HEMISPHERIC SPECIALIZATION AND COGNITION

THE ASSOCIATION OF HEMISPHERIC SPECIALIZATION AND COGNITIVE ABILITIES WITH REGARD TO SEX, HAND PREFERENCE, AND BIRTH STRESS

By

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ABSTRACT

The relationship of patterns of hemispheric specialization to verbal and non-verbal cognitive abilities were studied as well as the effects of birth stress on the etiology of left-handedness. Using verbal and non-verbal dichotic listening tests 28 right- and left-handed boys and girls with a mean age of 10.6 years, were assessed as being unilaterally or bilaterally organized for processing verbal and non-verbal material. The subjects were also assessed for verbal and non-verbal ability using standard intelligence tests. Birth records were obtained in order to assess whether birth stress resulted in perinatal anoxia, the agent for altering hand preference. It was found that:

1) Boys may show a left ear effect for some non-verbal material but girls may not.

2) Bilateral organization for processing non-verbal material is not necessarily correlated with poorer spatial ability in girls.

3) The relationship of bilateral organization for processing verbal material with overall verbal ability were inconclusive.

4) There is no evidence to indicate that birth stress and/or oxygen deficit are necessary for left-handedness to occur, since both right- and left-handers exhibit these factors to the same degree and at least some of the left-handers appear to show no evidence of birth stress at all.

CHAPTER I

INTRODUCTION

Hemispheric Specialization for Cognitive Abilities

Since the mid 19th century it has been known that certain cognitive functions are subserved by one side of the brain but not by the other. When Marc Dax and later Paul Broca (Benton 1972) observed that trauma to the left side of the head resulted in deficits in speech which was not observed in association with trauma to the right side of the head, the notion arose that the left side of the brain mediated language and the right side did not. In spite of Hughlings Jackson's (1915) opposition the notion of a dominant hemisphere arose. That notion being that the left hemisphere is lateralized for language and the right hemisphere performs only the basic perceptual and regulatory tasks common to any human brain. Jackson disagreed with this notion since he believed that the right posterior portion of the brain had a role in visual orientation and face recognition. Furthermore, Jackson argued that the speech of right hemisphere damaged patients he has observed was not normal at all, but tended to lack fluidity and spontaneity.

Support for the importance of the right hemisphere in cognition was subsequently reported in many sources (Butters and Barton, 1970; Critchley, 1953; Denny-Brown, Meyer and Horenstein, 1952; Kohn and Dennis, 1974; Weisenburg and McBride, 1936; Zangwill, 1961).

On the basis of our present knowledge the left side of the brain is dominant for speech and most verbal processing and the right side is dominant for visuo-spatial processing and some non-verbal skills. However there are several qualifications to this statement. First, all of this evidence for cerebral dominance is based upon observations of neurologically damaged individuals. Unilateral brain damage could have an abnormal effect on the brain as a whole, not just in the one hemisphere Second, the dysfunctions caused by trauma are often transitory and disappear over time. This leads to the question of whether the damage to the brain caused the disruption of an ability because the function was localized in the damaged section and reappears somewhere else, or was the function always localized somewhere else and just interfered with by the damage?

A final qualification which must be made regarding left-right dominance is that dominance is at least a term expressing relative superiority at some task. It is not an all or none phenomenon, but one of degree.

There are three major factors which have been associated with the degree of lateralization of verbal and non-verbal skills: age, sex and handedness. Recovery of a lost skill or function is much more likely before puberty than after (Basser, 1962; Lenneberg, 1967). If the patient is female the language deficits following a left hemisphere lesion are less marked than if the patient is male (Basser, 1962; Hécaen and Ajuriaguerra, 1964; McGlone, 1976). If the patient is left-handed, the effects of damage to the speech area, be it in either hemisphere, are less severe than the deficits caused by insult to the left hemisphere speech area of a right-handed person (Hécaen and Ajuriaguerra, 1964).

