processing according to its own specialization.

Special Abilities: Architecture. Peterson and Lansky (1974) studied architects and architecture students for the incidence of left handedness and found that both groups showed a higher than expected percentage of left handers, the expected percentage being 8-10%. Of 17 architecture faculty members, 29.4% were left handed. The 484 full time male students were divided by year of study. Only the first year students approximated the expected rate of left handedness (10.8%). The percentage of left handed students in years two through six was higher than expected, ranging from 14.6% (fifth year students) to 23.9% (fourth year students).

Several years later, Peterson and Lansky (1977) again explored the incidence of left handedness among architects. For this second study, subjects were 484 students enrolled in the architecture program between 1970 and 1976. Findings confirmed the prediction that proportionately more left handed students (73.4%) would complete the program than right handed students (62%). A subset of these students, those entering the program in 1976 (n=76), was studied further. The left handed males (21% of all males, 16% of the total sample) obtained the highest mean scores on all three of the factors extracted from a set of 11 variables: academic predictors, design scores and grade point averages.

A third study by Peterson and Lansky (1980) involved a reexamination of the earlier data. Each of the students had been asked to make a simple line drawing of a cube at the beginning of the first design class. Architecture students and faculty tend to draw what the eyes really see - a visual or isometric cube. Students in other disciplines draw a cube that has been labelled cognitive or conceptual because it does not actually match what the eyes see. Peterson and

Lansky found that the drop-out rate of the students differed significantly according to how they had drawn the cube: 43% of those drawing the cognitive cube had dropped out, while less than 15% of those drawing the visual cube did.

Special Abilities: Art. The handedness of student artists was studied by Mebert and Michel (1980). They administered a 12-item handedness questionnaire and found a significant handedness difference between the artists and nonartists, with more left handers among the artists. Mebert and Michel believe that

> the artist group forms a particular subset of the population with respect to hand use . . . What we may be seeing in the artist group is a shift in the distribution of handedness toward the expected normal curve, rather than so strongly toward the right. (p. 277)

Aesthetic preference has also been studied for its relation to laterality. Levy (1976) investigated the preference of sinistrals and dextrals for mirror versions of vacation slides and found that over 40% of the sinistrals preferred the slide that was a mirror image of that preferred by the dextrals. Levy also found that dextrals preferred slides with the important content on the right. In conclusion, she notes the overwhelming influence of lateralization on numerous and varied aspects of human functioning, and states that "the results of the present investigation seem to show also that the human aesthetic sense is profoundly affected by the fact that the human brain is laterally differentiated" (p. 443).

Galin and Ornstein (1974) probed the connection between occupation and the hypothetical reliance on right or left hemisphere. Eighteen lawyers and 17 artists, all strongly right handed males, mean ages 34 and 33, respectively, participated. Subjects were screened to omit those apparently specialized in both cognitive modes, i.e., the verbal-analytic and the spatial-holistic. Both vertical and lateral eye movements were obtained following questions requiring verbal or spatial thought processes.

Results showed lawyers to differ from artists only on vertical eye movements, with more up movements for artists than lawyers. Confirmation of Galin and Ornstein's previous findings on the effect of question type was obtained: Verbal questions evoked more down movements and more right movements than spatial questions. They discuss their findings as follows:

> In discussing individual differences in the use of the verbal-analytical and spatial-holistic cognitive modes, it is important to consider three aspects which can interact in complex ways: preference for one mode or the other, ability to shift modes with shifting task requirements, and competence in each mode. For example, a person may persist in using an analytic approach when a problem calls for an holistic approach because he prefers it, or because he is more competent in the verbal-analytic mode, or because he cannot inhibit the verbal-analytic mode when necessary. (p. 372)

Charman (1981a) also predicted a difference in processing style depending on occupation. He hypothesized that physical scientists would process information in the left hemisphere better than the right, and that artists would process more efficiently in the right hemisphere. Subjects were eight right handed male teachers, four from fine arts and four from physical science departments. A second study used 16 dextral male students, eight from fine arts and eight from engineering.

Results of tachistoscopic presentations to left and right visual fields supported Charman's hypothesis. Charman conceded that his findings are controversial, but such a result at least "opens the door to a large area for future research concerning different hemisphere asymmetries and differences in personal style" (p. 457).

Coren and Porac (1982) also studied laterality expression in various career fields. A 13-item laterality questionnaire assessing hand, foot, eye, and ear preferences was administered to 497 university students in science and the graphic arts (225 subjects) and languages and literature (262 subjects). Coren and Porac found that handedness, but not the other laterality measures, was associated with academic major. The consistently right handed (on four handedness questions) were more prevalent among language and literature majors than science and graphic arts. Coren and Porac hold that "the various manifestations of lateral preference form separate dimensions. Some, but not all, of the indexes of lateral preference may covary with differences in variables related to cognitive abilities" (p. 790).

This section on cognitive abilities and hemispheric specialization has consisted of a review of the literature on the following topics: cognitive deficit, sinistral advantages, verbal and performance IQ discrepancies, academic achievement, and special abilties in music, architecture, and art. This literature has been reviewed because of its potential appeal to educators. It also serves to raise important questions on the relationship among cognitive processing style, handedness, and the topics mentioned above. Whether cognitive processing style is distinct from IQ, for example, is a question worth raising in the context of the present study, even though there is no attempt to answer it.

Summary

The literature relevant to the present study of cognitive processing style and handedness has been reviewed.

Previous research on individual differences in cognitive processing style as a function of hemispheric specialization was presented. The concept of hemisphericity was introduced, and subcultural differences in its expression were discusssed. Previous research using Your Style of Learning and Thinking was summarized.

Handedness was next discussed, with studies reviewed on handedness criteria, reliability, validity, and classification of handedness, followed by a review of studies correlating handedness with one or more of the other laterality dimensions.

The next section of the chapter dealt with subject variables associated with differences in hemispheric specialization. Sex, familial sinistrality, and writing posture were factors with direct relevance to the present study.

The final section of the literature review pertained to cognitive abilities. Specific attention was paid to studies in the areas of cognitive deficit, sinistral advantages, and verbal and performance IQ discrepancies. The relationship between academic achievement and hemispheric specialization was next discussed, and focused on reading and math achievement. Literature was also reviewed relating hemispheric specialization to special abilities in music, art, and architecture.

CHAPTER III

PROCEDURES

The Procedures Chapter is organized in six sections. First, the sample will be described. Second, the instruments used will be detailed. Third, data collection procedures will be presented. Fourth, the hypotheses and methods of data analysis will be described. Fifth, additional analyses will be previewed. Finally, the chapter will be summarized.

Sample

The sample was limited to adults because of the need to obtain fully lateralized subjects capable of responding to the instruments used. Although a matter of dispute, consistent hand preference is probably finally established between six and nine years of age (Beaumont, 1974), and all aspects of laterality are not fully developed until at least puberty.

Following Torrance (1982), older subjects were considered preferable for the present study:

> It is doubtful that many children and early adolescents possess the psychological insights into their mental functioning that will enable them to respond appropriately to self-report instruments such as "Your Style of Learning and Thinking." (p. 36)

Although some laterality research confines itself to using right handed subjects, both left and right handers were used in the present study.

Because of voluminous evidence of sex differences in laterality, both male and female subjects were chosen. Subjects were 50 white male and 50 white female adults who volunteered to participate.

Most of the subjects were co-workers of the investigator, employed at the Michigan Department of Public Health. Other subjects were obtained through contacts outside of the employment setting. When potential subjects were encountered, they were asked if they would be interested in participating in a study of handedness and style of thinking. If interest was expressed, they were asked to complete the questionnaire packet shown in the Appendix, which included instructions. Some subjects received the request to participate and the questionnaire packet through the mail.

The sample was initially categorized according to sex and writing hand: 25 male sinistrals; 25 female sinistrals; 25 male dextrals; and 25 female dextrals. The sample was confined to one race because of research evidence showing race differences in hemisphericity (Thompson and Bogen, 1976).

The following demographic information on the subjects in the present study, all Michigan residents, was obtained through the Biographical Information questionnaire:

Age

Mean	38.3
Median	37.3
Range	23-63

Occupation	N
Homemaker/Student	4
State Government Clerical	14
Other Clerical	0
State Government Professional	43
Other Professional	21
State Government Supervisory	3
Other Supervisory	2
State Government Technical	4
Other Technical	2
Business	7

Degree	N
High School	21
Associate	14
Bachelor	22
Master	34
Ph.D, MD	9

Major	N
High School	21
Arts	36
Science	28
Business	15

Evidence of familial sinistrality in the sample was obtained through the Handedness in Your Family questionnaire. The number of known left handed relatives over total relatives for whom handedness was known was computed as a percentage for each subject. Subjects were asked about handedness in five generations: grandparents, parents, the subject's own generation, children, and grandchildren. Percentages were used because the number of relatives varied across subjects. Those subjects with an incidence of familial sinistrality greater than 12% were considered to have a positive family history. This is a generally accepted figure for the incidence of left handedness in the population. All others were considered to have no familial sinistrality. By this definition, 38 subjects showed positive familial sinistrality, and 62 subjects showed no familial sinistrality. Of the 100 subjects, 45 claimed no left handed relatives at all.

The number of left handed relatives found in this sample was as follows:

	Number of Left Handed Relatives	Number of Subjects
	0	45
	1	29
	2	18
	3	4
	4	2
	6	2
Totals	97	100

Writing posture for the subjects in this sample was determined through a Writing Position Assessment based on Levy and Reid (1976). The number of subjects in each writing posture group was as follows:

Writing Posture	Number of Subjects
Standard Posture - Right Handers	49
Standard Posture - Left Handers	29
Inverted Posture - Right Handers	1
Inverted Posture - Left Handers	21

Table 2 provides a summary of frequency data for the four subject variables: sex, familial sinistrality, handedness, and writing posture.

Instrumentation

Your Style of Learning and Thinking (SOLAT). The dependent variables in the present study were the SOLAT and the HCP, described below.

Your Style of Learning and Thinking (Torrance, Reynolds, Riegel, and Ball, 1977) is a measure of hemisphericity, which is "the relative psychological dependence of an individual on the right or left hemisphere of the brain" (Reynolds, Katsounis, and Torrance, 1979, p. 757). Four adult forms and three forms for children and adolescents have been developed. Subjects answer questions by choosing one of the three alternatives designed to measure the left hemisphere, right hemisphere, or integrated style of thinking. Answers to the 36 items in Form A and the 40 items in the other forms yield ipsative left, right, and integrated hemisphericity scores. A high level of internal consistency is claimed for the items.

Validity data is summarized by Torrance and Reynolds (undated Preliminary Norms-Technical Manual) as follows:

> The Right hemisphere seems to relate consistently to measures of creative ability, personality and motivation while the Left hemisphere style seems to relate negatively to these measures. Scores of participants in the Creative Problem Solving Institute are differentiated significantly from those of the larger norms group. Additional studies are of course needed. (p. 6)

Table 2. Summary of Frequency Data for Four Subject Variables: Sex, Familial Sinistrality, Handedness, and Writing Posture.

		Left Handed		Ambidextrous		Right Handed		TOTALS
		Inverted	Noninverted	Inverted	Noninverted	Inverted	Noninverted	
Males	FS+	4	3	3	0	0	4	14
	FS-	6	4	2	3	1	20	36
Females	FS+	5	6	0	6	0	7	24
	FS-	1	6	0	1	0	18	28
TOTALS		16	19	5	10	1	49	100

For Torrance and Reynolds, the validity of the SOLAT seems to be based on its ability to differentiate creative from uncreative subjects, with the creative tending to obtain higher right hemisphericity scores. Given Torrance's previous work on the development of The Torrance Tests of Creative Thinking, this approach should come as no surprise.

Data on the relationship between hemisphericity and physical measures of cerebral specialization (handedness, eyedness, earedness) is not presented in the SOLAT norms-technical manual. A part of this data, that relating handedness to hemisphericity, is what the present study intends to provide.

Norms for nine different groups, a total of 1,675 persons, are presented in the manual. The mean integrated score was higher than either right or left in seven of the nine groups; one group showed right hemisphericity to be the highest score; and one group obtained equally high scores for right and integrated styles.

The number of left, right, and integrated responses for the present sample on each item of the SOLAT appears in Table 3. Means, medians, standard deviations, and ranges for the three SOLAT scales follow:

Scale	Mean	Median	Standard Dev.	Range
SOLAT Left	12.42	11.61	5.16	2-26
SOLAT Right	11.55	10.50	4.77	0-28
SOLAT Integrated	16.03	16.10	5.43	4-34

Table 3. SOLAT Frequencies Per Item

Item	Right	Left	Integrated	Item	Right	Left	Integrated
1	39	29	42	21	20	51	29
2	47	34	19	22	10	12	78
3	17	52	31	23	5	31	64
4	19	34	47	24	8	27	65
5	16	42	42	25	26	49	25
6	45	19	36	26	26	27	47
7	24	29	47	27	31	43	26
8	8	71	21	28	4	54	42
9	45	22	33	29	15	42	43
10	28	32	40	30	44	23	33
11	26	14	60	31	16	24	60
12	38	37	25	32	32	16	52
13	34	29	37	33	40	16	44
14	27	40	33	34	38	31	31
15	34	29	37	35	13	38	49
16	27	24	49	36	47	27	26
17	14	40	46	37	50	18	32
18	35	45	20	38	18	39	43
19	32	18	50	39	50	25	25
20	40	7	53	40	67	12	21

Hemispheric Consensus Prediction Profile II. According to its author, the Hemispheric Consensus Prediction Profile II (HCP) is "one of the first simple paper-and-pencil measures for determining right brain-left brain dominance or equipotentiality" (Loye, 1982, p. 1). The test has two forms. The first consists of ten items measuring left and right hemispheric specialization, and the second consists of seven items assessing bilaterality as well. The second form was used in the present study. No reliability data for either form was presented in the test manual.

Validity data was derived primarily from studies of the first form, on which scores of less than 1.5 indicate left hemisphericity, and those over 1.5 indicate right hemisphericity. An experimental version of the HCP was administered to putatively left hemisphere specialized students (20 UCLA Gradute School of Management students and economics majors) and right specialized individuals (27 UCLA psychic research volunteers and design majors). Mean scores were 1.3 for economics majors and 1.8 for design majors. Results were interpreted as support for the association between hemi-spheric specialization and area of study/interest. Other reported studies, with similar results, used subjects from the movie industry, from the Naval Postgraduate School in Monterey, California, and from college art and social science programs.

Validity data reported for the second form was more limited. One study "tested the ability of 135 subjects to forecast outcomes in the areas of U.S. politics, economics and foreign affairs" (p. 12). The subjects' forecasting ability was compared with the HCP scores, and better prediction was found to be associated with equipotentiality. From the validity data reported, it is apparent that Loye considers the HCP valid to the extent it can differentiate among groups based on area of study or interest and on ability to forecast.

