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Anne McShane
Utah State University

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A STUDY OF THE RELATIONSHIPS BETWEEN HEMISPHERIC ASYMMETRIES AND INTELLECTUAL ABILITIES

by

Anne McShane

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Anne McShane

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ABSTRACT

A Study of the Relationships Between Hemispheric Asymmetries and Intellectual Abilities

by

Anne McShane, Master of Science

Utah State University, 1987

Major Profesor: Dr. Michael Bertoch
Department: Psychology

This study investigated the functional significance of cerebral asymmetries. Width measurements of the human brain were derived from computerized tomographic (CT) films and related to intellectual variables as determined by the Wechsler Adult Intelligence Scale Revised (WAIS-R). Subjects were adults of both sexes who had been referred for neurologic examination and were diagnosed as having no abnormalities (N=28). Reasons for referral included headache, dizziness, or to rule out central nervous system damage following various types of trauma. The asymmetry of hemispheric widths (left minus right) in the frontal, temporoparietal, and occipital areas was correlated with Verbal IQ minus Performance IQ scores within subjects. The difference between verbal and performance IQ scores was used because it reflected an IQ imbalance (IQ-I). Correlations obtained were -.30,-.26, and .06 (respectively). None of these correlations were significant by means of a two-tailed test. There were relationships between particular width asymmetries and individual subtest scores ($p \leq .05$). The Verbal 1 (V1) subtest (Information) was correlated -.50, -.39 and -.47 with brain width asymmetries at 25%, 33% and 50% of the AP distance respectively. V1 correlated .39 with width asymmetry at 80%. Verbal 3 (Vocabulary) , verbal 4 (Arithmetic) and verbal 5 (Comprehension) correlated .53 .38, and .39 with width asymmetry at 60% of the AP distance. Performance 1 (Picture Completion) correlated .46 with the width asymmetry at 20% of the AP length. In summary, there does appear to be some specific correlation between individual variation in brain asymmetry and cognitive processing. Relative size of the area of the brain that is involved in a key aspect of a particular cognitive processing may be a factor in the effectiveness of that processing. Further research appears warranted to confirm and clarify a possible relation between anatomical asymmetry and patterns of intellectual ability.

(66 pages)

CHAPTER 1

INTRODUCTION

For many years attempts have been made to associate *gross* morphological shape and size of the human brain with *overall* cognitive functional and intellectual abilities (Galaburda, LeMay, Kemper, & Geschwind, 1978). These attempts have been unsuccessful. Therefore, researchers in the neurosciences have concluded that gross brain anatomy is not correlated with global measures of mental function and intelligence (Harcum, Filion & Filion, 1968; Inglis, 1968; Van Valen, 1974). Although gross anatomy appears not to be associated with measures of mental function it may be the case that asymmetries can be shown to relate to function. That is to say that one side of the brain is larger or smaller than the other side and that fact might relate to a specific function.

Prior to investigating the possibility of a relationship between morphological asymmetries and lateralization of function, a pattern of neuroanatomical asymmetries must be demonstrated (Geschwind & Galaburda, 1985). Refined morphological studies of the human brain have concentrated on studying brain asymmetries rather than gross morphological shape (Chui & Damasio, 1980; Geschwind & Galaburda, 1985; Wada, Clarke & Hamm, 1975). Asymmetries represent differences between the left and right hemispheres and perhaps could account for additional variation in terms of function among individuals. Geschwind and Levitsky (1968) found that the planum temporale was larger in the left hemisphere with respect to the right in 65% of their sample of 100 post mortem brains. Another example of documented human brain asymmetries was found by Lemay and Kido (1978). Through the use of computed tomography, they discovered the left parietal region to be larger than the right in right handers. Lemay and Kido's 1978 study of asymmetrical variation is a refined approach breaking down brain morphology into the smaller components of frontal, occipital and parietal areas. One can conclude specific neuroanatomical asymmetries probably exist.

Specific cognitive processes have been found to be mediated by specific areas of the brain. Recent studies of language function, for example, have demonstrated that language, one important mental function, is located or "lateralized" to one side of the brain (Geschwind & Levitsky, 1968; Witelson & Pallie, 1973). From findings such as lateralization of language, a major theory has evolved which attempts to systematically relate structural asymmetry to certain functional variables, including handedness, dyslexia, and the immune system (Geschwind & Galaburda, l985). For example, sinistrals (left handers), who are less lateralized than dextrals (right handers), have more allergies than dextrals. The mechanisms underlying the relationship are as yet unclear.

Problem Statement

Up to this point, there has been little research which related structural asymmetry with higher order cognitive processing. Existing data, what there is of it, supports the concept that anatomical features of brain structure are not correlated with functional measures of intelligence. This may represent an impediment to an increased understanding of constructs such as "intelligence" and "cognition". Accounting for variance in operationally defined measures of intelligence such as the Wechsler Intelligence Scale for Adults-Revised may depend on a better understanding of brain structure-function relationships. Geschwind and Galaburda's (1985) theory attempting to relate asymmetry to handedness and dyslexia suggests that several functional measures may in fact have structural correlates. Perhaps the *structural* components of the brain may be related to *functional* components of brain operation.

Yeo,Turkheimer, Raz, and Bigler (in press) found a correlation of .57 between the asymmetry of hemispheric volumes and Verbal Intelligence Quotient minus Performence Intelligence Quotient on the WAIS in a sample of 41 subjects. Their rationale for using the

VIQ-PIQ difference measurement was that certain cognitive abilities are known to be lateralized to a particular hemisphere. The WAIS-R is standardized so that averaged across individuals VIQ equals PIQ. For individuals in which scores are not equal, one could say there existed an IQ imbalance. Such a functional discrepancy could be associated with congruent structural differences between hemispheres.

In the past, attempts at finding intellectual correlates of human brain structure have been handicapped by inadequate techniques for determining accurate quantitative measures of the intact, living, human brain. With the advent of computer tomography(CT) and other sophisticated technology such as nuclear magnetic resonance this is no longer the case. The problem this study will address is that there has been inadequate research, in terms of amount and design, on brain asymmetry and IQ imbalance.

Purpose

Rather than examine a single general measure of cognitive functioning, it perhaps a more effective approach might be to explore patterns of intellectual abilities, for example a consideration of individual factors which together constitute global intellectual ability. The approach this study will take is to examine differences between individuals on a variety of cognitive tasks and compare such differences with relative hemispheric width differences (asymmetries) at various cross sections of the human brain. The WAIS-R has eleven subtests which require different cognitive processing skills (Matarazzo, 1972). Studies suggest that many human brains may have a larger left occipital area and at the same time have a larger right frontal lobe (Bear,Schiff, Saver, Greenberg, & Freeman, 1986, & Kertesz, Black, Polk, & Howell,1986). This project will consider neuroanatomical asymmetries as measured on CT scans to be the independent variable. Verbal intelligence minus performance intelligence as measured on the WAIS-R will be the dependent variable together with selected individual subtest scores. It is proposed that such an examination will increase our understanding of the relationship between structure and function in the human brain. Practical application of such knowledge would include prediction of recovery in stroke patients and the implementation of more effective, individualized instructional methods for both a normal and a neurologically impaired population.