This would seem to indicate a difference in cerebral organization for children, females and left-handers when compared to adults, males and right-handers respectively, but for different reasons for the various groups. When one hemisphere is damaged in a developing individual the other hemisphere may take over some of the cognitive functions normally found in the damaged hemisphere, but not without some cost. For example, Dennis and Kohn (1975) found that in their early brain-damaged subjects the language of those without a left hemisphere was poorer in syntax than the language of those without a right hemisphere, suggesting that although one hemisphere can take on the cognitive functions of the other hemisphere, it may not be able to do so to the same extent as the other "normal" hemisphere would. Still, the neural organization representing cognition of the child's brain has greater plasticity than the adult's brain and has a greater capacity for equipotentiality between hemispheres prior to puberty (Basser 1962).

The evidence regarding women is that they have more residual language following damage to the left hemisphere speech area than do men. Why this is the case is not clearly understood. However, it does indicate that women would appear to have more bilateral representation of language than do men (McGlone, 1976).

Regarding non-verbal material there appears to be less specialization in hemispheric functioning in females than in males in visuo-spatial processing (McGlone and Kertesz 1973).

The organization of function in left-handed patients generally leads to fewer deficits in language as a result of lesion in the language area in the left or right hemisphere compared to left hemisphere lesion in right-handers, indicating more bilateral speech representation in left-handers than in right-handers (Hècaen and Ajuriàguerra, 1964; Newcombe and Radcliff, 1973).

Neuroanatomical Asymmetries

Neuroanatomical differences in morphology have been found which tend to corroborate the clinical evidence relating to hemispheric lateralization. The area associated with the temporal speech cortex in the left side of the brain called the planum temporale is larger than the corresponding area on the right side of the brain in 65% of the brains examined (Geshwind and Levitsky, 1968). There appears to be less of an asymmetry in women than in men (Wada, Clark and Hamm, 1975).

This asymmetry is also found in neonates (Witelson and Pallie, 1973).

The left occipital horn is generally larger than the right (McRae, Branch and Milner, 1968) which has been interpreted as meaning that the left occipital cortex is smaller than the right occipital cortex (Harris, 1973). This may be related to the right hemisphere's superiority with visuo-spatial processing.

Studies With Neurologically Intact Individuals

While far from perfect, the clinical evidence cited thus far is still less speculative than the normal studies on hemispheric lateralization since this evidence most easily shows that unilateral and bilateral organizational characteristics of the sexes and the handedness groups.

There are several methods by which one may test verbal and non-verbal processing in normal subjects either between individuals or within the individual; that is comparing one hemisphere with the other. Tests between individuals may show differences in verbal or non-verbal processing between one segment of the population and another e.g., males versus females.

A within subject test may show which hemisphere is dominant for a particular function when there is an asymmetry to be found. Also, data of this type can be compared to data from other groups to see if asymmetries are shown.

Sex Differences In Hemispheric Specialization

There are numerous studies which report differences between the sexes (Maccoby, 1966). Of relevance here are differences in cognitive ability. Cognitive differences between the sexes have been largely restricted to two basic areas; verbal and spatial, with females being superior at the former and males superior in the latter. It must be emphasized at this point that these differences are of a quantitative and not qualitative nature. For example, in some spatial tests the scores of the males are higher than the females overall, but only by about 5-10 per cent (Maccoby, 1966). It is the consistency of these differences over time and across different studies which leads to statements about male spatial superiority or female verbal superiority. Furthermore, one cannot make predictions about individual performance based on this evidence since some girls are better than boys at spatial tasks and some boys better than girls at verbal tasks.

It must also be pointed out that no one test devised always shows a sex difference.

Most tests of hemispheric lateralization for verbal material show that females as well as males show left hemisphere superiority for verbal material (Kimura, 1963; McGlone and Davidson, 1973) yet females display a more "bilateral" pattern for language than do males when brain damage occurs. This is not a real contradiction since the term "superiority" only implies that one hemisphere performs a task better than the other hemisphere, not that one hemisphere only performs a certain task. (An interesting study by Ray, Morrell, Fredient and Tucker (1976) shows that females seem to process verbal material more bilaterally than do men. Using bilateral electroencephelogram (EEG) recordings they demonstrated that males display more unilateral EEG activity while performing a verbal task than did females. Research of this nature may prove to be the most conclusive regarding the role of the hemispheres in processing cognitive material).