The number of left, right, and integrated responses for the present sample on each item of the HCP is presented in Table 4. Means, medians, standard deviations, and ranges follow:

Scale	Mean	Median	Standard Dev.	Range
HCP Left	2.90	2.98	1.74	0-7
HCP Right	1.63	1.36	1.45	0-7
HCP Integrated	2.47	2.41	1.52	0-7

Table 4. HCP Frequencies Per Item

Item	Left	Right	Integrated
1	59	23	18
2	53	33	14
3	38	18	44
4	41	21	38
5	27	36	37
6	24	17	58
7	46	15	38

Coefficient alphas obtained in the present study for each of the six hemisphericity scales follow. The values were considered acceptable. Inasmuch as the HCP contained only seven items, the reliabilities were adequate. Predicted reliabilities based on the Spearman-Brown prophecy formula for an HCP test with 42 items are also shown below.

Scale	Alpha	Predicted Reliability
SOLAT Left	.72	
HCP Left	.55	.88
SOLAT Right	.69	
HCP Right	.49	.85
SOLAT Integrated	.71	
HCP Integrated	.42	.81

Both the SOLAT and the HCP were designed to measure cognitive processing styles reflecting hemispheric specialization. Manuals for neither test, however, provide direct validity data. Both tests validate by assessing groups hypothetically different in hemispheric specialization based on their choices of college majors, occupations, or interests. The present study attempts to trace validity one step further, by investigating the relation between cognitive processing styles and handedness.

Concurrent validity evidence for the present study was obtained by intercorrelating the six hemisphericity scales. Coefficients are shown in Table 5. SOLAT Left correlated significantly and positively with HCP Left. The same held true for the paired right hemisphericity and integrated hemisphericity scales.

Table 5. Pearson Correlation Coefficients for Six Hemisphericity Scales

	SOLAT			HCP		
	Left	Right	Integrated	Left	Right	Integrated
SOLAT Left						
SOLAT Right	-.40 p=.001					
SOLAT Integrated	-.59 p=.001	-.50 p=.001				
HCP Left	.57 p=.001	-.36 p=.001	-.22 p=.014			
HCP Right	-.17 p=.050	.39 p=.001	-.19 p=.032	-.56 p=.001		
HCP Integrated	-.49 p=.001	.05 p=.33	.43 p=.001	-.61 p=.001	-.31 p=.001	

The Edinburgh Handedness Inventory. The Edinburgh Inventory (Oldfield, 1971) is a 10-item measure of handedness which was developed in response to the need for a simple and short screening device to assess direction and degree of handedness. Initially, Oldfield (1969) selected 20 items from Humphrey's (1951) scale, for his study of handedness in musicians. With a few minor changes, he then administered the 20 items to 1,128 undergraduates, 394 males and 734 females, from English and Scottish universities. Item analysis resulted in a reduction of the number of items from 20 to 10.

The present study used handedness as the index of cerebral specialization for four reasons. First, a considerable portion of the laterality literature relies on relatively simple assessments of handedness. The results of this study, then, will fit into a body of existing literature. Second, a measure of laterality that requires sophisticated instrumentation is severely limited in its applicability. Application of laterality findings in education or psychology will require simple laterality assessments. Third, handedness measures are economical to obtain on large samples of subjects. Use of assessment procedures such as dichotic listening or tachistoscopic tests would result in the testing of fewer subjects. Fourth, the validity and reliability of paper and pencil handedness inventories are well established (Thompson and Marsh, 1976).

Oldfield's Edinburgh Handedness Inventory was used for the present study because it has been used in numerous other studies, thereby permitting direct comparisons to be made with previous results, and becuase it measures both the direction and degree of handedness. Degree, or strength, of handedness is generally thought to be an important variable because handedness is continuously distributed, not dichotomous. Although degree of handedness is probably more critical for differentiating among the left handed, it is also important when considering dextrals who have a family history of sinistrality.

The first 10 items of the Edinburgh Inventory deal with hand preference. The last two (research) items, dealing with foot and eye preference, were not included for analysis in the present study. Coefficient alpha was reduced from .95 to .94 when the items on foot and eye preference were added to the 10 handedness items.

Although the instructions for the Edinburgh Inventory call for the use of a double check mark to indicate strong hand preference, 39 subjects failed to use any double checks. Because of this apparent failure to follow directions, single and double check marks were considered to be equivalent for scoring purposes.

Laterality quotients were derived from the handedness responses, according to the formula $\frac{\sum Right - \sum Left}{\sum Right + \sum Left} \times 100$. The laterality quotients were then categorized into three groups. Scores between -100 and -33 indicated left handedness;

scores between -32 and +32 indicated ambidexterity; and scores between +33 and +100 indicated right handedness.

An ANOVA using the Edinburgh Inventory as the dependent variable revealed no significant differences between sexes or between familial sinistrality groups. A writing posture main effect was highly significant, as expected, because all but one of the subjects with an inverted writing posture was left handed.

Responses to the 12 Edinburgh Handedness Inventory items are presented in Table 6. Ambidextrous responses were highest for items eight (uppermost hand on a broom) and ten (hand guiding the lid when opening a box). Left handed responses were highest for items one (writing hand) and two (drawing). Right handed responses were highest for items four (cutting with scissors) and 11 (preferred foot).

Table 6. Edinburgh Handedness Inventory Frequencies per Item

Item	Left Handed	Right Handed	Ambidextrous
1	50	49	1
2	50	49	1
3	33	59	8
4	25	67	8
5	40	52	8
6	33	59	8
7	42	49	9
8	39	33	28
9	35	53	12
10	29	33	38
11	28	65	7
12	37	48	15

Writing Posture Assessment. Levy and Reid (1976) used two criteria to determine the presence of an inverted writing posture: 1) holding the hand above the line of writing; and 2) pointing the pencil toward the bottom of the page. The authors find that over 90% of the writing postures they have observed can be clearly classified as either inverted or standard. The present study used Levy and Reid's criteria. Subjects were presented with an illustrated check sheet for a self-report of writing posture.

The validity of writing posture as a measure of hemispheric specialization is derived from its ability to index the hemisphere specialized for visuospatial versus language processing. Levy and Reid administered two tachistoscopic tests and found that standard posture subjects had the linguistically specialized hemisphere contralateral to the dominant hand; the reverse was true for inverteds.

Levy and Reid (1976) present data in support of their view that

> the two traditional measures, handedness and sex, supplemented by our new measure of hand position, allow very simple, rapid and reliable prediction of hemispheric specialization and lateralization. These observations allow us to meaningfully subcategorize left-handed writers and the method should be useful in lateralization research and in clinical medicine. Additional research is needed to determine . . . the possible cognitive correlates of handedness and hand position in writing. (p. 339)

In view of these recommendations, the present study assessed writing posture.

<u>Biographical Information</u>. Subjects were asked to provide information on sex, age, race, occupation, education, and handedness. The Biographical Information form was used for this purpose.

<u>Handedness in Your Family</u>. Measuring familial sinistrality has usually been accomplished by assessing the presence of sinistrals in the subject's first-degree relatives, i.e., parents, siblings, and children (McKeever and Van Deventer, 1977). One problem with a simple numerical

count of such relatives is that family size is not entered into the equation. Bishop (1980b) suggests two ways to avoid this problem.

> Groups of subjects with and without Familial Sinistrality should be matched on family size, or alternatively Familial Sinistrality should be rated purely in terms of those relatives common to all individuals, namely parents and grandparents. (p. 313)

Another option was used in the present study. Scoring of Handedness in Your Family controlled for family size by requesting information on the number of relatives for each respondent. The percentage of left handed relatives was obtained for each subject.

Data Collection

Questionnaire packets were distributed to volunteers, who were asked to return the completed forms within one week. The forms were distributed and returned during the last six weeks of 1982. Of 178 packets distributed, 115 were returned. The first 100 complete packets, subject to sample constraints of sex and writing hand, were submitted for analysis.

Hypotheses and Data Analysis

The general hypothesis of the present study was that handedness would be associated with cognitive processing style. The general hypothesis was tested by one-way ANOVAs to determine whether persons classified as left handed, ambidextrous, or right handed differ on the left, integrated, or right style of thinking. Additionally, handedness scores were correlated with hemisphericity scores.

The first specific hypothesis tested Hardyck and Petrinovich's (1977) model of individual differences in handedness and cognitive functioning. Their continuum of laterality is shown in Figure 1; the expected direction of hemisphericity scores on the SOLAT is also shown. FS- indicates that the percentage of left handed relatives was under chance expectation, i.e., 12%. FS+ indicates a percentage greater than 12%.

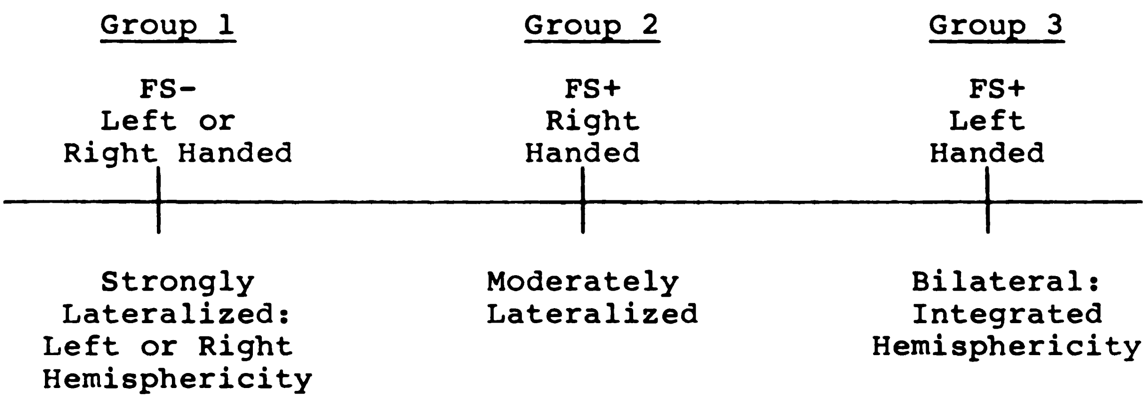


Figure 1. Hypothesized Continuum of Laterality

<u>Hypothesis 1</u>. The three handedness/familial sinistrality groups will differ on the integrated hemisphericity scale of the SOLAT and HCP, such that:

a. Group 3 will outscore Group 2.
b. Group 3 will outscore Group 1.
c. Group 2 will outscore Group 1.

Hypothesis 1 will be tested using a one-way ANOVA followed by post-hoc pairwise comparisons (Sheffe). Differences among the three groups on the right and left hemisphericity scales of the SOLAT and HCP are also expected.

Hypothesis 2. Females will obtain higher integrated scores than males. This hypothesis will be tested by means of a *t* test. Males and females are also expected to differ on right and left hemisphericity.

Hypothesis 3. Subjects who use an inverted writing posture will obtain higher integrated scores than those who use a noninverted, or standard, posture. This hypothesis will also be tested by means of a *t* test. Differences between inverteds and noninverteds are also expected on right and left hemisphericity.

Additional Analyses

Additional analyses (*t* tests and correlations) will be conducted to explore the following questions:

1. Do left handers and right handers with no family history of sinistrality differ on left, right, or integrated hemisphericity?

2. Is writing hand associated with other items measuring handedness?

3. Do left handed writers differ from right handed writers on left, right, or integrated hemisphericity?

4. Do left handed and right handed writers differ in family history of sinistrality?

5. Do subjects with a family history of sinistrality differ from those with no such history on left, right, or integrated hemisphericity?

6. Does familial sinistrality correlate with hemisphericity scores?

7. Do males and females differ on familial sinistrality?

Finally, multiple 3-way ANOVAs will be run, using sex, handedness, writing posture, and familial sinistrality, to determine the interactions among these factors.

Standard SOLAT and HCP scoring procedures will be used. In addition, scoring revisions will be implemented for experimental purposes.

Summary

Justification for the choice of broad sample characteristics was given. Adult subjects were chosen to insure that hemispheric specialization was fully developed and to insure ability to respond to the instruments. The inclusion of left handers and subjects of both sexes in the sample was necessary for hypothesis testing. The sample was confined to one race because of research evidence showing race differences in cognitive processing style.

Demographic data on the sample was presented. Fifty males and fifty females from the State of Michigan, mean age 38.3 years, participated. The number of left handed relatives for respondents ranged from zero to six. The number of known left handed relatives over total relatives for whom handedness was known was computed as a percentage for each individual, and ranged from 0% to 50%. Those with percents over 12 were considered to have a positive family history of sinistrality; 38 subjects were in this group. Subjects with less than a 23% incidence of familial sinistrality were considered to have no family history; 62 persons were in this group. The sample's writing posture breakdown was as follows: 49 right handed noninverteds (standard writing posture); 29 left handed noninverteds; one right handed inverted; and 21 left handed inverteds.

The instrumentation for the present study was then described. Two measures of hemisphericity were employed as dependent variables: the 40 item SOLAT and the 7 item HCP

Profile II. Both instruments measure a person's relative psychological reliance on one or the other cerebral hemisphere, and both offer three choices of response, left, right, or integrated. Scores were obtained for each subject, then, on six hemisphericity scales.

Other instrumentation included the 10 item Edinburgh Handedness Inventory, from which laterality quotients were derived. From visual inspection of the resulting distribution, subjects scoring between -100 and -33 were called left handers; those between -32 and +32 were ambidextrous, and those between +33 and +100 were right handers. Data on writing posture (inverted or noninverted) and family history of sinistrality were also obtained.

Data were collected during the last six weeks of 1982. Of 178 questionnaire packets distributed, 115 were returned and 100 comprised the sample.

Three specific hypotheses were tested. The first predicted differences among three handedness/familial sinistrality groups on the hemisphericity scales. The second and third predicted differences based on sex and writing posture. Data for these hypotheses were analyzed by means of a one-way ANOVA and *t* tests, respectively. Additional research questions were posed and answered by means of *t* tests, ANOVAs, and correlations.

CHAPTER IV

RESULTS

The Results Chapter is organized in four sections. First, the hypotheses will be restated and findings pertaining to each will be described. Second, the results of additional anaylyses (*t* tests and ANOVAs) will be discussed. Third, revised scoring procedures will be discussed. Finally, summary tables of significant findings will be presented.

Hypotheses and Findings

General Hypothesis. Handedness will be associated with cognitive processing style.

Findings. The general hypothesis was tested in two ways: by conducting one-way ANOVAs to determine whether persons classified as left handed, ambidextrous, or right handed on the Edinburgh Inventory differ on the left, integrated, or right hemisphericity scales of the SOLAT and HCP; and by correlating handedness scores with hemisphericity scores.