Objectives

A specific objective of this study was to determine whether hemispheric width asymmetries of the human brain are correlated with subtest scores on the WAIS-R or with the individual's Verbal IQ score minus their Performance IQ score.

This objective was selected because: 1) there are individual differences in human brains (Bryden,1982); 2) behavior is ultimately dependent on the organization (anatomical components and how they fit together) and action of the brain (Bryden,1982); 3) it would be informative to determine patterns between individual differences on a widely used and accepted measure of cognitive function (WAIS-R)and a specific measure of relative left-right asymmetry. Asymmetry Quotient (AQ)(Yeo, Turkheimer, Raz, & Bigler, in press).

Justification

Recently, Geschwind and Galaburda (1985) proposed a theory attempting to relate neuroanatomical asymmetry to functional lateralization. Specifically, the area known as the planum temporale is larger on the left side than on the right for most people. In a sample size of 100, it was significantly larger in 65% of the sample, whereas the right side was larger in 11%; approximately 24% of the sample exhibited near symmetry of the planum temporale (Geschwind & Levitsky,1968). Prior work with aphasics, having specific areas of cortical damage, led Geschwind to argue that the most parsimonious hypothesis is that in most cases bilateral representation of speech is present. Bilateral representation of speech varies over the population, however, ranging from almost complete left dominance to approaching equal representation, to rare cases of superior right sided control of language (Geschwind & Galaburda,1985). Lateralization of speech could possibly correlate with the relative left-right asymmetries found in the planum temporale. The direction, magnitude, and consistency of hemispheric asymmetries do support the theory that they are involved as neurological substrates for language (Geschwind & Galaburda, 1985).

Most recent studies of localization of function have concentrated on verbal dimensions and have concluded that at least 95% of the population has a definite left hemisphere advantage for speech and language (Restian,1983). This has led to the development of a verbal-nonverbal dichotomy proposed to simplistically explain specializations of the left vs. right hemispheres (Bradshaw & Nettlton,1983). However, complexity arose in reference to defining nonverbal and visio-spatial tasks (Bradshaw & Nettleton, 1983). These investigators amplified the verbal-nonverbal classification by suggesting that the left hemisphere has an advantage for speech, language, and tasks requiring sequential processing. The right hemisphere appears to play a larger part in the integration of information over space and time, or tasks requiring a holistic or gestalt approach.

The present study extends the recent correlational findings between asymmetry of the planum temporale and location of the language centers by including a neuroanatomical substrate for different patterns of abilities, and/or varying methods and strategies of cognitive functioning. For example, do individuals with high verbal ability have a wider hemisphere on the side that processes verbal materials in the majority of the population? Perhaps the various asymmetries indicate a relatively greater efficiency of one hemisphere for a particular method of cognitive processing as compared to another. Although a larger area does not necessarily mean that it is more important for a specific function, there are precedents in neural organization to suggest that size of cortical representation of function is positively correlated with degree of function (Witelson,1977).

Intelligence testing theory has traditionally favored the existence of two clusters of abilities; verbal and performance (Matarazzo,1972). The latter consist of pattern and space perception, shape , geometry, and form. This study was designed to detect a relationship between relative performance on these two groups of abilities and relative left-right asymmetries, thus extending the findings of other researchers and adding to the theoretical framework.

Definitions

Throughout the thesis, various terms are used in a specific way. To aid the reader some terms are defined.

Asymmetry. This term refers to brain structure. specifically, to the case where one side of the human brain is larger in terms of length-width dimensions than the corresponding opposite side. If a sagittal plane were to divide the brain into left and right halves asymmetry would be indicated by a difference in size between specific regions of the two sides of the brain. See Diagram 1.

Frontal Areas. This term refers to the first 25% of the brain directly behind the forehead. It includes the area of the brain from 0% through 25% of an anterior-posterior (AP) line running from the front to the back of the brain. The frontal horns of the lateral ventricles are within the frontal lobes. These horns are visible in the CT projections used in this study.

Lateralization of Function. This term refers to function, specifically a function that one hemisphere does more efficiently or better than the other. For example, most cognitions involved in reading require the left hemisphere. Dyslexia more often accompanies lesions in the speech areas of the left hemisphere than when lesions are present in corresponding areas on the right.

Occipital Areas. The occipital lobes are defined as that area of the brain lying posterior to a line drawn between the preoccipital notch and the parietal-occipital sulcus. On the CT scans used in this study, the calcified glomi of the choroid plexus are visible posterior to such a line. The occipital region is represented by a combination of the measurements taken 75%, 80% and 90% along the AP line of the brain.

Temporoparietal Areas. This area accounts for approximately the middle third of the transverse brain slice visible on the CT scan. It lies above the zygomatic arch and includes Broca's and most of Wernicke's areas. On the scans used in this study the temporoparietal areas include the measurements taken at 40%, 50%, and 60% of the brain's AP line.

CHAPTER II
REVIEW OF LITERATURE

Neuroanatomical Asymmetry

Awareness that functional differences exist between the two halves of the brain has intrigued researchers and lay persons alike. Recently , researchers have investigated anatomical asymmetries as possible substrates for the easier to observe functional asymmetries. However, the possibility also exists that lateralization of function is not accompanied by any significant anatomical differences. Asymmetry would explain functional differences in a parsimonious manner, even if the asymmetry consisted solely of varied patterns of neural connections. Geschwind and Levitsky (1968), in a sample of 100 post mortem brains, found that the planum temporale (see Figure 1)was larger on the left side in 65% of the cases, and larger on the right side in 11%. Witelson and Pallie (1973) found similar differences, and a summary of various studies with human brains by Witelson (1977) reported a mean of 69% having a larger left planum temporale. The degree of difference between left and right is also of a large magnitude, the area of the right side only averaging 60% of the area on the left and is on occasion up to ten times smaller (Wada et al.,1975). Rubens, Mahowald, and Hutton (1976) in a study involving 36 fixed brains attributed the asymmetry to a sharper angulation of the right lateral fissure resulting in a shorter right planum temporale. Rubens et al. (1976) speculated the right planum temporale might lie in a different and more vertical plane; this is supported by their finding of a larger right inferior parietal area posterior to the lateral fissure. Witelson and Pallie (1973) demonstrated the asymmetry of the planum in fetal and neonate brains, also suggesting that the anatomical asymmetry observed in adults precedes, or at least is not a result of, a functional asymmetry.

The examination of post mortem brains has disadvantages. Often, during the fixation process some shrinkage of brain tissue will occur (Galaburda et al.,1978). As Witelson (1977) suggests, it is often difficult to define the neural area of interest, and measurements may depend to a degree on the subjective decision of the examiner.

The development of the CT scanner allows for the examination of a cross section of a human brain in vivo. Chui and Damasio (1980) assessed the presence or absence of petalia and the degree of cerebral asymmetry of tomograms in a sample of 75 patients. A petalia is defined as a "more marked indentation in the inner table of the skull on one side that results from the greater protrusion of adjacent cerebral lobe on that side than on the other" (Geschwind & Galaburda, 1985, p.437). Chui and Damasio found left occipital petalia more common than right occipital petalia, right frontal petalia more common than left (although frontal petalia were uncommon) and no significant difference in the asymmetries present in right handers as compared to sinistrals.