Sex differences in hemispheric specialization have been observed in processing non-verbal material in certain modes of perception. Ray et al (1976) demonstrated that processing non-verbal material is more unilateral in males than in females. This corresponds to the results of McGlone and Kertesz (1973) in their study of a clinical population. One interpretation of these findings put forth by McGlone and Kertesz is that females may be verbally processing the non-verbal material, hence the involvement of both hemispheres. This could result in poorer performance by females on these tasks, thus explaining why females tend to perform worse on spatial tasks than do males.

Further evidence for females processing non-verbal material with both kinds of cognitive processing comes from McGee (1976) who showed that left-handed females (who should be the most bilaterally organized) performed worse on a spatial test than right-handed females. McGee found no differnce between right-and left-handed males on this test although the left-handed males were slightly better than the right-handed males as was predicted. Hannay (1976) demonstrated no visual field asymmetries in females in a visual spatial task but found a right visual field superiority for males on this task. Witelson (1976) has shown that boys only show a right hemisphere superiority for spatial processing in the tactual mode suggesting "unilateral" processing for boys and "bilateral" processing for girls. However the overall score of the girls was not worse than the overall score of the boys. This seems to indicate that "bilateral" processing of a spatial task does not necessarily mean that poorer performance compared to "unilateral" processing will result as previously suggested.

The studies on processing of non-verbal material in the auditory mode do not show a sex difference in hemispheric specialization. Knox and Kimura (1970) showed that both sexes display a left ear superiority for recognition of environmental sounds in a dichotic listening test. However it was shown that boys were better at overall recognition of these sounds. Again this would seem to indicate that performance and pattern of hemispheric specialization processing are not necessarily correlated.

The relationship between the cognitive differences for males and females and hemispheric specialization for cognitive tasks is noteworthy. Both sexes usually show a left hemispheric superiority for verbal material although females generally display more linguistic ability on cognitive tests overall. Yet clinical, EEG, and possibly neuroanatomical data indicate that females are more bilaterally organized linguistically than are males. One could conclude from this that bilateral processing of verbal material leads to superior verbal performance. But this is not the case in processing non-verbal material. Bilateral processing of this material may not affect performance at all, but when it does, it tends to hinder this performance not to enhance it. The relative merits of unilateral and bilateral processing of non-verbal material are not clear yet, because although it has been demonstrated that females show a bilateral organization for spatial material in the visual and tactual modes, not unilateral as in males, females do show a unilateral organization for processing non-verbal material in the auditory mode. (Knox and Kimura, 1970).

If hemispheric specialization for cognitive processing is related to overall cognitive ability it may be tested by comparing males and females on tests of hemispheric specialization for both verbal and non-verbal material in the auditory mode and then subjects on overall tests of cognitive abilities. If a pattern of hemispheric specialization occurs for one sex group and a different pattern emerges for the other sex group, then the results of the test of cognitive abilities may reveal whether or not a particular pattern of processing is related to a particular cognitive ability.

The Relationship of Handedness and Hemispheric Specialization

As previously stated hand preference can be a factor related with hemispheric lateralization along with age and sex. However the precise nature of the relationship between cognitive functional asymmetry of the brain and handedness is not clear. Some evidence indicates that left-handers are generally more bilaterally organized for verbal material than are right-handers (Bryden, 1965). However Branch, Milner and Rasmussen (1964) using Wada's sodium amytal test show that only 20% of left-handers are bilaterally organized for language. Similarly, Warrington and Pratt (1973) show that few left-handers display the bilateral pattern, using unilateral electroconvulsive shock.

One would expect that manual preference for writing should be directly related to cerebral organization of language since this would be the most efficient form of writing due to better contralateral control over precise hand movements. It would appear that some proportion of left-handers require their right hemisphere to control writing but not language, or the left hemisphere is exercising ipsilateral motor control for the writing task.