On the basis of responses to all of the first ten Edinburgh items, subjects were classified as left handed (n=35), ambidextrous (n=15), or right handed (n=50). The results of one-way ANOVAs are shown in Table 7. The handedness groups were significantly different on one scale, SOLAT Right. A significant handedness by familial sinistrality interaction for SOLAT Right (See Table 20) complicates this result.

TABLE 7. Means and One-Way ANOVAs for Three Handedness Groups on SOLAT and HCP Scales.

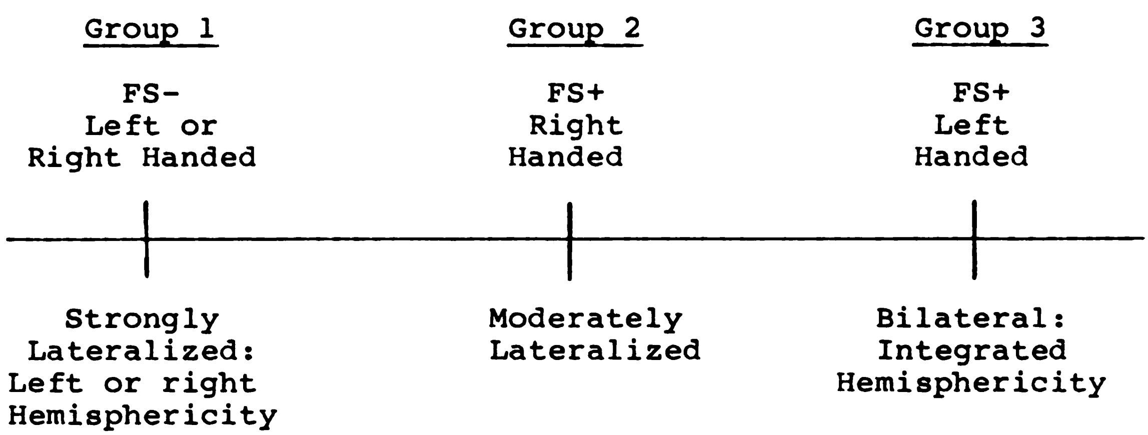
	Means			F-Ratio	Probability
Scale	Left Handed	Ambi-dextrous	Right Handed		
SOLAT Left	13.5	13.6	11.3	2.52	.086
SOLAT Right	11.0	9.3	12.6	3.44	.036
SOLAT Integrated	15.5	17.1	16.1	.48	.619
HCP Left	3.4	2.5	2.7	2.05	.134
HCP Right	1.4	1.2	1.9	2.41	.095
HCP Integrated	2.3	3.3	2.4	2.57	.082

Laterality quotients on the Edinburgh Inventory correlated negatively with left hemisphericity and positively with right hemisphericity for four scales; right handedness was, therefore, associated with right hemisphericity. The correlations between handedness and integrated hemisphericity were not significant. Table 8 shows these correlations.

TABLE 8. Pearson Correlation Coefficients for Six Hemisphericity Scales and Handedness.

Scale	Handedness	Probability
SOLAT Left	-.22	.014
SOLAT Right	.19	.030
SOLAT Integrated	.04	.332
HCP Left	-.21	.019
HCP Right	.18	.039
HCP Integrated	.07	.248

The first specific hypothesis tested Hardyck and Petrinovich's (1977) model of individual differences in handedness and cognitive functioning. Their continuum of laterality is shown in Figure 1; the expected direction of hemisphericity scores is also shown. FS- indicates that the percentage of left handed relatives was under chance expectation, i.e., 12%. FS+ indicates a percentage greater than 12%.



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a. Group 3 will outscore Group 2.
b. Group 3 will outscore Group 1.
c. Group 2 will outscore Group 1.

Differences among the three groups on the right and left hemisphericity scales of the SOLAT and the HCP are also expected.

<u>Findings</u>. A one-way ANOVA revealed no significant differences among these groups on any hemisphericity scale. Table 9 displays these findings. Since none of the ANOVAs were significant, no post hoc analyses were conducted. Based on the one-way ANOVA results, therefore, the first hypothesis received no support.

TABLE 9. Means and One-Way ANOVAs for Three Handedness/Familial Sinistrality Groups on SOLAT and HCP Scales

	Means			F Ratio	Probability
Scale	FS- Right or Left Handed	FS+ Right Handed	FS+ Left Handed		
SOLAT Left	11.9	12.4	14.4	1.65	.198
SOLAT Right	11.9	12.3	10.0	1.26	.290
SOLAT Integrated	16.2	15.4	15.6	.17	.844
HCP Left	2.9	2.9	3.3	.43	.652
HCP Right	1.8	1.5	1.2	1.20	.306
HCP Integrated	2.3	2.6	2.4	.34	.712

Hypothesis 2. Females will obtain higher SOLAT and HCP Integrated scores than males. Males and females will also differ on the SOLAT and HCP Right and Left scales.

Findings. Results of the *t* test are presented in Table 10, which shows that females did obtain higher integrated hemisphericity scores on the HCP Integrated scale. Differences on the SOLAT Integrated scale were not significant. Partial support was obtained, then, for the hypothesis that females would evidence higher integrated scores.

Significant sex differences were also found in left hemisphericity. On HPC Left, males obtained higher left hemisphericity scores than females.

TABLE 10. Means and *t* Tests for Females and Males on SOLAT and HCP Scales

	Means		t-Value	Probability
Scale	Females	Males		
SOLAT Left	12.0	12.9	-.85	.396
SOLAT Right	12.1	11.0	1.07	.288
SOLAT Integrated	16.0	16.1	-.13	.898
HCP Left	2.4	3.4	-2.72	.008
HCP Right	1.8	1.5	1.03	.305
HCP Integrated	2.8	2.2	2.07	.041

Hypothesis 3. Subjects who use an inverted writing posture will obtain higher SOLAT and HCP Integrated scores than those who use a noninverted, standard posture. Differences between inverteds and noninverteds will also be found on right and left hemisphericity scales of the SOLAT and HCP.

Findings. A *t* test revealed no significant differences between inverteds and noninverteds on either the SOLAT Integrated or the HCP Integrated scale. Results appear in Table 11.

Highly significant writing posture differences were found, however, on all other scales, with inverteds scoring higher than noninverteds on both of the left hemisphericity scales; the reverse was true for the two right hemisphericity scales.

Contrary to Hypothesis 3, then, there was no difference between the groups on the integrated scales. However, those subjects with an inverted writing posture scored higher on the SOLAT and HCP Left and those with a standard writing posture scored higher on the SOLAT and HCP Right.

TABLE 11. Means and t Tests for Inverted and Noninverted Writing Postures on SOLAT and HCP Scales.

	Means		t-Value	Probability
Scale	Inverted	Noninverted		
SOLAT Left	13.0	11.7	2.74	.007
SOLAT Right	4.8	12.1	-2.73	.008
SOLAT Integrated	15.2	16.3	-.78	.435
HCP Left	4.1	2.6	3.88	.000
HCP Right	.9	1.8	-3.63	.001
HCP Integrated	2.0	2.6	-1.49	.139

Additional Analyses and Findings

Further tests were conducted to answer the following questions:

1. Do left handers and right handers with no familial sinistrality differ on the SOLAT and the HCP?

Findings. The *t* test on the difference between left handed and right handed subjects with no familial sinistrality was not significant. Table 12 presents these results.

TABLE 12. Means and t Tests for Left Handers and Right Handers with No Familial Sinistrality on SOLAT and HCP Scales.

	Means		t-Value	Probability
Scale	Left Handers	Right Handers		
SOLAT Left	12.6	11.0	1.09	.283
SOLAT Right	12.0	12.7	-.49	.625
SOLAT Integrated	15.4	16.3	-.54	.591
HCP Left	3.4	2.6	1.72	.091
HCP Right	1.5	2.1	-1.22	.229
HCP Integrated	2.1	2.3	-.59	.557

2. Is writing hand associated with other items measuring handedness?

Findings. The first item of the Edinburgh Inventory asks which is the preferred hand for writing. The next nine items ask about preferred hand in other tasks, for example, throwing, using a toothbrush. Laterality quotients ranging from -100 to +100 were obtained for each subject. Those scoring between -100 and -33 were considered left handed, those scoring between -32 and +32 were ambidextrous and those between +33 and +100 were right handed. Using this procedure, 35 subjects were left handed, 15 subjects were ambidextrous and 50 subjects were right handed. Of the 35 subjects classified as left handed by virture of their laterality quotients, all 35 were left handed writers. Of the 15 ambidexters, 13 were left handed writers, one was right handed and one was an ambidextrous writer. Of the 50 right handers, 48 wrote with the right hand and two were left handers for writing.

3. Do persons who write with the left hand differ from those who write with the right hand on the SOLAT and HCP?

Findings. Results for the writing hand *t* tests are shown in Table 13. Those subjects who write with the left hand were found to score significantly higher on SOLAT Left than those who write with the right hand. Differences on all other scales were not significant.

TABLE 13. Means and *t* Tests for Left and Right Writing Hand on SOLAT and HCP Scales.

	Means		t-Value	Probability
Scale	Left Handed	Right Handed		
SOLAT Left	13.6	11.2	2.34	.021
SOLAT Right	10.6	12.5	-1.93	.056
SOLAT Integrated	15.8	16.3	-.50	.622
HCP Left	3.1	2.7	1.27	.209
HCP Right	1.4	1.8	-1.45	.150
HCP Integrated	2.5	2.5	-.07	.948

4. Do left handed and right handed writers differ on familial sinistrality?

Findings. Significant writing hand differences were found on familial sinistrality. The mean percentage of left handed relatives for those who write with their left hand was 12.8; for right handed writers it was 6.9 (p=.01).

5. Do subjects with a family history of sinistrality differ from those with no such history on the SOLAT and HCP?

Findings. When t tests were run, no significant differences between familial sinistrality groups were found on any of the six hemisphericity scales. Table 14 presents these findings.

TABLE 14. Means and t Tests for Positive and Negative Familial Sinistrality on SOLAT and HCP Scales.

Scale	Means FS-	Means FS+	t-Value	Probability
SOLAT Left	11.9	13.0	-1.07	.289
SOLAT Right	11.9	10.9	1.15	.255
SOLAT Integrated	16.2	16.1	.14	.891
HCP Left	2.9	2.8	.20	.841
HCP Right	1.8	1.4	1.38	.172
HCP Integrated	2.3	2.8	-1.54	.128

6. Does familial sinistrality correlate with hemisphericity scores on the SOLAT and HCP?

Findings. The correlations between familial sinistrality and hemisphericity were not significant. Table 15 presents these findings.

TABLE 15. Pearson Correlation Coefficients for Six Hemisphericity Scales and Familial Sinistrality.

Scale	Familial Sinistrality	Probability
SOLAT Left	.12	.120
SOLAT Right	-.07	.237
SOLAT Integrated	-.05	.314
HCP Left	-.03	.382
HCP Right	-.09	.191
HCP Integrated	.12	.118

7. Do males and females differ on familial sinistrality?

Findings. Significant sex differences were found on familial sinistrality. The mean percentage of left handed relatives for females was 12.4; for males it was 7.2 (p=.03).

8. What interactions among sex, handedness, familial sinistrality and writing posture are found for the six hemisphericity scales?

Findings. ANOVAs using all possible 3-factor combinations were run for each of the six hemisphericity scales. Cell size considerations prohibited the testing of 4-factor interactions. Significant ANOVA findings follow.

Significant Handedness by Writing Posture Interactions

Results of the SOLAT Integrated ANOVA for handedness by writing posture by familial sinistrality appear in Table 16. Figure 2 presents the significant handedness by writing posture interaction. The graph shows that the noninverted ambidexters obtained higher integrated scores (Mean=19.4) than the inverted ambidexters (Mean=12.6). For left handers, the inverted (Mean=16.5) outscored the noninverteds (Mean=14.6). The finding for right handers is tempered by small cell size - there was only one inverted right hander in this sample.

TABLE 16. ANOVA on SOLAT Integrated: Handedness by Familial Sinistrality by Writing Posture.

Source of Variation	Sum of Squares	DF	Mean Square	*F*	Probability of *F*
Main Effects					
Handedness	30.832	2	15.416	.603	.549
Familial Sinistrality	7.130	1	7.130	.279	.599
Writing Posture (WP)	15.486	1	15.486	.606	.438
2-Way Interactions					
Handedness by FS	57.290	2	29.645	1.121	.330
Handedness by WP	271.073	2	135.537	5.306	.007
FS by WP	113.147	1	113.147	4.429	.038
3-Way Interactions					
Handedness by FS by WP	228.969	1	228.969	8.963	.004

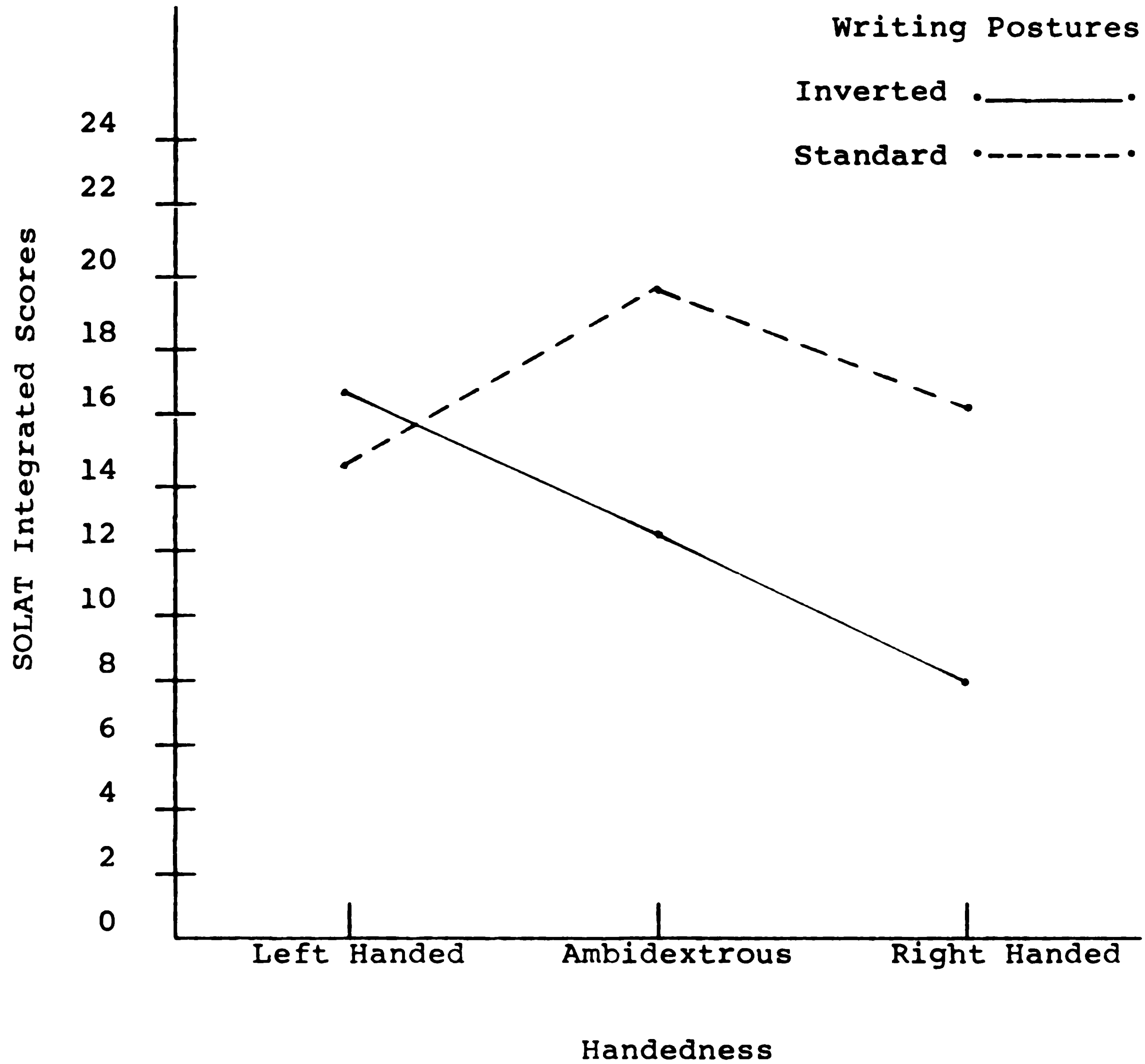

Figure 2. SOLAT Integrated: Significant Handedness by Writing Posture Interaction.