It is possible that CT imaging can be used as a more accurate index of lateralization of language than can handedness. The Wada test can accurately determine dominance of the cerbral hemispheres for language, but is more expensive and considerably more risk is involved than in CT imaging. The findings of Chui and Damasio support LeMay (1976)who showed the anteroparietal and the posterooccipital areas are more often larger on the left, and the right frontal and central hemisphere are generally wider than the corresponding area on the left. The brain is sometimes characterized as having a "counterclockwise torque" (Galaburda et al., 1978).

Witelson (1977) found some evidence for the fact that the typical "torque" or asymmetry might be reduced or reversed in a group of non-right handers. Similarly, Ratcliffe, Dila, Taylor, and Milner (1980) studied carotid angiograms of 59 patients for whom the lateralization of speech representation was known because of previous sodium amytal (Wada et al.,1975) studies. They found that the middle cerebral artery as it passes through the Sylvian fissure had a significantly different angulation for those patients who were left hemisphere dominant for language than for those who were right hemisphere dominant.Their subjects consisted primarily of sinistrals because only left handers are routinely tested with Amytal.

Deuel and Moran (1980) failed to find a statistical relationship between handedness and cerebral asymmetry in a sample of 94 subjects between the ages of 7-17. The only criteria they used for assessing asymmetry patterns was presence or absence of petalia; width differences were not taken into account. It becomes apparent on examining the literature that cerebral asymmetry indices of functional lateralization are inconsistent, differences are often small, and they are continuously distributed rather than dichotomously present or absent. While handedness has been used as a marker for language lateralization, CT imaging of the brain may represent a more accurate indicator of functional lateralization, and may possibly provide support for a neural substrate of language as well as other abilities if appropriate correlations are found.

Other documented asymmetries include the pyramidal fibers, the medulla and the arrangement of neurons in various structures (Witelson, 1977). The latter could include both cell size and density. Geschwind, citing Galaburda (1984), indicates that the lateralis posterior nucleus is larger on the left than on the right in over 80% of human brains. The left hemisphere also has more fissures than the right, a fact that would presume more cortical surface area(Connolly, cited in Gur et al., 1980).

Gur et al. (1980) in a sample of 36 right handed males, determined that the left hemisphere has a statistically significant higher percentage of grey matter to white matter than does the right hemisphere. The procedure they used was a noninvasive method for measuring cerebral blood flow based on varying rates of isotopic clearance. Gur did not examine regional differences such as the frontal, temporoparietal, or occipital areas. Grey matter is composd primarily of nonmyelinated fibers and nerve cells whereas myelinated fibers are the primary constituents of white matter. Such results might suggest that the left hemisphere would subsume those functions involving the processing and transfer of information within regions such as those involving verbal-analytic tasks. Analogously, the right hemisphere is perhaps functionally better able to transfer information across regions, an operation that would conceivably be paramount for spatial-gestalt functions (Gur et al.,1980).

In summary, gross morphological asymmetries do exist in the human brain. CT imaging facilitates the measurement of discrete anatomical areas of the in vivo brain thus avoiding the problems with dead material. The left occipital lobe is generally found to be larger than the right occipital lobe. Less conclusive evidence suggests the right frontal area is larger than the corresponding region on the left. A neurological example of size correlating with degree of function would be the fact that the sensory and motor representation areas for hands in the human brain are larger than the area for the rest of the body (Witelson, 1977).

Functional Lateralization

There are many examples of functional lateralization in both humans and nonhumans. The intent here is to examine previous research that is most directly related to cognitive abilities and methods of brain processing.

Andreassi, Rebert, and Larsen, (1983), found using reaction times that the left hemisphere responded more quickly to a visually presented "T" and the right hemisphere was faster when responding to the inverted T, an apparent nonverbal stimulus. They only had a sample size of 12 right handed males. However their findings do support research that verbal material is perceived more efficiently when presented directly to the left hemisphere (Bryden, 1966). Hugdahl and Carlgren (1981), measuring conjugate lateral eye-movements, found a greater frequency of eye movement to the right for questions that were verbal and non emotional in nature, and eye movements to the left for tasks requiring spatial or emotional responses.

In a study involving patients with varying degrees of commissurotomy, Bogen and Gazzaniga (1965) presented evidence that the left hemisphere was impaired in tasks requiring "visuoconstructive" processes and the right hemisphere was incapable of responding accurately to language. Gazzaniga (1977) later revised his view that the right hemisphere was not able to process language; but concluded that in most people the left hemisphere does it better.

Borod, Carper, Naeser, and Goodglass (1985) examined the performance of a group of patients with known unilateral left hemisphere lesions on the WAIS Performance Scale and found that left handers showed a poorer performance than right handers on nonverbal tasks involving visio-spatial organization. Such findings suggest that left handed aphasics, have more left hemisphere representation for processes that are more lateralized to the right hemisphere for right handed aphasics.

Witelson's (1977) review of the literature relating asymmetry of the temporal lobes to functional lateralization, support her theory that dyslexics have difficulty reading because they have bi-hemisphere representation for spatial and wholistic functions rather than right hemisphere dominance characteristic typical of normal individuals. The neural processing of spatial functions in the left hemisphere interferes with the verbal, linguistic functioning that is usually lateralized to that area, and linguistic, sequential processing is thereby deficient, resulting in a dyslexic's use of spatial-holistic strategies and impaired reading performance

(Geshwind & Galaburda, 1984).

Most researchers now conclude that females are less lateralized than males (Cohen & Levy, 1986; Levy,1974). Levy (1974) argues that females have more bilateral representation of language than do males. Zoccolotti and Oltman (1976) found that individuals who were less lateralized in terms of cognitive functioning (women and non right handers) were more "field dependent" whereas groups that were more lateralized were more "field independent". Conversely, individuals that were relatively more field independent were more lateralized to the left hemisphere for verbal abilities and more lateralized to the right hemisphere for processing spatial tasks.

Conflicting results have been reported on whether or not gender differences exist on WAIS score patterns following unilateral cerebral lesions. McGlone (1978), for example, found that females had a Verbal IQ minus Performance IQ (VIQ-PIQ) difference that was only half of that found in male subjects and that there was a significant sex-by-lesion interaction for the VIQ but not for PIQ. Herring and Reitan (1984) performed a similar study but obtained different results. Their results indicated a similar pattern of impairment for both males and females following unilateral cerebral damage, however the magnitude of the lateralization effect was less for females than for males. Some of the disparity in results may be accounted for by the fact that Herring and Reitan controlled for more of the relevant but extraneous variables such as type of lesion than did McGlone. One can conclude that the magnitude and perhaps also the pattern of VIQ-PIQ difference is different for males and females following unilateral lesions.

To summarize, implications for the present study include the fact that differences in cognitive patterns and structural asymmetries are likely to be of small magnitude, continuously distributed, sex related and not universal.

CHAPTER III

PROCEDURE AND METHODOLOGY

Hypothesis

In an adult caucasian sample,free from major debilitating neurological abnormalities, there is no correlation between Verbal IQ minus Performance IQ and regional hemispheric asymmetry. The regions under consideration will include the frontal areas, the temporoparital areas, and the occipital regions.