Part of the reason why the information regarding left-hand preference is so confusing is that its precise incidence in the population is not really known. Estimates range from 1% to 25% (Hécaen and Ajuriaguerra, 1964), with the current opinion hovering around 8%. Annett (1967) reports that 66% of the population are right-handed, 30% ambidextrous and 4% left-handed. This lack of precision in assessing handedness is partly due to the fact that investigators do not always use the same criterion for testing handedness. Self report for handwriting is the most popular method, but many researchers use different handedness batteries e.g., Edinborough Handedness Inventory (Oldfield, 1970). Also some investigators make no distinction between ambidexterity and left-handedness.

Before one can assess the relationship between handedness and hemispheric specialization, it is necessary to ask how handedness can possibly be related to hemispheric specialization or vice versa? One theory regarding the etiology of left-handedness will shed some light on this question.

The theory to be tested is that birth stress is a possible cause of left-handedness as proposed by Bakan (1971, 1973). Bakan (1971) found that there was a higher proportion of left-handers reporting what he called high risk birth order. He found that more left-handers were either first born or fourth born or more in their families (the higher risk group) than were second or third born (the low risk group). Moreover, he found more right-handers in the low risk group than in the high risk group. Bakan, Dibb and Reed, (1973) asked questions of their subjects related to birth stress, such as were they a blue-baby; were their mothers over 30 when they were born; were they premature; or did they have a breech birth. Their results were that twice the percentage of left-handers reported birth stress factors than did right-handers. This led Bakan to conclude that perinatal anoxia due to birth stress contributed to the population of left-handers by 40%.

This hypothesis is supported by a good deal of indirect evidence. The incidence of left-handedness in certain pathological populations such as epileptics; retardates; alcoholics; and possibly dyslexics (Bakan, et al, 1973) is higher than in normal populations. The figure invariably quoted is 18% (Satz, 1973). It has also been reported that twins appear to have a higher incidence of left-handedness (Hubbard, 1971; Teng, Lee, Yang and Chang, 1976). It is possible that a mild anoxia would be more likely to cause damage to the left hemisphere and thus interfere with right-hand usage, because of a reduced supply of blood to that hemisphere (Carmon, 1971). Carmon showed that the blood volume of the artery supplying blood to the left hemisphere was lower than that of the artery supplying blood to the right hemisphere in right-handed individuals.

To a lesser extent higher blood volume in the left hemisphere was correlated with left-handed individuals. This indicates that the oxygen supply of the left hemisphere is less than that of the right hemisphere in right-handed individuals. Since some left-handers show this same oxygen supply pattern as right-handers it is possible that they were predisposed to being right-handed but something caused them to alter this predisposition. Proluzzi and Bravaccio (1967) report that in those cases where there is a unilateral cerebral pathology (excluding cases of head wounds) the left hemisphere exhibits that pathology by a ratio of 7 : 3 over the right hemisphere.

By combining this evidence it is possible to hypothesize that since the left hemisphere is more succeptible to damage due to an oxygen deficit than is the right hemisphere, a mild lack of oxygen at birth could result in slight damage to the left hemisphere but not to the right hemisphere. The reported higher incidence of left-handers in pathological groups lends credence to the notion that brain damage can shift manual preference. The mild damage in the left hemisphere caused by anoxia at birth, as might be experienced by a twin for example could lead to: 1) a shift in hand preference from right to left, and 2) a more bilateral language representation in the brain.

In order to properly test this hypothesis one would have to examine the birth records of known right-and left-handers to see if birth stress factors did in fact produce some form of anoxia since birth stress factors per se may not necessarily result in oxygen deficit. Then the results of the two handedness groups could be compared to see if left-handers do show a higher incidence of perinatal anoxia. If they do, mild anoxia could be said to be a contributing factor in causing left-handedness.