The handedness by writing posture interaction for HCP Integrated is presented in Table 17. Figure 3 shows that noninverted subjects obtained higher HCP Integrated scores than inverteds. The greatest difference was found among the ambidexters, with noniverted ambidexters obtaining the highest score overall (Mean=4.1). A similar pattern was found on the SOLAT Integrated scale (See Figure 2).

TABLE 17. ANOVA on HCP Integrated: Handedness by Familial Sinistrality by Writing Posture.

Source of Variation	Sum of Squares	DF	Mean Square	*F*	Probability of *F*
Main Effects					
Handedness	10.927	2	5.046	2.464	.091
Familial Sinistrality	4.986	1	4.986	2.434	.122
Writing Posture (WP)	7.834	1	7.834	3.825	.054
2-Way Interactions					
Handedness by FS	3.205	2	1.603	.782	.460
Handedness by WP	14.830	2	7.415	3.620	.031
FS by WP	4.856	1	4.856	2.371	.127
3-Way Interactions					
Handedness by FS by WP	1.807	1	1.807	.882	.350

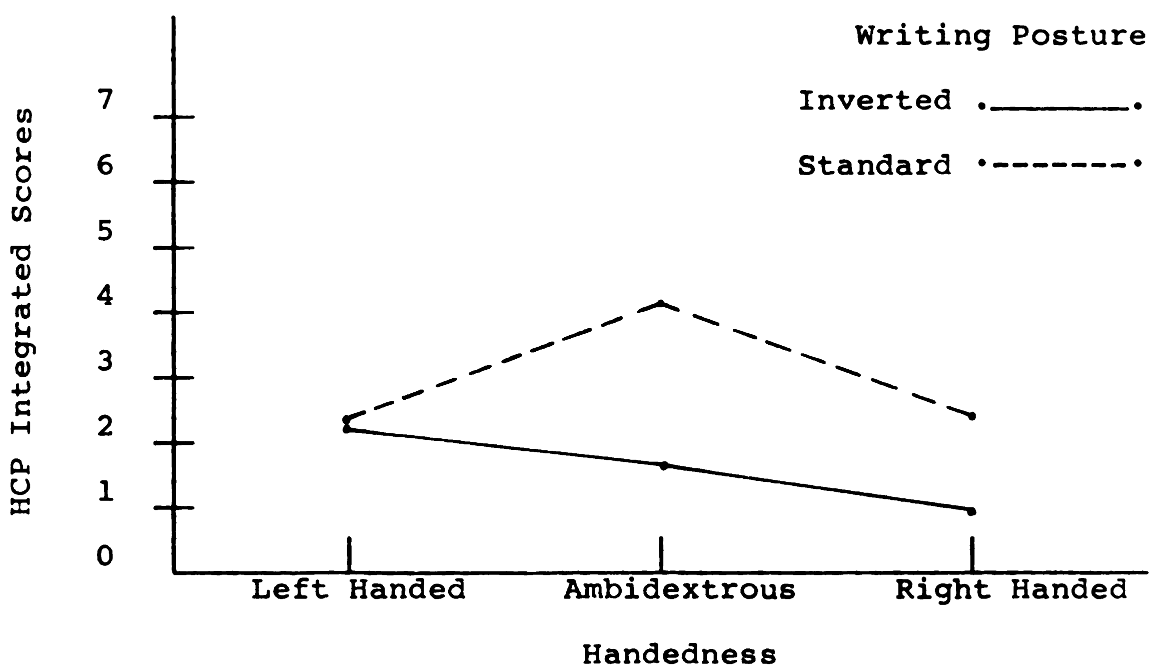

Figure 3. HCP Integrated: Significant Handedness by Writing Posture Interaction.

Significant Sex by Handedness Interactions

Table 18 and Figure 4 show that males outscored females on the HCP Left. The greatest difference between the sexes occurred among the ambidexters. The mean for male ambidexters was 4.13 while that for female ambidexters was .71, the highest and lowest means, respectively, of any handedness and sex groups. The 3-way interaction among sex, handedness, and writing posture is not included because of empty cells for inverted posture ambidextrous and right handed females (See Table 2).

TABLE 18. ANOVA on HCP Left: Sex by Handedness by Writing Posture.

Source of Variation	Sum of Squares	DF	Mean Square	*F*	Probability of *F*
Main Effects					
Sex	10.248	1	10.248	4.148	.045
Handedness	5.428	2	2.714	1.099	.338
Writing Posture (WP)	21.285	1	21.285	8.616	.004
2-Way Interactions					
Sex by Handedness	16.977	2	8.489	3.436	.036
Sex by WP	3.869	1	3.869	1.566	.214
Handedness by WP	.879	2	.439	.178	.837

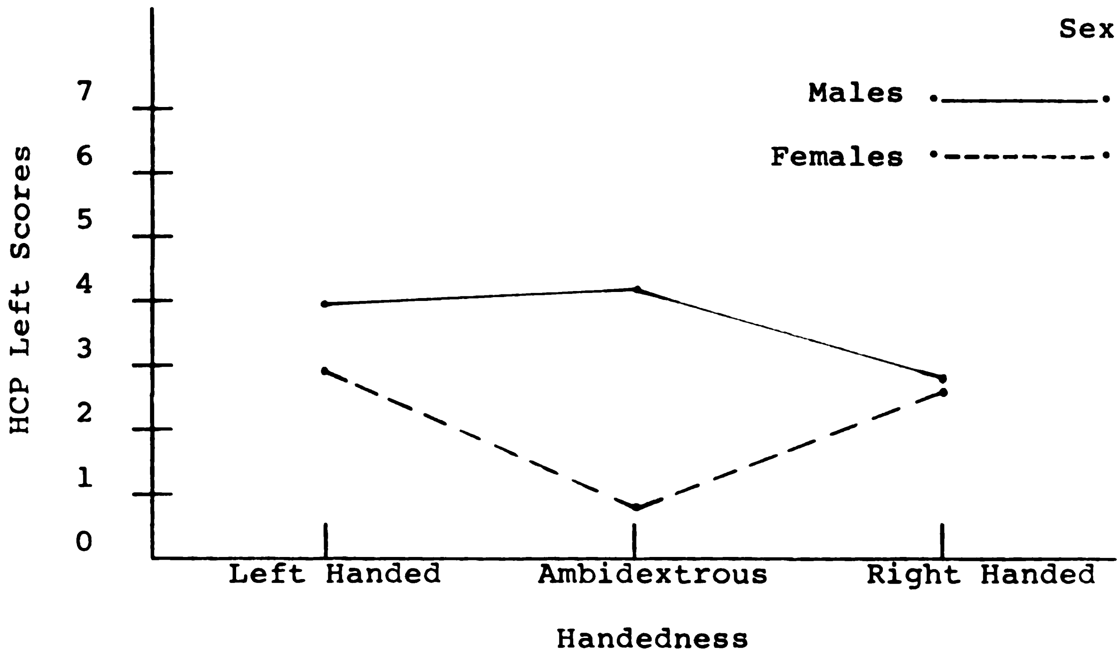

Figure 4. HCP Left: Significant Sex by Handedness Interaction.

The significant sex by handedness interaction for HCP Integrated appears in Table 19. Figure 5 shows that virtually no difference existed between males and females who were left handed or right handed. A large difference was found, however, between male and female ambidexters. Ambidextrous females obtained the highest integrated score of any group (Mean=4.71).

TABLE 19. ANOVA on HCP Integrated: Sex by Handedness by Familial Sinistrality.

Source of Variation	Sum of Squares	DF	Mean Square	*F*	Probability of *F*
Main Effects					
Sex	7.836	1	7.836	3.752	.056
Handedness	10.696	2	5.348	2.561	.083
Familial Sinistrality	2.162	1	2.162	1.035	.312
2-Way Interactions					
Sex by Handedness	19.224	2	9.612	4.603	.013
Sex by FS	.867	1	.867	.415	.521
Handedness by FS	1.788	2	.894	.428	.653
3-Way Interactions					
Sex by Handedness by FS	1.227	2	.613	.294	.746

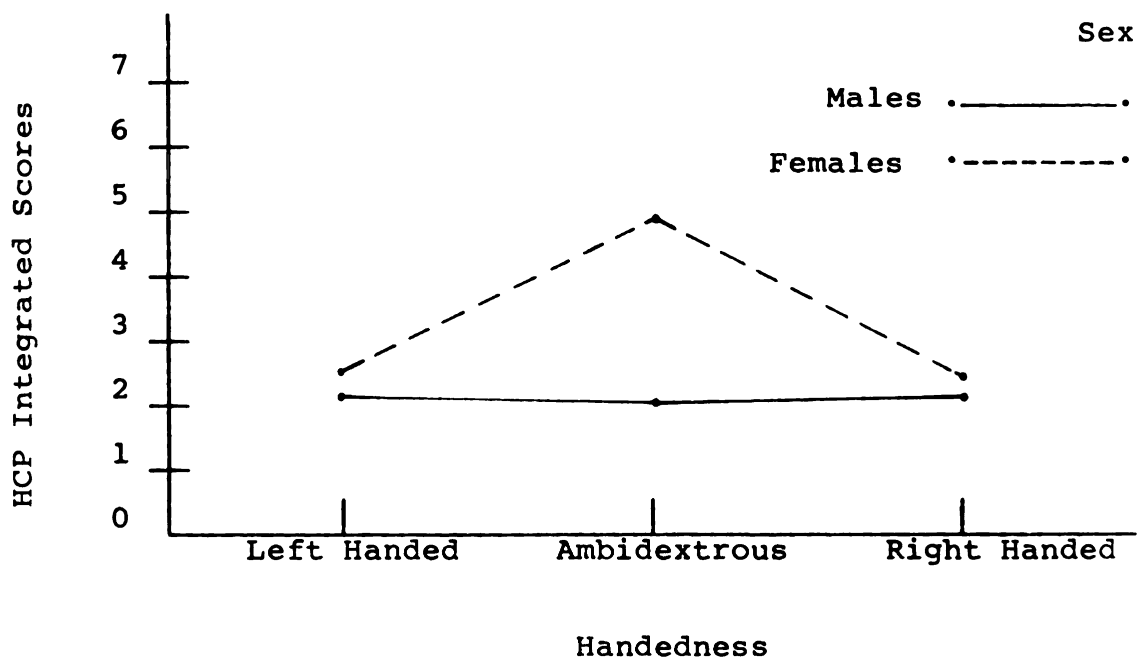

Figure 5. HCP Integrated: Significant Sex by Handedness Interaction.

Significant Handedness by Familial Sinistrality Interaction

ANOVA results showing the significant handedness by familial sinistrality interaction for SOLAT Right appear in Table 20. Figure 6 shows that ambidextrous subjects with no family history of sinistrality score much lower than all other groups on SOLAT Right.

TABLE 20. ANOVA on SOLAT Right: Handedness by Familial Sinistrality by Writing Posture.

Source of Variation	Sum of Squares	DF	Mean Square	*F*	Probability of *F*
Main Effects					
Handedness	81.621	2	40.811	1.971	.145
Familial Sinistrality	.211	1	.211	.010	.920
Writing Posture (WP)	29.102	1	29.102	1.406	.239
2-Way Interactions					
Handedness by FS	127.984	2	63.992	3.091	.050
Handedness by WP	75.100	2	37.550	1.814	.169
FS by WP	10.085	1	10.085	.487	.487
3-Way Interactions					
Handedness by FS by WP	28.538	1	28.538	1.378	.244

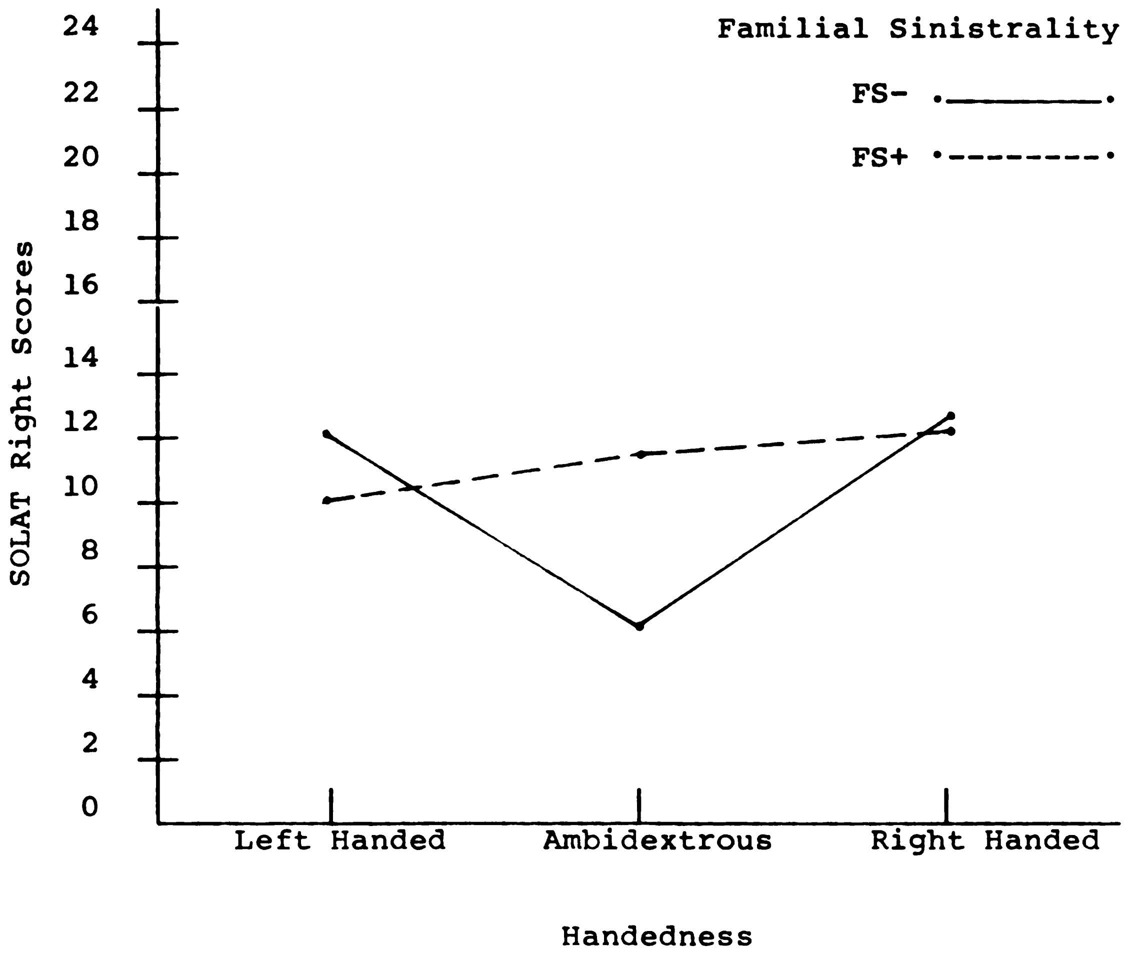

Figure 6. SOLAT Right: Significant Handedness by Familial Sinistrality Interaction.