Sample Population and Selection

Subjects were selected by the experimenter from both inpatients and outpatients having, or having had, computerized tomograms taken at Logan Regional Hospital. Subjects were selected from all possible individuals who had CT scans within 18 months of this study and met the following criteria: (a) their CT scans were judged to be normal by a certified CT technician, (b) no schizophrenic or major affective disorder had ever been diagnosed according to self report, (c) the subjects were volunteers, signed a consent agreeing to participate in the study and were willing to take the WAIS-R, (d) they were adults ranging in age from 18 to 76. The subject pool is not a representative sample of the general population nor of the LRH population. Selection was not random but included all subjects who met these criteria.

A consent form with cover letter was sent to each prospective subject informing them of the study and allowing them to refuse to participate and indicating whether or not they would be willing to participate in a test of cognitive functioning an example of the letter and consent form are in Appendix A. Subjectswere given the opportunity to have their WAIS-R scores interpreted to them. The identity of the subjects was protected by keeping all identifying material in locked file cabinets. Only those people directly involved in the data collection had knowledge of the individual's identity. Confidentiality was accorded highest priority.

Logan Regional Hospital primarily serves three counties in northern Utah. The population of these counties is 96 per cent caucasian according to a 1980 census with the remaining 4 per cent consisting of Blacks, Hispanics, and other minorities. The sample selected for this study was not assumed to be representative of the population. Attempts were made to include a wide range of ages and an approximately equal number of male and female subjects. The final sample consisted of 28 caucasian adults with a mean age at CT of 44.4 (s.d. 16.4) and a mean age at IQ testing of 46.0 (s.d. 16.2). The final sample included 20 females and 8 males. Three of the subjects were left handed. Many studies cited in the review of literature involved samples of individuals clearly suffering pathologies such as dyslexia, Alzheimers, or schizophrenia (Raz, Raz, Turkheimer, Bigler& Collum in press). The present study however, attempted to include a more "normal" population by specifically excluding overt pathologies. Threats to generalizability (external validity) in the present study include dangers inherent any time a sample consists of volunteers. In addition, while attempting to exclude abnormal CT scans, those with neoplasms, central venous accidents, or surgical interventions, it was the case that the subjects had presented themselves to their physicians with some complaint thereby differentiating them from the general population. CT scans of the brain are diagnostically used to rule out pathologies, such as subdural hematomas, and therefore many scans are in fact normal. Examples of physical symptoms of patients used in this study included headaches and/or dizziness. Patients found to have neurologically abnormal scans including neoplasms, gliomas, or central venous accidents, were excluded.

Measurement of Neuroanatomical Asymmetries

All CT scans were obtained under standard hospital practice using a Phillips scanner, a second generation model. The slice of brain viewed on the computed tomogram is an axial view with zero angulation. The frontal lobes are pictured anteriorly and the occipital lobes posteriorly in the section viewed. The frontal horn of the lateral ventricles and the pineal body are notable landmarks in this cross section. The scans are stored on computer floppy discs at the hospital. The hospital CT technician transfered the brain scans to hard copies and a research assistant from the University then transfered them to paper copies using the method outlined in Appendix B.

Width measurements were made at particular percentage distances of the anterior-posterior length of the brain for all subjects. Percentages refer to the percentages of the anterior-posterior length dividing the brain down the middle on a transverse plane. Seventy five % through 90% represents the occipital lobes, 60% through 33%, the temporoparietal region, and 25% through 10% percent, the frontal lobes.Such percentages correspond roughly to the neuroanatomic geographic features that define those regions. For purposes of selection in this study the widths taken at the 90, 80, and 75 percentage points were used to determine whether the left or right occipital lobe was larger. For the practical reason that an accurate and readily accessible method for obtaining area or volume was not available, the sum of the widths taken at the 90, 80, and75 percent for each of the left and right hemispheres was used as an indicator of size rather than a volume or area measure.

Measurements were taken by a trained research assistant who was blind to the age and sex of the patient. Data concerning the dependent variable, IQ test scores, were kept separate from any measures taken on the independent variable until all data had been collected and was ready for analysis.

An inter-rater reliability for measurement of the CT scans was computed by having a 15 scans traced and measured twice by different research assistants blind to the previous measurements. An interrater correlation for the various width measurements of .81 to .92 was obtained.

Measurement of Functional Abilities

The WAIS-R was administered individually by graduate students in psychology who were being instructed in the correct administration and scoring of this measure of cognitive abilities. Each student was closely supervised by an experienced faculty person during training but not during testing for this study. Each student was required to have administered a minimum of two WAIS-Rs under close supervision of the faculty instructor of the intelligence testing course before becoming involved in the study. They were instructed to follow a testing protocol which adhered to the standardization of the WAIS-R. The researcher talked with each test adminstrator and debriefed them in order to determine any possible extraneous sources of variability that might have effected the validity of the test. Examples of such factors might include hearing or vision difficulties, illness, unusual fatigue approaching the end of the testing period, or uncooperativeness. Reliability using split-half coefficients for the Verbal IQ on the WAIS-R range from .95-.97 and reliability for Performance IQ is .88-.94 (Anastasi,1982). The WAIS-R manual reports standard error of measurement for VIQ to be 2.50 to 3.30, depending on the age of subject, and 3.68-5.18 for PIQ. Matarazzo(1972) has reported evidence supporting content validity and concurrent criterion-related validity of the WAIS-R.

Analyses

Pearson product moment correlations were computed to determine the relationship between brain and behavioral measures since data was continuous for both variables. Asymmetry measures were expressed as the sum of all left occipital widths minus the sum of all right occipital widths for each subject. This is labeled as an Asymmetry Quotient, or AQ. Asymmetry measures were also individually determined for the frontal and temporal-parietal lobes in similar fashion. Behavioral measures are expressed as Verbal IQ minus Performance IQ within individuals, and referred to as an IQ imbalance (IQ-I).

In order to detect other possible relationships that might exist,a Pearson correlation was performed correlating every variable with every other variable. The independent variables involved were: sex, age at CT, age at IQ testing, length of brain (an AP measurement), width of brain at 60 percent (the widest diameter), difference measures- left minus right at each of the following percentage points, 90, 80, 75, 67, 60, 50, 40, 33, 20 and 10, the total difference score for the widths representing the occipital, the temporoparietal, and the frontal lobes respectively, and the length of any existing frontal or occipital petalia. The brain AP and the largest width were included as a means of determining variable changes that might be correlated with increasing overall brain size. Dependent variables consisted of each of the subtest scaled scores on the WAIS-R, the VIQ, PIQ, and fullscale IQ score, as well as VIQ minus PIQ (IQ imbalance).

The results are illustrated in tables summarizing the correlation between VIQ-PIQ and occipital asymmetry, temporoparietal asymmetry, and frontal asymmetry.

CHAPTER IV

RESULTS

There were no significant correlations obtained between IQ imbalance and regional structural asymmetries. The correlation obtained between the sum of the width differences in the frontal areas and VIQ minus PIQ was -.30. This is not statistically significant for a two-tailed test. However, there were several significant correlations between individual subtests and specific width differences.