Since both right-and left-handers are to be studied, it is appropriate to also examine the correlation between handedness and the relationship between hemispheric specialization and cognitive abilities. In cognitive abilities the verbal-non-verbal distinction is again important regarding hand preference. Regarding verbal performance there does not appear to be any difference between right-and left-handers (Hécaen and Ajuriaguerra, 1964). Whether or not the two groups differ on non-verbal tests appears to be an open question. Levy (1969) and Miller (1971) report that left-handed males are worse on Performance tests (generally spatial) than they are on Verbal tests. However, Newcombe and Radcliff (1973) and McGlone and Davidson (1973) do not find a verbal-spatial distinction in their left-handed males. McGlone and Davidson did report that female left-handers were poorer in spatial ability than were female right-handers, as does McGee (1976). McGee also reported that right-and left-handed males did not differ significantly in spatial ability. Peterson and Lansky (1974) show that left-handed males are in fact superior in spatial ability than are right handers. The evidence regarding hemispheric specialization for cognitive functions indicate that right-handers have verbal superiority in the right hemisphere (Kimura, 1963; Knox and Kimura, 1970). Ambidextrous and left-handed subjects do not show such a pattern and appear to be more "bilaterally" organized than right-handers (Bryden, 1965; McGlone and Davidson, 1973).

By observing the pattern of hemispheric organization in the two handedness groups to be studied it may be possible to determine whether or not bilateral processing of non-verbal material is associated with poorer performance on tests of overall spatial ability. If the left-handers show a more bilateral organization for processing non-verbal material as expected, will they perform worse than the "unilateral" right-handers on non-verbal tests? Also will their non-verbal performance be worse than their verbal performance?

This study has two main purposes. One is to determine the relationship between pattern of hemispheric specialization and level of cognitive abilities in the two sexes. This will be done by the pattern of hemispheric specialization in males and females and correlating the observed patterns with level of cognitive abilities. The second purpose of the study is to test the theory that birth stress is a causative factor in determining left-handedness. Right-and left-handers will also be compared on their patterns of hemispheric specialization and the relationship of this to overall cognitive abilities.

Since this study incorporates the use of birth records, it appears best to test children around the age of 10 years.

There are several reasons why this age was selected. First, most recent birth records of children are easier to obtain since children are less mobile than adults, hence their records may be available from the local hospitals. Second, since one of the major criteria for assessing hand preference is preferred hand for writing, the subjects have to be old enough to have acquired writing skills. Third, the clearest evidence of sex differences in lateralization of cognitive abilities is found in children between the ages of six through fourteen (Witelson, 1976).

CHAPTER II

METHOD

Subjects

There were 28 subjects in the study obtained from grades four, five, and six. They ranged in age from nine to eleven years, with the mean age of 10.6 years. All but one of the subjects came from the same urban Catholic parochial school. The other subject also went to a parochial school from the same School Board.

The subjects were selected by obtaining all of the left-handed children available within the appropriate age and grade range in one school, whose parents were willing to allow the children's participation, as well as give consent for the author to examine the children's birth records. Each child was then matched, by the special education teacher, with a right-handed child of the same age and sex whose parents also gave their consent. There were about thirty left-handed children in the proper age range. Out of these fourteen returned the consent forms. In the study there were seven left-handed boys, seven right-handed boys, and seven right-handed girls and seven left-handed girls.

Hand preference was initially determined by self report with subsequent verification by questionnaire and observation of writing preference. One child was incorrectly included in the left-handed group on the basis of self report, but was rejected from the study when it was determined that the child was right-handed.

No child had reported any history of learning problems, as reported by the special education teacher and all of them were in the normal school grade for their age.

Materials

Tests of Level of Cognitive Abilities

The verbal and non-verbal tests used to assess cognitive abilities were the Thurstones' Primary Mental Abilities (P.M.A.) Elementry Space Test (Thurstone, 1948); a non-verbal test, the Thurstones' (P.M.A.) Intermediate Word Fluency Test (Thurstone, 1947); a verbal test and the Wechsler Intelligence Scale for Children-Revised (WISC-R), Wechsler, 1971), both verbal and non-verbal.

The Thurstones' Space Test is a timed test requiring the subject to choose a segment of a square from four alternatives which will complete a square which has a segment missing. Maximum time for the test is seven minutes. The Thurstones' Word Frequency test is a timed test requiring subjects to write down all the words they can think of beginning with the letter "S", in five minutes. The WISC-R is a test which is scaled for age, that is scores for children of different ages (at four month intervals) are equated and thus comparisons between a nine year old and an eleven year old can be made, without unfair advantage being conferred to either age group.