Significant Familial Sinistrality by Writing Posture Interaction

The significant familial sinistrality by writing posture interaction is shown in Figure 7. Those subjects with an inverted writing posture and a history of familial sinistrality obtained the lowest SOLAT Integrated scores (Mean=13.83) of any group. Means of the other three groups ranged from 16.09 to 16.90. Table 16 shows the ANOVA table for this result.

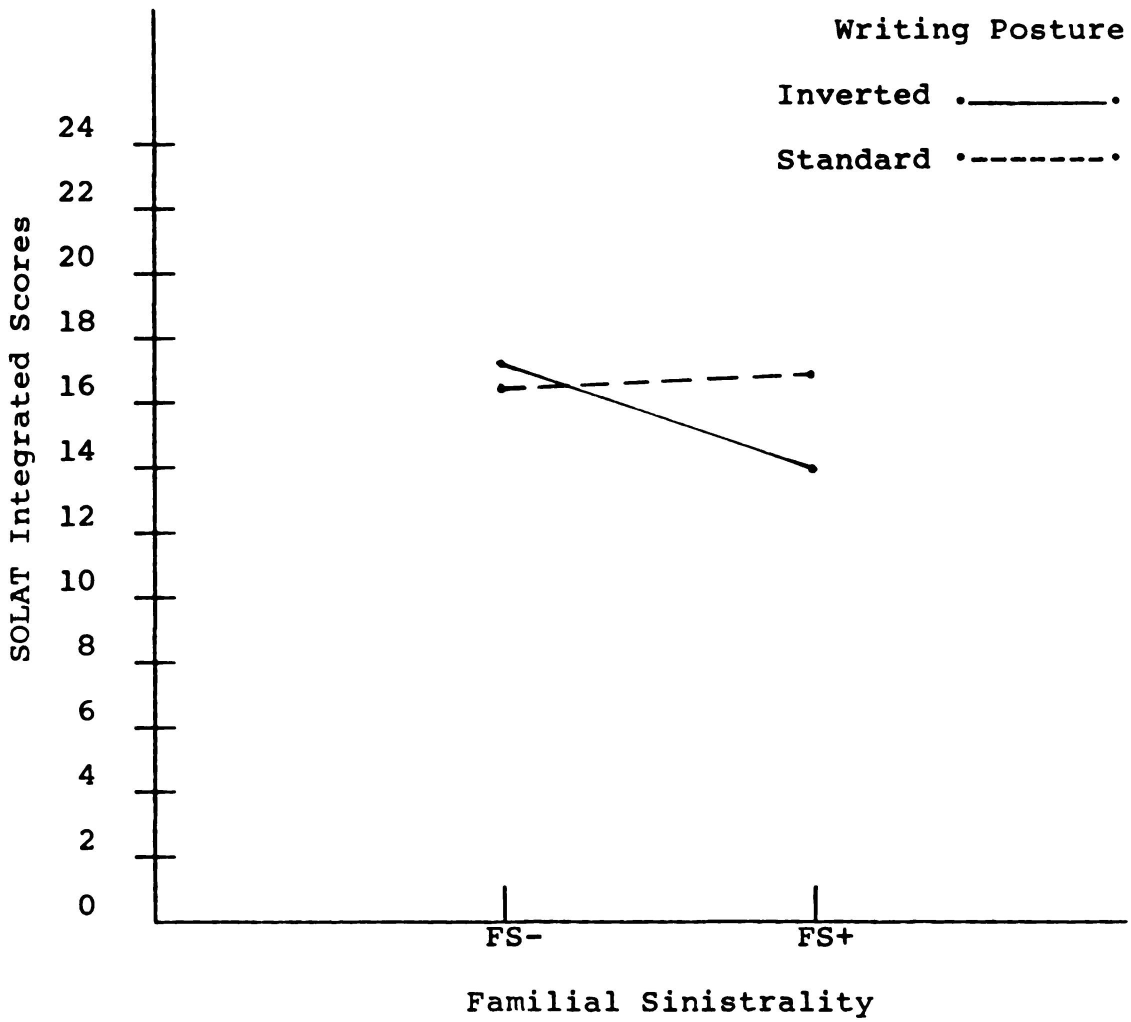

Figure 7. SOLAT Integrated: Significant Familial Sinistrality by Writing Posture Interaction.

Significant Handedness by Familial Sinistrality by Writing Posture Interactions

The significant handedness by familial sinistrality by writing posture results for SOLAT Left are presented in Table 21. Figure 8 shows that inverteds had higher left hemisphericity scores on the SOLAT, except for left handed inverteds with no family history of sinistrality. Means and cell sizes are presented in Table 22.

When interpreting this result, caution is required for several reasons: First, small cell sizes for the interaction make the results somewhat tentative; second, one cell was empty because there were no right handed subjects with an inverted writing posture and a history of familial sinistrality; third, the significance level was only .048.

TABLE 21. ANOVA on SOLAT Left: Handedness by Familial Sinistrality by Writing Posture.

Source of Variation	Sum of Squares	DF	Mean Square	*F*	Probability of *F*
Main Effects					
Handedness	19.910	2	9.955	.417	.660
Familial Sinistrality	9.791	1	9.791	.410	.523
Writing Posture (WP)	87.046	1	87.046	3.648	.059
2-Way Interactions					
Handedness by FS	87.618	2	43.809	1.836	.165
Handedness by WP	65.855	2	32.928	1.380	.257
FS by WP	55.672	1	55.672	2.333	.130
3-Way Interactions					
Handedness by FS by WP	95.837	1	95.837	4.016	.048

TABLE 22. Means and Cell Sizes for Handedness by Familial Sinistrality by Writing Posture: SOLAT Left.

		Left Handed	Ambidextrous	Right Handed
FS-	Inverted	10.86 *n*=7	21.50 *n*=2	15.00 *n*=1
	Noninverted	13.90 *n*=10	12.50 *n*=4	10.87 *n*=38
FS+	Inverted	16.78 *n*=9	15.00 *n*=3	----- *n*=0
	Noninverted	12.00 *n*=9	11.00 *n*=6	12.36 *n*=11

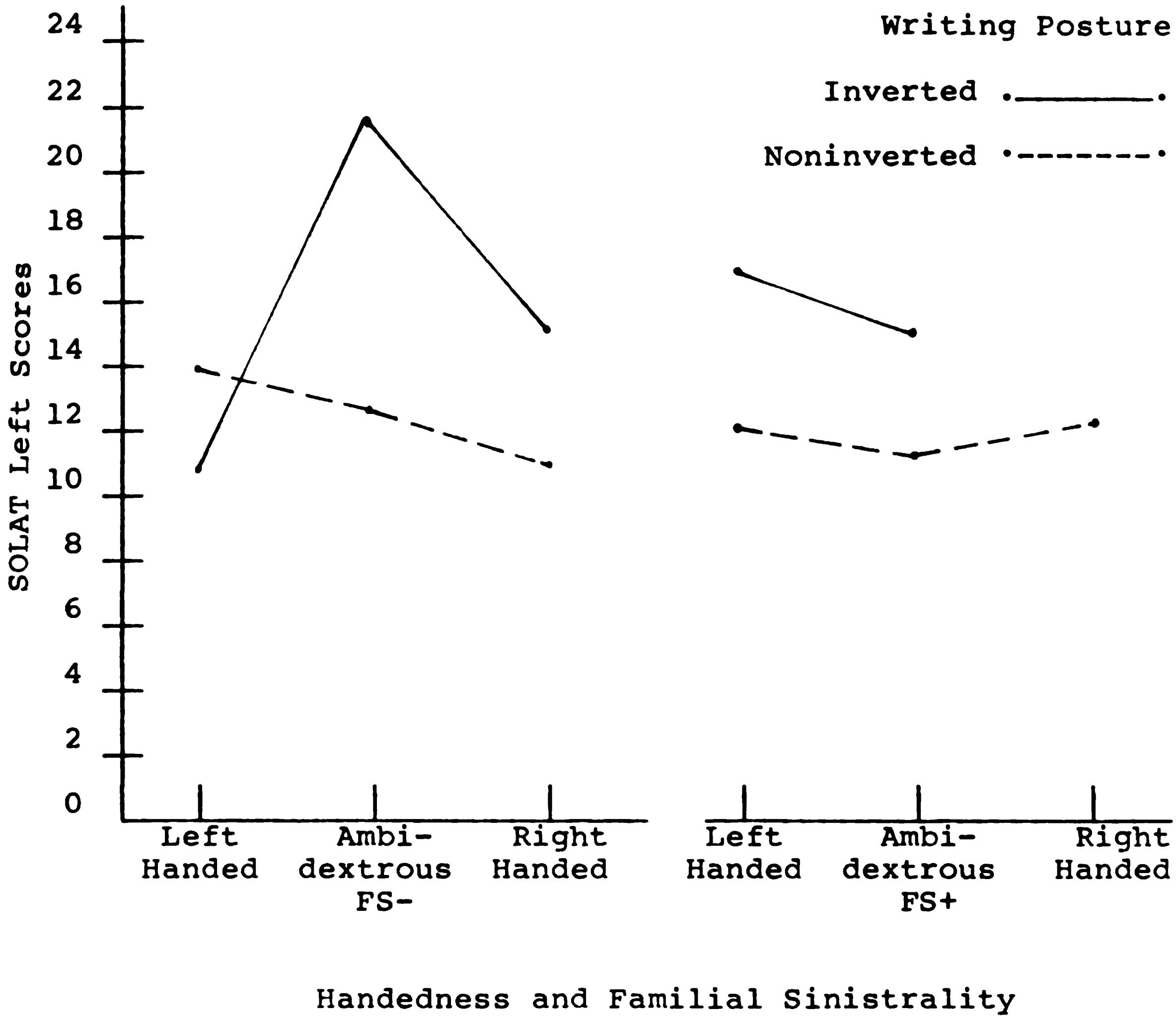

Figure 8. SOLAT Left: Significant Handedness by Familial Sinistrality by Writing Posture Interaction.

Results of the ANOVA on SOLAT Integrated reveal the same significant 3-way interaction as for SOLAT Left. Results indicate that those left handed, inverted subjects who have no familial sinistrality form a distinct subgroup. All other inverted subjects scored lower on the SOLAT Integrated than did noninverteds. For left handed subjects with no familial sinistrality, however, the inverteds obtained higher integrated scores than the noninverteds. This result is consistent with the finding, previously mentioned, of the same significant 3-way interaction on SOLAT Left. Again, the left handed inverteds with no familial sinistrality stood apart from the other groups, in this case by obtaining lower left hemisphericity scores.

Because of the significant 3-way interaction for SOLAT Integrated, displayed in Table 16 and Figure 9, the 2-way interactions on this scale must be treated cautiously. On the other hand, small cell sizes for the 3-way interaction also require caution of interpretation. Means and cell sizes are shown in Table 23.

TABLE 23. Means and Cell Sizes for Handedness by Familial Sinistrality by Writing Posture: SOLAT Integrated.