The means and standard deviations for the IQ tests on the study sample are as follows:

Full Score IQ x=106.7 s.d.=13.8
Verbal IQ x=103.9 s.d.=11.3
Performance IQ x=109.2 s.d.=15.2

All tables referred to are found in Appendix C. Table 1 is a rank ordered list of all subjects ranging from those with the most negative VIQ-PIQ difference to the most positive. Individual asymmetry scores for the frontal, temporoparietal, and occipital areas are shown as are age, sex, and handedness. With a criterion established such that: frontal (F) ≤ -5, temporoparietal (T)≤ -3, and occipital (O) ≥ 3, then 6 out of the 8 subjects with positive VIQ-PIQ scores are accounted for. Subjects who do not have such a pattern, have negative VIQ-PIQ scores(19/21).

The asymmetry, as determined by sum of the widths, in the temporoparietal area correlated with VIQ-PIQ at -.26 as shown in Table 2. The correlation of the VIQ-PIQ difference and asymmetry in the frontal areas was -.30 (see Table 2). The correlation of VIQ-PIQ and frontal petalia was -.35 (p<.1). The correlation of VIQ-PIQ difference and occipital width differences was .06. Most variation in the IQ imbalance score appears to involve primarily the PIQ. None of the measures of gross brain size (brain AP or largest width) was significantly correlated with any of the intellectual variables.

When individual structural differences were correlated with WAIS-R subtest scores however, several significant correlations were obtained (See Table 3). PIQ correlated with width difference at 20% at r.=.34. As the left side gets bigger at 20% (frontal area) PIQ increases, and correspondingly VIQ-PIQ becomes more negative. The correlation of VIQ, PIQ, and FSIQ with asymmetry at 60% (width difference left minus right at 60% of the AP line) was .36, .34, and .34 (p<.1) respectively. As the left side of the brain gets larger in comparison to the right side at 60%, FSIQ increases (See Table 3).

When scores of subtests are considered and correlated with structural differences other correlations are evident. As the left occipital petalia increases and left occipital area widens, as shown in Table 4 , verbal 1 (V1-information) also increases. V1, correlated with width asymmetry at 20%, is -.50, and at 60% at .53 (p<.01). The subtests, verbal 3, verbal 4 ,and verbal 5 (V3, V4, & V5)are correlated with width asymmetry at 60% at .53, .38, and .39 respectively. V5 is correlated with width asymmetry at 20% at r=.41(See Tables 4 & 5).

As the relatively larger asymmetry to the left at 20% increases, the following subtests: performance 1, performance 2, and performance 3 (P1, P2, & P3) also increase r= .46, .33, and .34 respectively (p<.01). As the brain gets larger on the right side at 90%, P2 and P5 increase, r= .31. (See Tables 6 & 7).

CHAPTER V
SUMMARY, CONCLUSIONS, AND DISCUSSION

Summary

The results found in this study suggest that structural asymmetry (regional hemispheric width difference) may be moderately associated with cognitive processing abilities. Correlations were in the expected direction given the theory that the left hemisphere processes verbal information although they did not reach statistical significance. The variation of subtest scores within individuals suggest that the different subtests of the WAIS-R, particularly the Verbal subtests, may require different processing skills and are perhaps specialized in specific areas. The correlation between frontal asymmetry differences and IQ imbalance was less (and not significant) than the correlation Yeo,Turkheimer, Raz, and Bigler (in press) found between hemispheric volume asymmetry and VIQ-PIQ. The difference in the magnitude of the correlation may be attributed to the fact that they were using volumetric rather than width measurements, differences in the populations studied, or both.

Individuals that performed better on the Information, Vocabulary, and Comprehension subtests, had a wider left hemisphere than right at the 60% point. The performance subtests tended to be higher when the left frontal widths were larger than the right. Picture Arrangement subtest scores were higher when the left frontal lobe was wider than the right (r=.40). The Picture Arrangement and Digit Symbol subtests were higher when the right occipital width was also greater. Perhaps the right occipital and left frontal areas are largely involved in performance types of tasks. The Verbal subtests on the other hand, increased with increasing width in the left occipital and left temporoparietal areas and the right frontal and right anterior temporal regions. Most verbal subtests correlated positively with greater left width at 60%. This area is near the Sylvan fissure and approximates the speech and language processing areas (Pieniadz & Naeser,1984).

The highest correlations obtained were between individual subtest scores and width asymmetry at the 20%, 25%, 40%, and 60% distance of the AP line. They were in the .40-.50 range, and are of interest. The numerous interacting factors that go into a particular WAIS-R test score are very complex. Genetic makeup, education, career choice, and numerous other environmental factors would effect ability as well as motivation. Given this, a correlation of .4 may be considered relatively high.

In this study there were asymmetry patterns associated with directional VIQ-PIQ differences. When frontal widths were less than or equal to a -5, temperal widths were less than or equal to a -3, and occipital widths were greater than or equal to 3, then VIQ-PIQ was always positive (6/6) although that criteria missed two positives. When there was any other pattern than the above, VIQ-PIQ was found to be negative (See Table 1). If these findings were to be generalized, one might be able to predict an individual's relative ability on VIQ as compared to PIQ on the WAIS-R by knowing their pattern of asymmetries. As it is easier and less expensive to administer an IQ test than perform a CT scan, this is primarily of academic interest although it might be helpful in predicting an individual's potential for recovery following a CVA or in helping individualize a rehabilitation and reeducation program.

Conclusions

The major conclusion of this study is that anatomical asymmetry does appear to be related to patterns of intellectual ability. The asymmetries are however, much more regional than entire left hemisphere compared to entire right hemisphere. Most of the verbal skills measured in this study were correlated with increased asymmetry in the direction of left occipital and temporoparietal regions and greater right asymmetry in the frontal lobes. Performance subtests, which included cognitive tasks of a more holistic nature and required more simultaneous or gestalt types of processing, were correlated with increased asymmetry with the right increasing in the occipital regions and with the left increasing in the frontal lobes.

Discussion

What is the mechanism behind the asymmetry effect? Perhaps the asymmetries indicate the relatively greater efficiency that one hemisphere has as compared to the other at a particular width for a particular kind of cognitive processing. For example, at a distance 60% of the A-P line , the left side of the brain is more involved than is the right side in answering questions found on the Information, Vocabulary, and Comprehension subtests. In general, verbal processing occurs in the left hemisphere for most people. Cognitive tasks requiring spatial abilities and orientation more frequently are processed in the right hemisphere.

Evidence exists that rather than becoming lateralized during childhood, the neonate is hardwired so that specific methods of cognitive processing are located in one side of the brain only (Witelson & Pallie, 1973). This would seem to be a more efficient organization, avoiding the redundancy of bilateral representation.

One might speculate that the many cognitive processing tasks the human brain performs on a daily basis have unique neuroanatomical locations and that laterality of function is associated with hemispheric asymmetry at a particular cross section of the brain. Perhaps relatively high performance on a particular task can be correlated with larger asymmetry in "that task's locus in the brain".(See Figure 2) For example, scores on the Vocabulary subtest are correlated at r=.53 (p<.01) with an asymmetry pattern in which the left side is wider at 60% of the A-P line. Another example is the case where the left side is wider at 20% and right side is larger at 90% (r=.34 and -.31 respectively) that is associated with higher scores on the subtest Picture Arrangement.