This test has a Verbal and a Performance Component. There are six verbal and six performance subtests. The verbal subtests used in this study were: Information; Similarities, (What is the same about a telephone and a radio); Arithmetic; Vocabulary; and Digit Span, which is an optional test not used in computation of the verbal score. The Comprehension test was not used due to time constraints in the testing session, therefore, a prorated verbal score was used. The performance subtests were: Picture and Completion; Picture Arrangement, (Put a series of pictures in an order which tells a story); Block Design, (Put cubes with different coloured sides together to match a pattern); Object Assembly, (Analagous to a jig-saw-puzzle); Coding, (Matching symbols with numbers); and Mazes, an optional test not computed into the performance score. The times for the Mazes were recorded as well.

Tests of Hemispheric Lateralization

There were two auditory tests of hemispheric lateralization: one a dichotic digits test, and two a dichotic environmental sounds test. The dichotic digits test tape consisted of 39 sets of three pairs of synthetically voiced digits[1]. The digits ranged from 0 - 9 and the duration of a three pair set was one second. The amount of time between one stimulus pair and the next, the inter stimulus interval (I.S.I.), was zero.

The dichotic environmental sounds tape was made up of pairs of ten environmental sounds; a doorbell (ding-dong); a siren; a fog-horn; a ship's bell, (ding ding); a caliope; brushing teeth; a baby crying; a whistle; a cough; and knocking on a door[2]. The testing segment of the tape consisted of 25 sets of two pairs of sounds. Since the original tape has an I.S.I. of

750 msec., it resulted in the perception of pairs of sounds in a temporal order (Bryden, 1962, Witelson and Rabinovitch, 1971). In order to reduce the likelihood of recall by temporal order and possibly increase the likelihood of ear order recall which would enhance any possible ear differences, the speed of the tape was doubled from 3 3/4 inches per second (I.P.S.) to 7 1/2 (I.P.S.). This reduced the I.S.I. to 375 msec., however it reduced the duration of the stimulus itself from 400 msec. per sound to 200 msec. per sound. Also, this procedure causes the sounds themselves to sound distorted, as in a phonograph which is played at a faster speed than it should be played. Nevertheless, each sound was still clear, and distinct from the other stimuli.

Both sets of stimuli were played on a Tandberg (1200X) stereophonic sound tape recorder and the subjects listened through Sharp (HA - 10) stereo headphones. The sound pressure level was 66 decibels for channel 1, and 64 decibels channel 11.

Procedure

All subjects in this study were tested individually by the author and 26 were tested in two separate sessions on different days. The other two subjects were given all the tests in one day with a 30 minute break during the testing. The order of administration of the tests was: first session; handedness verification, Thurstones' Space, Thurstones' Word Fluency, WISC-R in the order specified in the manual, second session; dichotic environmental sounds and dichotic digits. This order was the same for all subjects.

The Thurstones; Space and Word Fluency and the WISC-R were administered as outlined in the test manuals.

The dichotic listening tests were administered in the same manner to all subjects. All counter-balancing of material and channels was done on a within subject basis.

The subjects were first given the environmental sounds test then the digits test. It has been demonstrated elsewhere, in several perceptual modes, that verbal material if presented first has the effect of priming the left hemsphere for responding to subsequently presented "right hemisphere" material. The reverse situation does not occur, hence the order of presentation employed in this study (Klein, Moscovitch and Vigna 1976, Witelson, 1974).

In the environmental sounds test the subjects were told that they would hear sounds which could be matched with the array of pictures displayed before them. Each sound was represented by one picture. They then heard each sound binaurally played at normal speed through the headphones and were asked to point to the picture which went with the sound. When they could do this perfectly they were then told that the sounds were going to be speeded up and that they would sound a little different. Again they had to match pictures with the sounds. Any confusions as to which sound went with which picture were set straight at this point.

For the dichotic listening practice they were told they would hear one sound in one ear and one sound in the other ear at the same time, and then they were to point to the pictures representing the sounds that they heard. They heard 25 pairs of sounds, switched the headphones around and the same 25 pairs of sounds were played again, so that each sound was presented to each ear an equal number of times.