		Left Handed	Ambidextrous	Right Handed
FS-	Inverted	20.00 *n*=7	10.50 *n*=2	8.00 *n*=1
	Noninverted	12.10 *n*=10	22.25 *n*=4	16.50 *n*=38
FS+	Inverted	13.78 *n*=9	14.00 *n*=3	----- *n*=0
	Noninverted	17.44 *n*=9	17.50 *n*=6	15.36 *n*=11

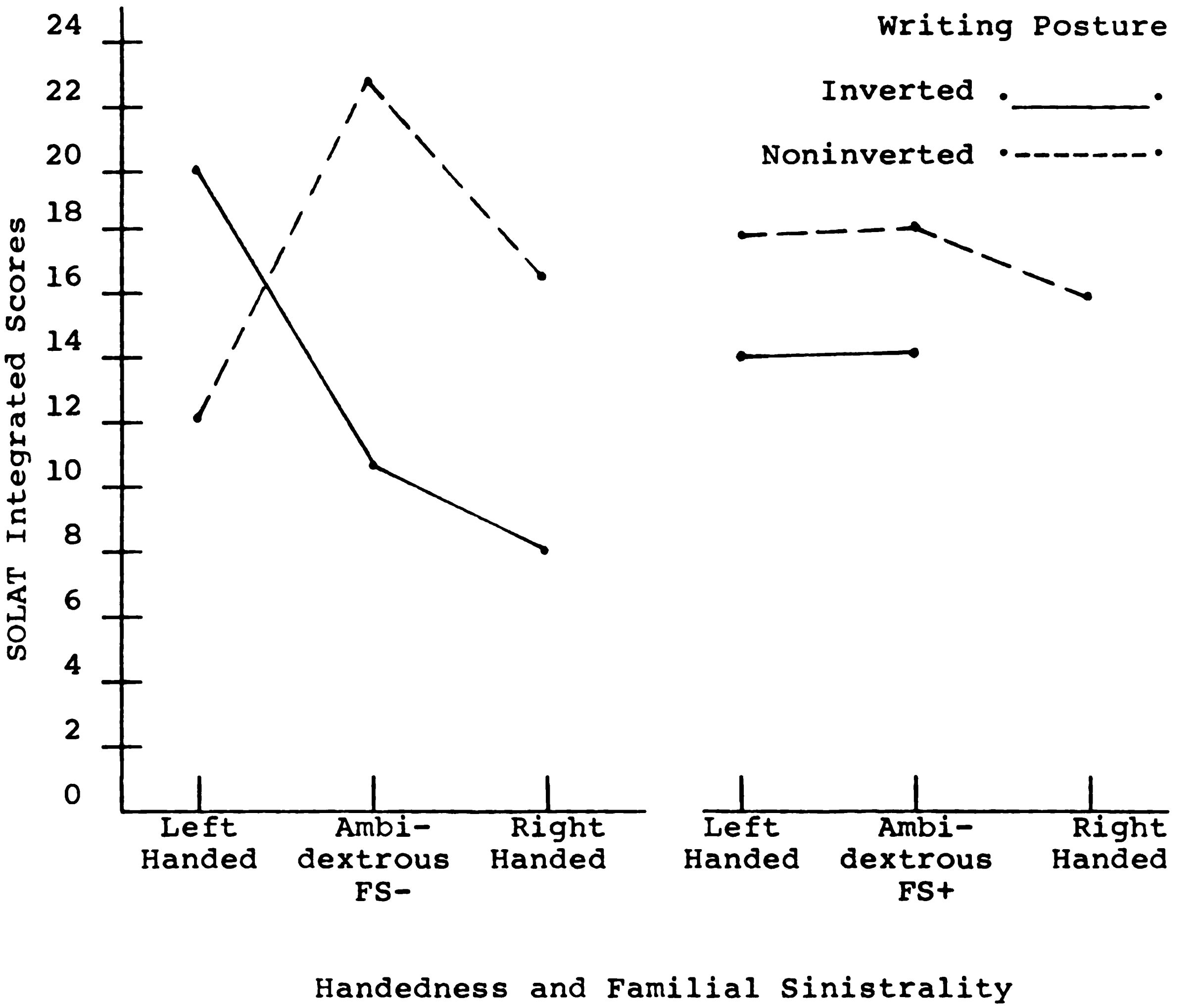

Figure 9. SOLAT Integrated: Significant Handedness by Familial Sinistrality by Writing Posture Interaction

Rescoring of SOLAT and HCP

Methods. For the original scoring method, subjects were assigned three separate, ipsative scores for the 40-item SOLAT and three scores for the 7-item HCP: left, right, and integrated.

Two revisions of scoring were conducted. The first revision involved the calculation of a "hemisphericity quotient" similar to the laterality quotient of the Edinburgh Inventory. The formula was the same in both cases: $\frac{\Sigma \text{Right} - \Sigma \text{Left}}{\Sigma \text{Right} + \Sigma \text{Left}}$ X 100. Scores on a continuum ranged from -100 to +100 with positive scores indicating some degree of right hemisphericity. As will be noted, the integrated items per se were not part of this formula.

The second revision involved the creation of another hemisphericity continuum. All right hemisphericity responses were assigned a value of 3, integrated responses were assigned a value of 2, and left responses a value of 1. Possible scores under this method ranged from 40-120 for the SOLAT and from 7-21 for the HCP, with higher scores indicating some degree of right hemisphericity.

Correlations. Computation of coefficient alpha was possible only for the second revisions of the SOLAT and HCP. The inter-item reliability for SOLAT and .70, for HCP it was .55.

The inter-scale correlations displayed in Table 24 reveal, as expected, highly significant relationships between revised scores and the originally scored left and right hemisphericity scales. It was noted that each revised score correlated highly and positively with the original right hemisphericity score, and strongly negatively with the original left hemisphericity scores. Neither SOLAT revision correlated with the original SOLAT Integrated and the second HCP revision correlated only weakly with HCP Integrated. It was concluded that on the whole, the revised scoring methods did not contribute significant new information.

TABLE 24. Pearson Correlation Coefficients for Original and Revised Scoring Methods.

	SOLAT			HCP		
	Left	Right	Integrated	Left	Right	Integrated
SOLAT Revision #1	-.75 p=.001	.85 p=.001	-.04 p=.357	-.52 p=.001	.29 p=.002	.32 p=.001
HCP Revision #1	-.33 p=.001	.41 p=.001	-.05 p=.314	-.79 p=.001	.87 p=.001	.07 p=.235
SOLAT Revision #2	-.85 p=.001	.82 p=.001	.08 p=.204	-.56 p=.001	.33 p=.001	.33 p=.001
HCP Revision #2	-.44 p=.001	.42 p=.001	.04 p=.346	-.91 p=.001	.86 p=.001	.22 p=.016

Summary

Table 25 summarizes significant *t* test findings; Table 26 shows significant ANOVA results. Only those findings which are not confounded by higher order interactions are presented.

TABLE 25. Summary of Significant *t* Test Findings.

Significant Group Differences	Scale	Description
Writing Posture**	SOLAT Right	Inverted< Noninverted
Writing Posture**	HCP Left	Inverted> Noninverted
Writing Posture**	HCP Right	Inverted< Noninverted
Writing Hand*	SOLAT Left	Left Handed>Right

* $p<.05$
**$p<.01$

TABLE 26. Summary of Significant ANOVA Findings.

Significant Findings	Scale	Description
Handedness by Writing Posture*	HCP Integrated	Overall, noninverteds outscored inverteds. Ambidexters with a standard writing posture obtained the highest HCP Integrated scores.
Handedness by Sex*	HCP Left	Overall, males outscored females. The difference between male and female ambidexters was greatest, with males obtaining the highest HCP Left scores and females obtaining the lowest.
Handedness by Sex*	HCP Integrated	Overall, females outscored males. The greatest difference between groups was for ambidexters: Females obtained the highest HCP Integrated scores, males the lowest.
Handedness by Familial Sinistrality*	SOLAT Right	Ambidextrous subjects with no family history of sinistrality scored much lower than all other groups on SOLAT Right.
Handedness by Writing Posture by Familial Sinistrality*	SOLAT Left	Subjects with an inverted writing posture had higher SOLAT Left scores than noninverteds, except for left handed inverteds with no family history of sinistrality. Ambidextrous inverteds with no familial sinistrality obtained the highest SOLAT Left scores overall.
Handedness by Writing Posture by Familial Sinistrality**	SOLAT Integrated	Left handed, inverted subjects with no history of familial sinistrality form a distinct group: All other inverted subjects scored lower on the SOLAT Integrated than did noninverteds. Ambidextrous noninverteds with no familial sinistrality obtained the highest SOLAT Integrated score overall.

*$p < .05$
**$p < .01$

CHAPTER V

DISCUSSION

This chapter will address four topics, followed by a summary. First, results and conclusions of the study will be discussed. Next, limitations of the findings will be described. Third, implications of this study for education will be presented. Fourth, suggestions will be made for further research. Finally, the chapter will be summarized.

Results and Conclusions

The purpose of the present study was to examine the relationship between handedness and cognitive processing style. In addition to handedness, three subject variables were investigated: sex, writing posture, and familial sinistrality. As expected, findings show that the relationship under study is far from simple. The subject variables exert powerful, complicated effects.

Two measures of cognitive processing style were used, the SOLAT and the HCP. Whether these instruments do indeed measure anything having to do with hemispheric specialization (reflected in handedness) was a question of considerable interest.

In the present study, the relationship between handedness and cognitive processing style was found to be statistically significant. The details of this relationship were not always in accord with previous research, however. One possible explanation for this inconsistency lies in the instruments used. Measures of cognitive processing style have been employed only infrequently in previous research. Limiations of the measures used in the present study are discussed in more detail below.

On balance, the evidence from the present study partially supports the validity of the SOLAT and the HCP as measures of cognitive processing style rooted in hemispheric specialization. Problems with these measures are sufficient to warrant much further validation research.

All subject variables investigated in the present study - handedness, sex, writing posture, and familial sinistrality - had significant effects on cognitive processing style scores. Handedness appeared as a variable in all six of the unconfounded significant ANOVA results. Writing posture appeared in three of six significant ANOVA interactions, and in three of four significant *t* tests. Familial sinistrality was a key variable in three interactions and sex appeared in two interactions.

Three sets of conclusions will be discussed: first, those relating to the general hypothesis and the three specific hypotheses; second, those relating to the additional research questions; and finally, a set of major conclusions distilled from the first two sets.

Conclusions Regarding Hypotheses. The general hypothesis of the present study was that handedness would be associated with cognitive processing style. One-way ANOVAs were conducted to determine whether persons classified as left handed, ambidextrous, or right handed differed on the left, integrated, or right style of thinking. Additionally, handedness scores were correlated with hemisphericity scores. The one-way ANOVAs showed the handedness groups to differ on one scale, SOLAT Right, but that result was confounded by an interaction of handedness with familial sinistrality. The correlation between handedness and style of thinking was significant for the left and right style, but not the integrated; the correlation for the right style of thinking was influenced by familial sinistrality. The conclusion with respect to the general hypothesis is based on the correlations and is that right handedness is associated with the right hemisphere cognitive style and left handedness is associated with the left. The failure to obtain a significant correlation between handedness and the integrated style of thinking was interpreted as evidence of problems with the integrated scales. These problems are discussed in the section on limitations of the study.

The study reported here has shown that cognitive processing style and handedness are definitely, but not simply, related.

The only other direct evidence in the literature of a link between cognitive processing style and handedness, as defined in the present study, was provided by Aliotti (1981), who found among a sample of gifted adolescents that right handedness was positively correlated ($\underline{r}$=.33) and ambidexterity negatively correlated ($\underline{r}$=-.42) with the left hemisphere style. Results of the study reported here, on the other hand, indicate that right handedness is positively correlated with the right hemisphere style and negatively correlated with the left. These findings, apparently contradictory, demonstrate the complexity of the relationship under study. Actually, the separate results of Aliotti and the present study may offer some verification of previous research indicating that right handers are more strongly lateralized than left handers, both to the left and to the right.

Conclusions regarding the three specific hypotheses are presented next. Following Hardyck and Petrinovich (1977), the first hypothesis was that differences on style of thinking would occur for three handedness/familial sinistrality groups. Results showed no significant differences among groups. It was concluded, therefore, that the Hardyck and Petrinovich model of individual differences in handedness and cognitive funtioning was not applicable to the sample and/or instruments used in the present study.

The second hypothesis predicted sex differences in cognitive processing style, with females specifically expected to show a more integrated style than males. This hypothesis received partial support, and it was concluded that females are more likely to use an integrated style of thinking and males to use a left hemisphere style, at least on one of the two hemisphericity instruments used. The fact that sex differences were not found on the SOLAT was interpreted as evidence that the HCP may be a better measure of cognitive processing style. The literature reviewed in Chapter II indicates that sex differences in cognitive functioning are well documented. The findings of the present study, for the HCP only, are consistent with previous research.

The third hypothesis of the present study predicted cognitive style differences between subjects with an inverted and those with a standard writing posture. While no significant differences were found for the integrated style, highly significant differences were obtained for the left and right styles. Those subjects with an inverted writing posture scored higher on the left hemisphere style, and those with a standard writing posture scored higher on the right hemisphere style. It was concluded that writing posture is an important variable in studies such as the one reported here, and that the integrated scales may fail to tap this variable.

Conclusions Regarding Additional Analyses. Given the exploratory nature of the present study, a number of additional analyses were conducted. Results and conclusions are summarized below.

1. There was no difference on a *t* test between left handed and right handed subjects without familial sinistrality on the cognitive style measures. It was concluded that, for those subjects with no family history of sinistrality, left handers do not use a cognitive style that is different from that used by right handers.

2. Of the 35 subjects classified as left handed by virtue of their responses to the Edinburgh Inventory, all 35

were left handed writers. Of the 15 ambidexters, 13 were left handed writers, one was right handed and one was ambidextrous. Of the 50 right handers, 48 wrote with the right hand and two with the left. It was concluded that writing hand is associated with other items measuring handedness.

3. Left handed writers were more likely than right handed writers to use the left hemisphere style of thinking. Although the use of writing hand alone is not generally recommended as a criterion of handedness, it was concluded that writing hand alone is powerful enough to differentiate among subjects on at least one of the six scales used in the present study.

4. The mean percentage of left handed relatives for left handed writers was significantly higher than the percentage for right handed writers. It was concluded that left handed writers differ from right handed writers on familial sinistrality and that this effect may be due to genetics as well as a greater awareness of left handedness among their relatives by left handers.

5. There was no difference in cognitive processing style between those subjects with and those without familial sinistrality. Given other results showing the interaction of familial sinistrality with handedness and writing posture, it was concluded that familial sinistrality interacts with other variables.

6. Correlations between familial sinistrality and cognitive processing style were not significant. It was

concluded that familial sinistrality, in and of itself, is not associated with cognitive processing style.

7. Females claimed significantly more left handed relatives than males. It was concluded that this effect may be due to genetics as well as a greater awareness of left handedness among their relatives by females.

8. Numerous interactions among subject vaiables were found. Table 26 summarizes these results. It was concluded that the subject variables studied - handedness, sex, writing posture, and familial sinistrality - exert their effects on cognitive processing style in complex ways.

Major Conclusions. The weight of the evidence presented here permits three major conclusions, all of which revolve around the differentiation of subgroups of left handers based on certain subject variables.

The first major conclusion of this study is that writing posture clearly differentiates among subjects on measures of cognitive processing style. Significant differences between writing posture groups were found for the left and right styles of thinking. Those 22 subjects with an inverted posture (21 of whom were left handed) were characterized by a left hemisphere style on both scales; standard posture subjects (n=78) were characterized by a right hemisphere style. The probabilities for these t tests were all less than .01. No writing posture differences were found on the integrated style of thinking when t tests were run. Writing posture, however, did appear as a significant variable in ANOVA interactions for the integrated style of thinking as well as the left.

The second major conclusion of the present study is that inverted left handers who have no family history of sinistrality are a distinct subgroup of all left handers. This subgroup was characterized by more of an integrated and less of a left hemisphere style than their standard posture counterparts.

Interpretation of this finding is, in part, based on previous writing posture research. Levy and Reid (1976) found that inverteds were less strongly lateralized than noninverteds. In the present study, however, only some inverteds were less strongly lateralized. These were the inverted left handers with no familial sinistrality. According to the findings reported here, familial sinistrality is a key variable in subdividing left handers. Levy and Reid assessed writing hand, writing posture, and sex, but not familial sinistrality. It seems likely that this last factor contributes significantly to a full description of group differences in hemispheric specialization and should be included in all lateralization research.