This study observed some correlations between particular subtests of the WAIS-R and a relative cerebral asymmetry. This suggests that specific tasks may be localized in a particular region of the brain and the more asymmetry that exists in a particular direction the better that individual is likely to do on a specific type of task. In other words, it may be that the relatively larger (but not absolute size) the cortical representation of a function is, the better that individual is at performing that function.

Individuals who are less lateralized perhaps have to contend with competition and interference from the other hemisphere and therefore do relatively poorer. Results suggest that tasks requiring spatial processing may be more effected by the degree of lateralization than are tasks requiring verbal skills. This study was able to categorize the subjects into groups having positive or negative VIQ-PIQ difference scores by placing an arbitrary criteria on asymmetry measurements of the frontal, temporoparietal, and occipital regions. The pattern including frontal width asymmetries of less than a -5 , temporoparietal less than or equal to a -3, and occipital widths greater than or equal to +3 accounts for 75% of subjects with positive VIQ-PIQ difference scores and does not misclassify any subject. Any other pattern resulted in a negative VIQ-PIQ score 93% of the time. This pattern is one of left occipital lobe larger than the right. A pattern defined by the above criteria would coincide with the "normal torque" to the brain that Witelson (1977) and others have documented.

A possible reason that a wider left *occipital* region rather than the left *temporoparietal* area is associated with positive VIQ-PIQ difference scores may be that the larger left planum temporale extends down into the left occipital areas displacing them, and resulting in a larger occipital area than that present on the right side. Nineteen of the 28 subjects in this study had larger PIQ scores than VIQ scores. It may be that Performance IQ more accurately reflects inherent abilities whereas Verbal IQ is to a certain extent dependent on academic achievement.

The intent of this study was to look at a possible relation between structure and measures of functional abilities, not to determine if males and females had differing patterns of relationship between cerebral structure and function. However, there did not appear to be any distinctive differences between male and female subjects in this study. Table 1 demonstrates a fairly even distribution between the sexes on the variables of regional width asymmetry sums and corresponding VIQ-PIQ difference scores.

Limitations and Suggestion for Future Research

The major limitation of this study lies in the wide range of variables that are uncontrolled for in the sample. Age range was 18 to 76 with a mean of 44 years. Education and past employment history of the subjects varied considerably. The sample also varied on Full Scale IQ scores. While no gross neurologic abnormalities were present and WAIS-R scores were representative of the general population, the subjects did have more medical difficulties than average. The sample size of 28 is relatively small and precluded the further subdivision into groups based on age or sex that might have yielded meaningful results.

Another limitation to the study lies in the choice of the dependent measure. Although the WAIS-R has the advantage of wide usage in both ability testing and neuropsychological assessment, a different combination of measures of cognitive processing may have more conclusively established a relationship between cerebral asymmetries specific to higher order functions. For example, Aysto (1987) used the Das, Kirby, Jarman model of information processing and divided cognitive processing into verbal and spatial modes and again into successive and simultaneous processes. Results of her research suggest that verbal tasks are performed in the left hemisphere and spatial tasks primarily in the right hemisphere. She suggests however that successive processing of either verbal or spatial tasks occur in the frontal regions of the brain on the appropriate side and simultaneous processing occurs in the occipital regions. At the present time Aysto's theory relies on inferences and mental constructs. However if it were established empirically, then a selection of various measures that reflect each of the four types of processing (successive verbal, simultaneous verbal, successive spatial, and simultaneous spatial) would be more appropriate.

Future research could involve narrowing the range of subjects so that a more uniform sample was selected. Magnetic resonance imaging rather than CT imaging might also provide significant information. It would have the advantage that there would be no risk to the subjects, therefore allowing their selection from any desired population. CT imaging does involve slight risk to the patient because of the use of ionizing radiation. More factors need to be addressed before definitive conclusions regarding patterns of human brain asymmetry and styles of cognitive processing can be made.

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APPENDICES

Appendix A

Research Correspondence

___ I do not wish to participate in this study by supplying information in any of the ways described below.

___ I would be willing to fill out the attached quetionnaire, be interviewed over the telephone for about ten minutes, and take some brief tests which would involve an hour and a half and show whether I was better at doing "right-sided" tasks or "left-sided" tasks (for instance, remembering some words vs. doing a puzzle). (Please fill out form, mail back, indicate telephone number here:___-___.

___ I am interested in getting the results of the study based on my participation.

______________ ______________

signature date

Dear:

The Department of Psychology at Utah State University , in collaboration with the Department of Radiology at Logan Regional Hospital, is conducting a research study concerning the relationships between the left and right sides of the brain.

Many human brains show an interesting characteristic; they usually larger on one side or the other. Some scientists have thought that this interesting organization in the structure of the brain may be related to the fact that the brain tends to use more of its left side for certain purposes. Some people seem to be better at doing things which tend to rely on the left side of the brain, while other people may be somewhat better at doing certain things depending on the right side of the brain. The question is whether the brains of those individuals who function well on "right-sided" tasks aren't a little larger on the right side, and whether the brains of those who function well on "left-sided" tasks aren't a little larger on the left.

The Department of Psychology is interested in finding individuals who already have had CT scans taken of their head and who would be willing to participate in the study. Agreement to participate would depend on your interest and you would be able to withdraw at any time during the study. There would be no physical or mental risk anticipated from the procedures used in this study. Your participation in this study would be confidential and no information which would identify participants will be released or used in reporting the results of this study.

Respectfully,

Anne McShane, Research Investigator
Dr. Michael Bertoch, Supervisor

Appendix B

Procedure for Measurement of CT Tracings

1. An overhead projector will display the scan onto paper.The outer table of the brain and the outer table of the skull as well as the outline of the ventricles will be traced onto 1 mm lined graph paper. A 5cm line present on all the scans allows the size to be adjusted to normal before tracing.

2. The hard copies to be traced will be alternated by the research assistant so that every other one is traced in a reversed position. The research assistant will record on a separate data sheet the ID number of the scan and the position it was traced in.Other identifying information including age, sex, presenting problem will also be recorded on this second data sheet. The paper tracings will only have the ID number recorded on them. The assistant who measures the brain will then have no way of knowing which is the left or right hemisphere thus preventing that source of bias. The protocol for measuring the tracings is that used by McShane (1986):

Using a red, fine point pen:

1. Draw horizontal line to outer edge of tracing with midpoint touching outer table of skull at frontal region.
2. Draw horizontal line with midpoint touching table of outer hemisphere of frontal area of cortex across both hemispheres. Locate

outermost point on lower hemisphere and place a carrot ( ) on that point (on inside of cortex tracing).

3. Draw horizontal line to outer edge of tracing with midpoint touching outer table of skull at occipital region.

4. Draw horizontal line with midpoint touching table of outer hemisphere of occipital area of cortex across both hemispheres. Locate outer most point on inner hemisphere and place a carrot ( ) on that point (on inside of cortex tracing).

5. Draw vertical AP line dividing hemispheres (this line begins at the occipital pole, extending through the occipital fissure, pineal gland, between the ventricles, and through the frontal fissure to outer edge of skull). Align this line with the center of the occipital fissure and the center of the frontal fissure.

6. Draw a square around each ventricle at longest and widest points using AP line as one side of square. Draw square by turning paper to draw side line.

7. Turn paper sideways and measure AP line in from outer table of skull at frontal region to outer table of skull at occipital region. Place first position of ruler exactly in the center of the traced line of the skull, and measure to opposite end, similarly, to the nearest .55 mm, at the center of the traced line.

8. Determine % level distances from table.

9. Mark with a small line each % level on AP line beginning at frontal

region of skull with 90% level. Place ruler on line as explained above.

10. In cases where a single line will not accurately bisect both frontal and occipital fissures draw with blue ink a straight line running the length of the fissure until it intersects with the red AP line if possible or to the deepest point of the fissure if the two lines do not intersect.
11. Measure total horizontal width from cortex at each level in .5 mm increments and record on data sheet. Place first position of ruler on center of traced line and measure to center of opposite line.
12. Measure width of left hemisphere from cortex tracing to AP line or to blue line if present with ruler positioning as stated above, and record on data sheet.
13. Measure ventricles right length, left length, right width, left width from AP line (or edge of ventricle if AP does not divide the ventricles) and record on data sheet.
14. Measure difference between right and left hemispheres at frontal and occipital lobes by measuring distance between carrot and red line. Record difference in .5 mm increments on record form. Equal measurements should be recorded as '0' in the R=L column.
15. Staple recording with ID and exam numbers and measurer's initial on the back of each tracing sheet.

16. Check reversal form and label data correctly (1=front,2=reversed).
17. Transpose data to computer input form.
18. Check data on computer form against original data sheets.

Appendix C. Tables

Table 1. Rank Order of VIQ-PIQ Differences With Frontal, Temporoparietal, and Occipital Asymmetries.

F	TP	OC	VIQ-PIQ	SEX	AGE	HANDEDNESS
12	-5	-15	-24	F	48	L
3	-3	14	-23	F	26	R
-19	-2	13	-21	F	27	R
-2	1	36	-20	M	38	R
-9	0	31	-18	F	62	R
6	2	-7	-15	F	52	R
11	1	-21	-11	F	64	R
-12	1	17	-9	F	40	R
-16	-1	-4	-9	F	21	R
0	-1	12	-8	M	18	R
7	-1	1	-8	F	47	R
-25	4	13	-7	M	31	R
0	-12	-1	-6	F	68	R
-5	-8	-1	-6	F	44	R
-2	-5	6	-4	F	54	R
-2	-6	-4	-3	M	35	L
13	6	-8	-3	M	33	R
6	5	12	-3	F	42	R
1	-10	12	0	F	60	R
17	3	11	2	M	39	R
-21	-11	23	2	F	58	R
-16	-12	21	4	F	20	R
-13	-6	9	5	M	64	R
-5	-3	2	5	F	39	L
4	0	2	5	F	76	R
-5	-5	3	7	F	47	R
-18	-4	-4	9	F	65	R
-28	-14	43	10	M	67	R

F= Sum of frontal width differences
TP= Sum of temporoparietal width differences
Oc= Sum of occipital width differences

$(Oc \leq 1)$=negative VIQ-PIQ
$(2 \geq Tp \geq -3)$=negative
$(F \leq -5,\ Tp \leq -3,\ Oc \geq 3)$=positive

Table 2

Correlations Between Structural Difference Total Measurements and Functional IQ Scores

(N=28)

	FPET	FRDF	TPDF	OCDF	OCPET
VIQ	.15	.09	.12	-.04	-.11
PIQ	**.33**	.25	.30	-.10	-.25
FSIQ	.26	.20	.24	-.10	-.22
VIQ-PIQ	- **.35**	-.30	-.26	.06	.16

FPET= frontal petalia
FRDF= sum of frontal width asymmetries
TPDF= sum of temporoparietal width asymmetries
OCDF= sum of occipital width asymmetries

bold indicates $p \leq .10$

Table 3. Correlations Between Individual Structural Difference Measurements and Functional IQ Scores

Difference at:	VIQ	PIQ	FSIQ	VIQ-PIQ
10%	-.04	.01	.00	-.14
20%	.16	**.34**	.26	**-.34**
25%	-.11	.07	.00	-.16
33%	-.11	.06	.00	-.19
40%	-.20	.06	-.05	-.28
50%	.06	.15	.11	-.17
60%	**.36**	**.34**	**.34**	-.11
67%	.10	.00	.02	.15
75%	.16	.13	.13	-.03
80%	.16	.16	.15	-.10
90%	-.14	-.23	-.22	.12

bold indicates $p \leq .1$

Table 4. Correlations Between Structural Difference Total Scores and Functional Verbal IQ Subtest Scores

	FPET	FRDF	TPDF	OCDF	OCPET
V1	.13	-.01	-.17	.22	**.31**
V2	.05	.14	.00	-.22	-.20
V3	.22	.18	**.36**	.00	-.09
V4	-.06	-.06	.17	.11	.18
V5	**.32**	**.38**	**.36**	-.10	**-.33**
V6	.29	.23	.27	-.14	-.20

Table 5. Correlations Between Individual Structural Difference Measurements and Functional Verbal IQ Subtest Scores

	10%	20%	25%	33%	40%	50%	60%	67%	75%	80%
V1	.07	.17	**-.50**	**-.39**	**-.47**	-.17	**.32**	**.31**	**.32**	**.39**
V2	.07	.18	.19	.03	.09	.07	-.06	-.22	-.04	-.03
V3	-.04	.18	-.05	-.07	-.05	.24	**.53**	.16	.08	.14
V4	-.20	.17	-.01	-.02	-.08	.05	**.38**	.26	.25	.18
V5	-.04	**.41**	.11	.08	.12	.23	**.39**	-.02	.04	.06
V6	.19	.28	.01	.01	-.09	.16	.25	-.04	-.07	-.07

bold indicates $p \leq .1$
underline indicates $p \leq .05$

Table 6. Correlations Between Structural Difference Total Scores and Functional Performance IQ Subtest Scores

	FPET	FRDF	TPDF	OCDF	OCPET
P1	**.33**	**.33**	.20	.05	-.05
P2	.26	**.40**	**.39**	-.19	-.28
P3	.12	.16	.18	.13	-.06
P4	.10	.00	**.39**	.03	-.28
P5	**.38**	.25	**.36**	-.26	**-.31**

Table 7. Correlations Between Individual Structural Difference Measurements and Functional Performance IQ Subtest Scores