The third major conclusion of the present study is that ambidexters tend to differ among themselves based on various subject variables. In the study reported here, 13 of 15 of the ambidextrous subjects were left handed writers. While the differences between ambidextrous subgroups found on the left, right, and integrated cognitive styles were striking, those between left handed and right handed subgroups were not. Among ambidexters with no familial sinistrality, those with a standard writing posture were most likely to use an integrated style of thinking, while those with an inverted posture were most likely to use a left hemisphere style. In addition, ambidexters with no familial sinistrality were least likely to use a right hemisphere style.

Other evidence showing the salience of the 15 ambidextrous subjects was found in significant handedness by sex results, again on left and integrated hemisphericity. Male ambidexters (n=8) preferred the left hemisphere cognitive style and female ambidexters (n=7) preferred the integrated style.

Previous research (Maccoby and Jacklin, 1974) has demonstrated that males excel in spatial ability and females excel in verbal. If spatial ability is right hemisphere lateralized and verbal ability is left hemisphere lateralized, as research and theory suggest, the present finding of male superiority on left hemisphericity is dissonant with this body of research on six differences. The explanation lies in the assumption that abilities and preferences do not show a one-to-one correspondence. Although a male may excel on tests measuring ability in spatial skills, he may choose to express this ability in a characteristically left hemisphere style, i.e., linear, sequential, logical, etc. Descriptions of the left hemisphere style are reminiscent of what this culture associates with masculinity (See Table 1).

To the extent that the SOLAT and HCP measure culturally sanctioned views of left and right, male and female thinking styles, then results of the present study support these sex differences. Research on sex differences in lateralization typically has found females to be more integrated than males. Males are more highly specialized, and the results cited above support that conclusion for the left hemisphere cognitive style.

Limitations of the Present Study

Limitations of the present study are of four kinds: sample, procedures, instruments, and data analysis limitations. The sample was white, middle class and, compared to the general population, highly educated. Of 100 subjects, 65 had at least a bachelor's degree; of these, 43 had masters, Ph.D.s or medical degrees. Another sample limitation had to do with place of employment: 64% of the sample worked for the State of Michigan, 61% for the Michigan Department of Public Health. To the extent that these sample characteristics affect cognitive processing style, generalizations based on the results of the present study are limited. The population addressed is composed of all white adults. In addition to factors such as social class, education and employment, the sample may not be representative because of the lack of adult subjects under 23 years and over 63 years of age.

Procedures limitations were due to the method of obtaining subjects. All subjects did not receive exactly the same explanation of the purpose of this study. Some subjects were contacted in person; others received notes in the mail requesting their participation. When personal contacts were made, certain subjects, notably left handers, expressed a great deal of interest in the research, and engaged the investigator in conversation. This variability in procedures constitutes a limitation of the study.

Limitations of the instruments are presented in the following sequence: Edinburgh Handedness Inventory, Handedness in Your Family, Writing Position Assessment, and the integrated hemisphericity scales.

Previous research was cited which recommends that handedness be assessed through observation of subjects performing unimanual tasks. Direct observations were uneconomical, given 100 subjects in the sample. Instead, a highly reliable (.95) paper and pencil handedness inventory was used. Of the 10 items on the Edinburgh Inventory, seven are unimanual and three involve the use of both hands. Results for the Edinburgh Inventory are also attenuated by the apparent failure of some subjects to follow directions. The directions call for the use of a double check mark to indicate very strong hand preference; 39% of the subjects used no double checks. Because of this, single and double check marks were considered to be equivalent for scoring purposes. Of interest was the fact that nine subjects, all left handed, used reversed check marks. These nine subjects all used the standard writing posture.

The accuracy of responses to the Handedness in Your Family form probably varied as a function of the subject's awareness of left handed relatives. Although subjects had the option of indicating "unknown" handedness for all relatives, some probably assumed that if a relative's handedness was unknown, it was most likely right handed. This may have occurred less among left handers, who are probably more attuned to other left handers in general and particularly those in their extended families.

Left handed writers had significantly more left handed relatives (Mean=12.8%) than right handers (Mean=6.9%). While a genetic interpretation is reasonable, part of this effect may be explained in terms of awareness of left handedness. Males and females also differed significantly on familial sinistrality. Mean percentage of left handed relatives for females was 12.8; for males it was 7.2. Again, the interpretation may largely be that an authentic sex difference exists, but that part of the effect is due to greater female sensitivity to individual handedness differences within the family. Accuracy of recalled information on left handedness in one's family remains problematic, and the solution lies in a verification process beyond the scope of the present study.

Limitations of the Writing Position Assessment are due to "unclassifiables". Levy and Reid (1976) suggest that about 90% of all subjects can be accurately classified based on their writing posture criteria. In the present study self-classification was used. Subjects who were unable to match their own writing posture with one of the four pictured were asked to describe their posture by answering two questions. This occurred for five subjects, all of whom were left handed and moderately inverted since the tips of their pencils pointed to the right side of the paper, not the bottom. For statistical analysis, these five subjects were classified as inverteds.

Other instrument limitations revolve around the integrated hemisphericity scales. The definition of an integrated style of thinking is elusive. The integrated option on both the SOLAT and HCP lacks face validity as a distinct cognitive processing style. The test manuals for both measures seem clear, relatively speaking, about what exactly constitutes left and right hemisphericity. The integrated style is an option by default, i.e., whatever's not right and not left. On the SOLAT, for example, the left hemisphericity option is phrased as the opposite or complement of the right hemisphericity option. The integrated option, on the other hand, is a "no preference", "equally skilled" or "no difference" option. The HCP, similarly, is clear about what constitutes left and right hemisphericity, but has the respondent check "both" for the integrated style of thinking. If the integrated style of thinking is distinct form the right and left, it should have its own characteristics which are able to be offered as distractors. If, however, integrated only represents a relationship between left hemisphericity and right, i.e., if it is only that part on the hemisphericity continuum between left and right, then no integrated option is needed. It is for this reason that the hemisphericity scales were rescored using only the left and right options in the formula.

A second problem with the integrated scales relates to responding types. Loye (1982) refers to the likely presence of extreme responders, those who choose all left or all right options. A similar phenomenon may be at work for the integrated option, with some subjects habitually choosing it, perhaps in a rather mindless fashion. Some evidence for this view is found by examining mean hemisphericity scores. Of 40 SOLAT items, the mean SOLAT Integrated score was 16.03, compared with 12.42 for SOLAT Left and 11.5 for SOLAT Right. This is also the case for data reported by the test authors. Given the length of the SOLAT, some subjects may tire of carefully weighing each option and resort to mechanically indicating the integrated option.

Responding types may also be differentiated according to sex. Males, for example, may tend to respond more extremely on cognitive style measures, which follows from their stronger specialization of brain functions. Females tend to be less strongly specialized; this would presumably result in an integrated responding type. Socialization factors may intensify this effect. In the present study, males obtained higher left hemisphere scores, and females obtained higher integrated scores. These findings are consistent with differential responding types by sex.

A third problem with the integrated scales is the failure to correlate significantly with handedness on the Edinburgh Handedness Inventory. Although handedness scores correlated significantly for the left and right hemisphericity scales, correlations between handedness and the SOLAT and HCP Integrated scales were around zero and not significant. This may signal a problem with the integrated scales.

A final problem with the integrated scales pertains to their relation to the two revised scoring methods, each of which yielded a continuum of scores. The first revision was obtained by applying the same formula used to convert scores on the Edinburgh Handedness Inventory, i.e.,

$\frac{\sum Right - \sum Left}{\sum Right + \sum Left} \times 100$. Scores ranged from -100 to +100. The integrated scales per se were not part of the formula. The second scoring revision did include the integrated times. For this revision, right, integrated, and left hemisphericity responses were assigned values of 3, 2, and 1, respectively. Possible scores ranged from 40-120 for the SOLAT and from 7-21 for the HCP. On both rescorings, higher scores indicated some degree of right hemisphericity.

Highly significant intercorrelations were obtained between the scoring revisions and the original scoring of the left and right hemisphericity scales. As expected, revisions correlated positively with the original right hemisphericity scales and negatively with the original left scales. Contrariwise, correlations betwen SOLAT Integrated and each scoring revision hovered around zero and were not significant. The original HCP Integrated score correlated moderately with the first (.32, p=.001) and the second (.33,p=.001) SOLAT revision. A correlation of .22 (p=.016) was obtained between the original HCP Integrated and the second HCP revision.

This difference between SOLAT Integrated and HCP Integrated correlations is but one of several important differences between the two dependent variables. Others include reliability coefficient differences and differences in behaviors sampled. These factors may have combined to produce results that were not strictly comparable.

Finally, certain limitations of the present study revolve around data analysis. Type I errors are typically introduced when several tests are used and the overall alpha is not controlled. With the use of two dependent variables, the SOLAT and HCP, each consisting of three ipsative scales, this problem may be exacerbated.

Cell sizes for the two significant 3-way interactions were woefully small. With a cell size of 38 for one of the 13 cells, the remaining 11 are left to divide among themselves 62 subjects, leaving an average cell size of 5.6, hardly enough to bestow overwhelming confidence in the findings.

Educational Implications

Differences in cognitive processing styles were found to be a function of certain subject variables. Handedness, while not as simple as only preferred writing hand, is nonetheless a relatively straightforward human characteristic, reliably measured by short paper and pencil tests. Left handers have posed problems for laterality researchers in the past because of their heterogeneity. Right handers are relatively homogeneous with respect to hemispheric specialization. For left handers, the existence of subgroups, as yet inconsistently or ill-defined by research, is the rule. The present study has defined these subgroups in terms of handedness, writing posture, sex, and familial sinistrality. On measures of cognitive processing style, subgroups of left handers were identified. Ambidexters (13 of 15 being left handed writers) form a distinct subgroup, as do inverted posture left handers.

Writing posture and handedness are easily assessed, although assessment is limited by developmental changes in lateralization until perhaps puberty. Consistent hand preference may not be firmly established until six to nine years of age (Beaumont, 1974), and writing posture has been shown to change over the elementary school years (Peters and Pedersen, 1978). Measurement of familial sinistrality is more problematic. The reliability of any instrument depending on recalled information is questionable. Until a measure of familial sinistrality can be obtained through other methods, or can be verified, it will be the variable of least confidence.

Before embracing research results on cognitive processing style, teachers will want to know if these results add any information to what they already have on student individual differences. Is cognitive processing style really distinct from cognitive abilities, or IQ? What are the practical benefits of this distinction in the classroom?

Whether children with identical IQs differ on a cognitive style dimension has not been fully tested. Aliotti (1981) studied gifted high school students and found a significant correlation between Binet IQ and handedness, for males only. Binet IQ correlated -.36 with right handedness and .34 with left handedness. He also found a significant positive correlation (_r_=.32) between the right hemisphere style of thinking and Binet IQ. Aliotti notes that other research using the SOLAT supports the link between the right hemiphsere style of thinking and giftedness. But further research is required.

The practical benefits of untangling the IQ-cognitive processing style relationship revolve around teaching methodolgy. Two students having the same IQs but different cognitive processing styles might require individualized teaching methods. The student who prefers to process information serially might benefit more from programmed instruction while the student who processes information simultaneously might thrive in a relatively unstructured learning environment. On the other hand, two children with quite different IQs but the same preferred processing style may be grouped for subjects where they would have traditionally been separated. Reading groups of today and yesterday, for example, follow ability lines. Those of the future may combine ability levels and use preferred mode of information processing as the criterion for grouping. This new approach might offer hope to the students who have failed to profit from the traditional method of teaching reading in ability groups. One caveat: Cognitive processing styles may change over the years. Frequent reassessment would be desirable, then, so that students don't get locked into a group which no longer suits their needs. One caveat: Cognitive processing styles may change over the years. Frequent reassessment would be desirable, then, so that students don't get locked into a group which no longer suits their needs.

Since the subjects for the present study were adults, consideration of the implications for adult and continuing education is appropriate. Second careers are becoming increasingly commonplace, both for men making mid-life changes and for women re-entering the work force after child-rearing or divorce. Given today's explosive technological changes, retraining for second careers is essential, as is continuing education for all those wishing to keep pace with new developments in their fields.

Retraining for the individual embarking on a second career begins with an assessment of previous successes and failures, strengths and weaknesses, likes and dislikes. If success was elusive during earlier schooling experiences, perhaps the brain's strengths were not being properly deployed. The individual may have been required to learn in a verbal, sequential fashion, when the preference was for a nonverbal, simultaneous style. Now, at the time of retraining, that discrepancy can be revealed and corrected.

Retraining for a second career often involves returning to school after a prolonged absence from formal educational settings. This situation demands that preferred cognitive style be analyzed in relation to the preferred field of study. For example, an individual may have chosen psychology as an undergraduate major, a field which lends itself to verbal, linear presentations typical of left hemisphere processing. It may be recognized only later that the highly verbal content of psychology was dissonant with the individual's preferred cognitive style.

When considering retraining, it is also possible that the preferred cognitive style may change over the individual's own lifetime. One who prefers to deal with material sequentially and verbally while in college may find that the preferred style at mid-life is nonverbal and simultaneous. There is some indication that lateralization crystallizes over the life span, with older adults more highly specialized than younger adults. It has already been noted that lateralization is not fully established until perhaps puberty. If lateralization changes throughout life, one would expect concomitant cognitive changes. This expectation underlies the need for reassessment periodically through life, and particularly prior to retraining.

Cognitive processing style should be assessed periodically, then, and especially at times of career changes. Because the present study was an exploratory one, recommendations regarding specific teaching methodologies are premature. In general, however, it seems safe to assert that teaching methods, whether applied to children or adults, should rely on the basic principle of respect for student individual differences. Teachers can, at a minimum, be aware of individual differences in cognitive processing style and permit the expression of these differences in academic settings. Studies such as the one reported here can also alert teachers to the possible link between handedness and cognitive style.

Other implications for adults arise from their roles as parents and employees. Education for parenting should include some mention of individual differences related to cognitive processing style and to handedness. Since genetics clearly is implicated in handedness, classroom exercises using familial sinistrality questionnaires, followed by a discussion of the impact of left handedness, may be appropriate. Previous research suggests that left handers may be over-represented in certain occupations. Employee job satisfaction may be related to the connection between preferred cognitive style and the style actually used on the job.

Suggestions for Future Research

Of primary importance, future research must concentrate on validating the cognitive processing style measures. The relationship between physical and psychological hemispheric specialization may be nothing more than an appealing theoretical construct. If this construct is to be of any value to educators, repeated validations and instrument refinements are required. The relation between cognitive processing style and hand preference, as well as eye and ear preference, demands scrutiny. The interplay among handedness, sex, familial sinistrality, and writing posture must be elucidated. Is hemispheric specialization reflected in cognitive processing style? How do various subject variables affect hemispheric specialization? These are questions for future research.