	10%	20%	25%	33%	40%	50%	60%	67%	80%	90%
P1	.25	**.46**	-.07	-.13	-.02	.21	.20	-.04	.17	.00
P2	.22	**.34**	**.33**	.12	.19	.16	.22	-.14	.06	**-.31**
P3	-.03	**.34**	.27	.07	.20	.10	.07	.10	.23	.08
P4	-.11	.24	.15	.16	.21	.04	**.34**	.12	.14	-.05
P5	.11	.28	.20	.20	.24	.25	.06	-.20	-.07	**-.31**

bold indicates p≤.1
underline indicates p≤.05

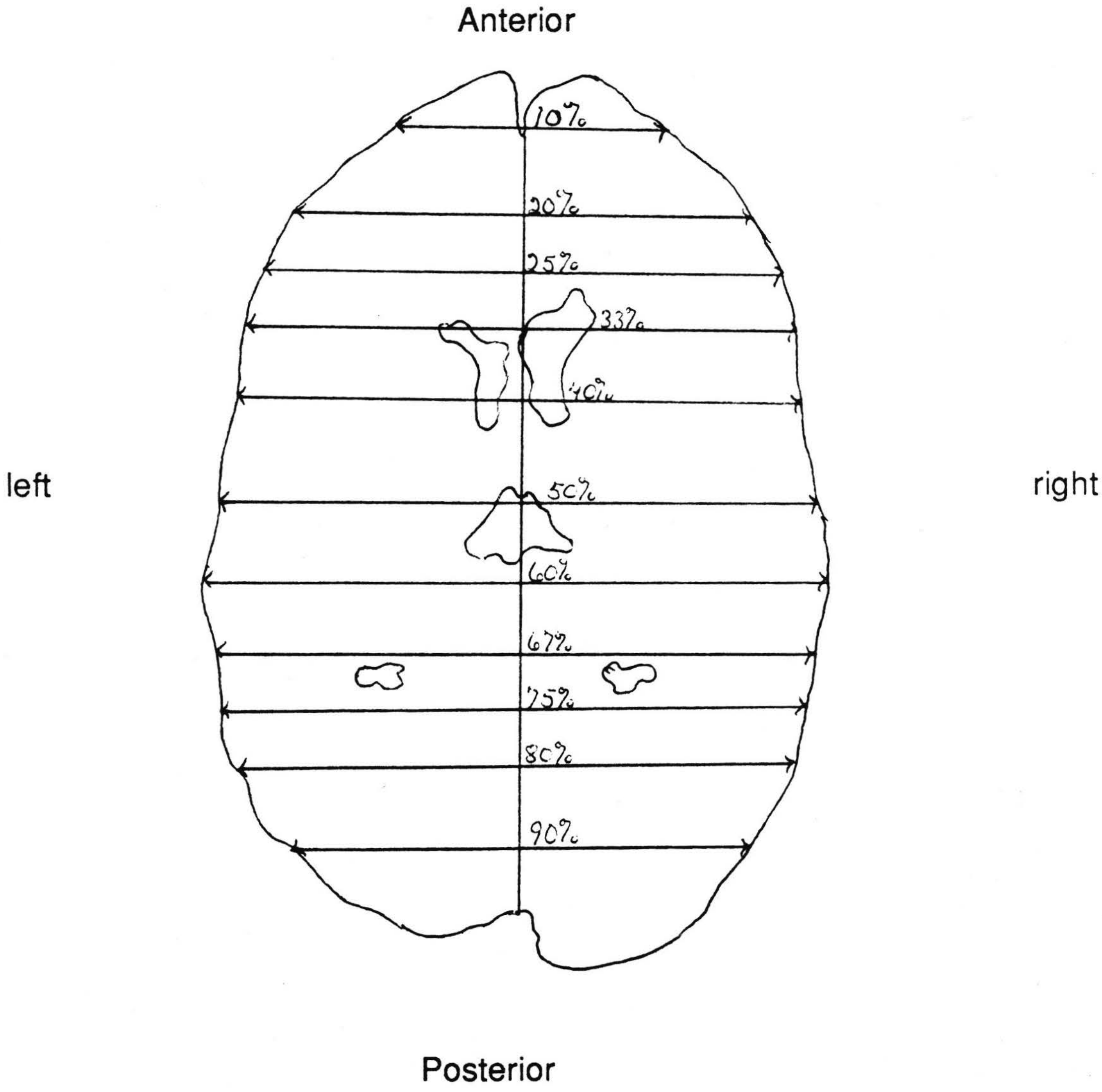
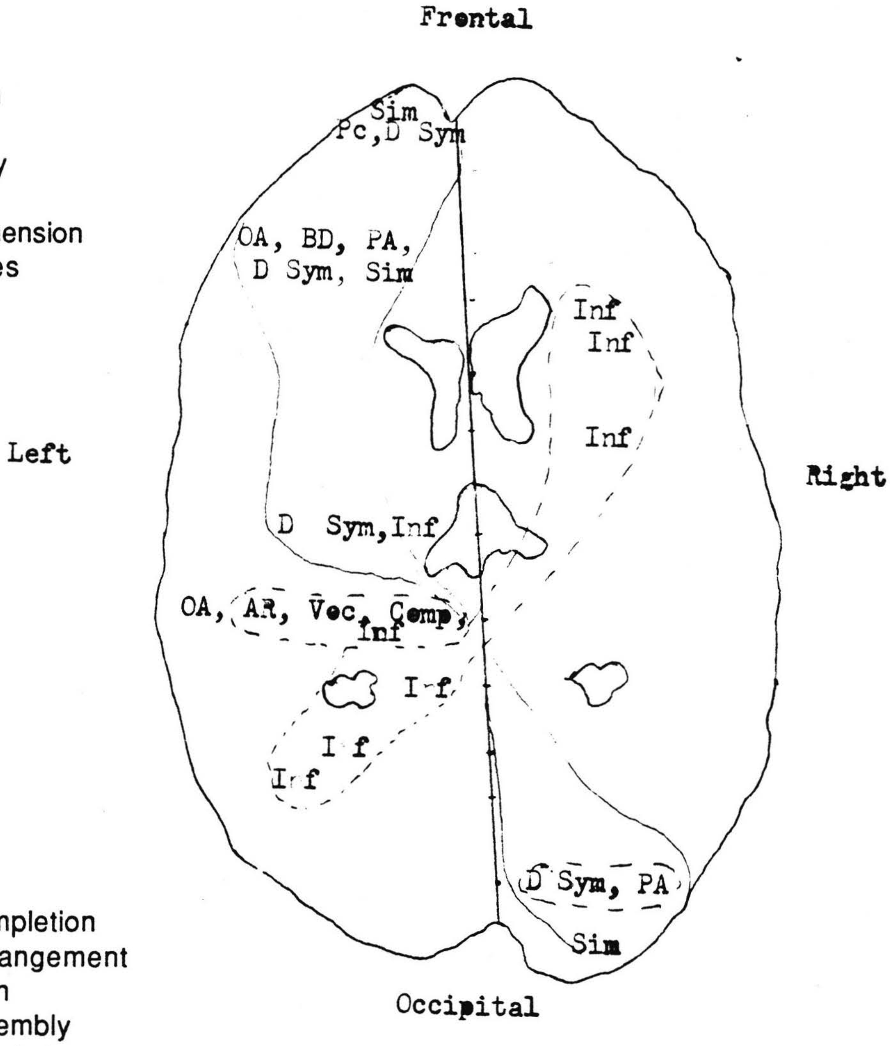


Figure 1. Illustration of Points Asymmetries Were Measured

VERBAL TESTS
Inf=Information
Ds=Digit Span
Voc=Vocabulary
Ar=Arithmetic
Comp=Comprehension
Sim=Similarities



PERFORMANCE
PC=Picture Completion
PA=Picture Arrangement
BD=Block Design
OA=Object Assembly
DSym=Digit Symbol

Figure 2. Locus of High Subtest Scores Associated With a Specific Asymmetry