The identification of subgroups of left handers and ambidexters in the present study leads to a second recommendation for further research. A study focusing on non-right handers should be conducted, with sex, familial sinistrality, and writing posture controlled. The goal of this recommendation is to expand the pool of subjects. Although 50 left handed writers were subjects for the study reported here, the number of variables under consideration made some ANOVA cell sizes disappointingly small. In spite of that, however, results were significant and tantalizing. At least twice as many left handed and ambidextrous subjects would be recommended for future studies.

Finally, a recommendation for future research arises from the paucity of direct evidence on the distinction between cognitive abilities and cognitive preferences. Given equal IQs, do individuals differ in the expression of their abilities on a cognitive processing style dimension? Put another way, does hemispheric specialization determine abilities and preferences separately or does it determine only abilities, from which flow preferences? Further research is required to sort this out.

Summary

Four topics have been addressed in the preceding discussion: results and conclusions; limitations of the present study; educational implications; and suggestions for further research.

Results and conclusions were presented in three parts. First, results and conclusions pertaining to the general and specific hypotheses were presented. Second, conclusions regarding additional analyses were discussed. Third, significant findings were distilled into three major conclusions.

The general hypothesis, that handedness would be associated with cognitive processing style, received partial support. Right handedness correlated with the right hemispheric cognitive style; left handedness correlated with the left style. Correlations between handedness and the integrated style of thinking were not significant.

The first specific hypothesis was based on Hardyck and Petrinovich's (1977) model of individual differences in handedness and cognitive functioning. It predicted cognitive style differences among three handedness/familial sinistrality groups. This hypothesis received no support from the data.

The second hypothesis predicted sex differences in style of thinking. Partial support was obtained. Females used an integrated style and males used a left hemisphere style.

The third hypothesis predicted cognitive processing style differences between writing posture groups. Partial support was obtained for this hypothesis. Subjects with an inverted writing posture were more likely to use the left hemisphere style; those with a standard posture used the right hemisphere style. No significant differences between writing posture groups were found on the integrated style of thinking.

Given the exploratory nature of the present study, a number of additional analyses were conduted. Statistically significant findings are summarized as follows:

1. Left handed writers were more likely than right handed writers to use the left hemisphere style of thinking.

2. The mean percentage of left handed relatives for left handed writers was significantly higher than the percentage for right handed writers.

3. Females claimed significantly more left handed relatives than males.

4. Numerous interactions among subject variables were found. The variables investigated - handedness, sex, writing posture, and familial sinistrality - affect cognitive processing style in complex ways.

The weight of the evidence permitted three major conclusions to be drawn, all of which revolve around the differentiation of subgroups of left handers.

1. Writing posture clearly differentiates among subjects on measures of cognitive processing style.

2. Inverted posture left handers who have no family history of sinistrality form a distinct subgroup of all left handers.

3. Ambidexers (13 of 15 being left handed writers) differ among themselves based on certain subject variables.

Limitations of the present study were discussed. Educational implications were presented, and finally, suggestions for future research were noted.

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APPENDIX

APPENDIX

GENERAL INSTRUCTIONS: The attached forms are the basis for research I am conducting on the relation between handedness and style of thinking. These forms will take about 20 minutes to complete. Each form has its own specific instructions.

Please complete the forms and return to me in the envelope provided within one week. Thank you for your assistance.

Pat Hebert

Form C

YOUR STYLE OF LEARNING AND THINKING

Instructions: Please describe your style of learning and thinking by circling the appropriate letter for each of the following 40 items. Try to describe your strengths and preferences as accurately as possible. If you wish to comment on any items, feel free to do so in the margins.

1. (a) read for main ideas
   (b) read for specific details and facts
   (c) read for main ideas and for details and facts equally.

2. (a) usually learn or remember only those things specifically studied
   (b) good memory for details and facts in the environment not specifically studied
   (c) have noticed no difference in my abilities in these areas.

3. (a) like to read fantasy stories
   (b) like to read realistic stories
   (c) no preference between fantasy and realistic stories.

4. (a) equally as much fun to dream as to plan realistically
   (b) more fun to dream
   (c) more fun to plan realistically.

5. (a) solve problems logically, rationally
   (b) solve problems intuitively
   (c) equally skilled in solving problems intuitively and logically.

6. (a) listen to music or radio while reading or studying
   (b) must have total quiet in order to read or study
   (c) listen to music or radio only if reading for enjoyment, not if studying.

7. (a) would like to write fiction books
   (b) would like to write non-fiction books
   (c) No preference between writing fiction and non-fiction.

8. (a) if seeking mental health counseling, would prefer group counseling and sharing of feelings with others
   (b) if seeking mental health counseling, would prefer the confidentiality of individual counseling
   (c) have no preference for group over individual counseling.

9. (a) enjoy drawing my own images and ideas
   (b) enjoy copying and filling in details
   (c) enjoy drawing my own images and copying and filling in equally.

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10. (a) believe I would be easily hypnotized
(b) could probably be hypnotized but it would be difficult
(c) do not believe I could be hypnotized.

11. (a) just as exciting to me to improve something as to invent something new
(b) more exciting to improve something
(c) more exciting to invent something new

12. (a) prefer to learn through free exploration
(b) prefer to learn systematically through ordering and planning
(c) no preference between learning through free exploration and learning through more systematic ways.

13. (a) no preference between mystery stories and action stories
(b) prefer action stories
(c) prefer mystery stories.

14. (a) no preference between algebra and geometry
(b) prefer algebra
(c) prefer geometry.

15. (a) like to organize things sequentially
(b) like to organize things to show relationships
(c) no preference for sequential over relational organization.

16. (a) skilled in sequencing ideas
(b) skilled in showing relationships among ideas
(c) equally skilled in sequencing and showing relationships

17. (a) good at remembering verbal materials
(b) good at tonal memory
(c) equally good at verbal and tonal memory.

18. (a) paces personal activity to time limits with ease
(b) uses time to organize self and personal activities
(c) has difficulty in pacing personal activities to time limits.

19. (a) have frequent mood changes
(b) have few mood changes
(c) stable; almost no mood changes.

20. (a) skilled in communicating with animals
(b) moderately good in communicating with animals
(c) cannot communicate very well with animals

21. (a) no preference for cats over dogs or vice versa
(b) preference for cats
(c) preference for dogs.

22. (a) enjoy clowning around
(b) can clown or be serious depending upon the occasion
(c) do not enjoy clowning around.

23. (a) conforming or nonconforming depending upon the situation
(b) generally conforming
(c) generally nonconforming.

24. (a) frequently somewhat absentminded
(b) occasionally absentminded
(c) almost never absentminded.

25. (a) no preference for well structured over openended assignments
(b) preference for openended assignments
(c) preference for well structured assignments.

26. (a) when viewing advertisements, am most often influenced by attractive signs, pleasant scenes, and sensual overtones
(b) when viewing advertisements, am most often influenced by the information comparing several products and demonstrating which works the best
(c) primarily influenced by the advertising medium only when accompanied by information on the quality of the product.

27. (a) enjoy analyzing stories
(b) enjoy creative storytelling
(c) enjoy equally analyzing stories and creative storytelling.

28. (a) equally valuable to discuss stories and illustrate them
(b) more valuable to discuss stories read
(c) more valuable to illustrate stories read.

29. (a) equally valuable to tell stories and to act out stories
(b) more valuable to tell stories
(c) more valuable to act out stories.

30. (a) moving rhythmically and rhyming are equally enjoyable
(b) moving rhythmically is more fun
(c) rhyming is more fun.

31. (a) producing ideas and drawing conclusions are equally enjoyable
(b) drawing conclusions is more fun
(c) producing ideas is more fun.

32. (a) would like to do impromptu interpretative dancing
(b) would like to do ballet dancing
(c) no preference for ballet over impromptu interpretative dancing.

33. (a) enjoy interacting affectively with others
(b) enjoy interpreting the affective interaction of others
(c) equal preference for affective interaction and interpretation of the affective interaction of others.

34. (a) strong in recalling verbal materials (names, dates, etc.)
(b) strong in recalling spatial imagery
(c) equally strong in recalling verbal and spatial imagery.

35. (a) can think better while lying down
(b) can think better while sitting up straight
(c) equal preference for thinking while lying down or sitting up straight.

36. (a) would like to be a music critic
(b) would like to be a music composer
(c) would enjoy equally music criticism and composition.

37. (a) skilled in the intuitive prediction of outcomes
(b) skilled in the statistical, scientific prediction of outcomes
(c) Equally skilled in intuitive and statistical-scientific prediction.

38. (a) generally attentive to verbal explanations
(b) generally restless during verbal explanations
(c) can control attention during verbal explanations.

39. (a) no preference between outlining and summarizing readings
(b) preference for outlining over summarizing
(c) preference for summarizing over outlining.

40. (a) no preference for demonstration over verbal instructions
(b) prefer demonstration
(c) prefer verbal instructions.

BIOGRAPHICAL INFORMATION

1.NAME (OPTIONAL): ____________________ TELEPHONE (OPTIONAL): __________

2.SEX: __________

3.AGE: __________

4.RACE: __________

5.OCCUPATION: ______________

6.EDUCATION: HIGHEST DEGREE ATTAINED ______________

7. MAJOR AREA OF STUDY ______________

8.Which hand do you use for writing? Right ______ Left ______

9.Do you ever write with your other hand? Yes ____ No ______

10.Do you consider yourself ambidextrous? Yes ____ No ______

11.What activities do you perform with your non-writing hand? ____________________

____

____

____

____

12.Was your handedness ever changed by a parent, teacher, or because of an injury, etc.?
Yes, from left to right _____
Yes, from right to left _____
No _____

13.If your handedness was changed, what was your age at the time? Age ______

14.Do any of your blood relatives consider themselves ambidextrous? Yes ______ No ______ Don't Know _____

15. Number of ambidextrous relatives _____

16. Relation to you ______

______

______

17.Is your child's other parent left handed? Yes ______ No ______

18.Does your child's other parent have any left handed relatives? Yes ______ No ______ Don't Know _____

19. Number of left handed relatives _____

20. Relation to your child ______

______

______

EDINBURGH HANDEDNESS INVENTORY

Please indicate your preferences in the use of hands in the following activities *by putting + in the appropriate column*. Where the preference is so strong that you would never try to use the other hand unless absolutely forced to, *put* ++. If in any case you are really indifferent *put + in both columns*.

Some of the activities require both hands. In these cases the part of the task, or object, for which hand preference is wanted is indicated in brackets.

Please try to answer all the questions, and only leave a blank if you have no experience at all of the object or task.

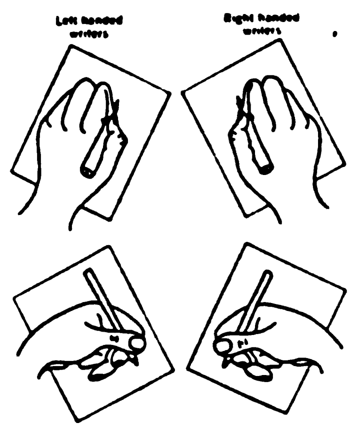
		LEFT	RIGHT
1	Writing		
2	Drawing		
3	Throwing		
4	Scissors		
5	Toothbrush		
6	Knife (without fork)		
7	Spoon		
8	Broom (upper hand)		
9	Striking Match (match)		
10	Opening box (lid)		
i	Which foot do you prefer to kick with?		
ii	Which eye do you use when using only one?		

L.Q.		Leave these spaces blank	DECILE	

WRITING POSITION ASSESSMENT

DIRECTIONS: Four common ways of holding a pen while writing are shown below. Please find the writing position you use and check the appropriate blank alongside the picture.

(A) ____ (C) ____



(B) ____ (D) ____

If your hand position does not at all resemble any of the four shown, please answer the questions below and describe in words or a drawing what your hand position does look like.

1. Does the tip of your pen point to the TOP ____
   BOTTOM ____
   LEFT SIDE ____
   RIGHT SIDE ____
   CORNER ____ of the page?
   (if corner, which one?)

2. Is your hand ABOVE ____
   BELOW ____
   EVEN WITH ____ your line of writing?

HANDEDNESS IN YOUR FAMILY

DIRECTIONS: Please check the space showing the hand used for writing (left, right, or unknown) by your blood relatives shown below, and indicate the number of blood relatives in each group. For example, if your mother had two brothers, and both were left handed, mark 2 in the "number" column and 2 next to "left" in the "handedness" column.

RELATIVE	NUMBER	HANDEDNESS	RELATIVE	NUMBER	HANDEDNESS
Your mother's father	1	Left___ Right___ Unknown___	Your father's father	1	Left___ Right___ Unknown___
Your mother's mother	1	Left___ Right___ Unknown___	Your father's mother	1	Left___ Right___ Unknown___
Your mother	1	Left___ Right___ Unknown___	Your father	1	Left___ Right___ Unknown___
Your mother's brothers	___	Left___ Right___ Unknown___	Your father's brothers	___	Left___ Right___ Unknown___
Your mother's sisters	___	Left___ Right___ Unknown___	Your father's sisters	___	Left___ Right___ Unknown___
Your sisters	___	Left___ Right___ Unknown___	Your brothers	___	Left___ Right___ Unknown___
Your daughters	___	Left___ Right___ Unknown___	Your sons	___	Left___ Right___ Unknown___
Your daughters' sons	___	Left___ Right___ Unknown___	Your sons' sons	___	Left___ Right___ Unknown___
Your daughters' daughters	___	Left___ Right___ Unknown___	Your sons' daughters	___	Left___ Right___ Unknown___

HCP PROFILE II

This is an experimental test of thinking styles. It will take about three minutes of your time. Please circle the ONE number for the answer that best fits you.

1. In grade and high school, were you best in: math, 1. Or art, 2. Or both, 3.
2. In grade and high school, were you best in: languages, 1. Or crafts, 2. Or both, 3.
3. Do you tend to get at solutions to problems by: analyzing them step by step, 1. Or by getting a "feel" for the solution all of a sudden, as a whole, 2. Or both, 3.
4. In regard to your work or personal life, do you follow hunches only if they are supported by logic? Yes, 1. No, 2. Both, 3.
5. In regard to your work or personal life, do you follow hunches if they may not seem logical but have the right "feel"? No, 1. Yes, 2. Both, 3.
6. When you work on projects, do you most want them to be: well planned, 1. Or designed to contribute something new, 2. Or both, 3.
7. In dealing with problems, which gives you the most satisfaction: solving it by thinking it through, 1. Or tieing fascinating ideas together, 2. Or both, 3.