In the testing phase the subjects were told they would hear one pair of sounds and right after that another pair would come and then they were to point to the sounds that they heard. They were presented with 25 sets (2 pair to a set), switched the headphones and the same 25 sets were repeated. The correct responses were recorded, the maximum score per ear was 100.

The array of pictures was changed each time the headphones were switched and between the practice and test sessions. The pictures in each array were the same but they were in different arrangements. This was done in order to avoid the possibility that a subject would point to a particular spot each time he heard a particular sound instead of pointing to a particular picture.

In the dichotic digits task the subjects were required to repeat verbally all the numbers that they heard. After 39 sets of three digit pairs the headphones were reversed and the same 39 sets were repeated. Maximum score per ear was 234.

The change of channels to ear with repetition of the stimuli was done in order to avoid the possibility of producing an artificial asymmetry of report due to the effects in a particular channel of the tape, tape recorder, headphones, volume settings, or any combination of these factors. Any asymmetries observed could only be due to the individual subjects report.

Birth Records

The examination of the birth records was done by the author with the cooperation of the two local hospitals concerned.

In examining the birth records, birth stress factors such as low birth weight, prolonged labour, breech birth, Caesarean section, mothers over 30 years old, and prematurity were looked for in addition to actual cases of oxygen deficit requiring resuscitation.

1. This tape was made at the Haskin's Laboratory at the Bell Laboratory and was furnished to the author through the courtesy of Dr. Danny Klein.

2. This tape was made at the Department of Linguistics Phonetics Laboratory, University of California at San Diego, La Jolla, Calif. from a tape of recorded sounds made by the author.

CHAPTER III
RESULTS

Sex Differences

Comparisons between performance of boys versus girls were made on tests assessing; 1) level of cognitive abilities and 2) hemisphere specialization cognitive skills.

Level of Cognitive Abilities

In Full Scale WISC IQ mean scores for the two groups did not differ significantly using a t Test for independent measures (see Table 1).

Separating the verbal from the performance sections of the WISC yielded no significant differences between the sexes in these two test categories. An analysis of variance employing a two way mixed design, with sex being the between subject variable and test-type, the within subject variable, was performed (see Table 2). The sex by test interaction was not significant and there were no reliable differences between the sexes on test type.

An analysis of each scaled subtest score in each category was carried out, including the Digit Span, Mazes and maze times, although these three

Table 1

Mean Scores of Full Scale IQ (WISC-R)

for Girls and Boys

Score	Sex		
	Girls (n = 14)	Boys (n = 14)	t
Full scale	102.28	103.42	.24

Table 2

Mean Scores of Verbal and Performance IO (WISC-R)

for Girls and Boys

Sex	Verbal	Performance
Girls (n = 14)	99.07	106.07
Boys (n = 14)	103.71	102.14

Summary of analysis of Variance

Sex:	F = 0.007	d.f. (1,26)
Test Type:	F = 1.45	d.f. (1,26)
Sex X Test Type:	F = 3.62	d.f. (1,26), p < .1.

measures were not included in the scoring of Full Scale verbal and performance IQ scores (see Table 4).

In the Information, Similarities and Vocabulary subtests there were no differences between girls and boys. In Arithmetic, a score which is reflected in Full Scale and verbal IO the boys were significantly better. Also, in the digit span, the boys performed significantly better.

In Picture Completion, Picture Arrangement, Object Assembly and Coding the girls performed slightly but not significantly better than the boys. In the Block design the boys were slightly but not significantly better. There was a very small and not significant superiority for the girls in the mazes. However, the mean maze times for mazed 5, 6, and 7 (mazes which all subjects performed), an additional unscaled measure of performance employed by the author, the boys tended to be faster than the girls but not significantly (see Table 3).

Comparisons of performance of girls versus boys on the Thurstones' Fluency Test and the Thurstones' Spatial Test revealed no significant difference. The test scores were not scaled for age. The amount of time taken to complete the spatial task was also

Table 3

Mean Scaled Scores of Verbal and Performance Subtests (WISC-R)

for Girls and Boys

Subtests	Sex		
	Girls (n = 14)	Boys (n = 14)	t
Verbal Scale			
Information	9.07	9.07	0
Similarities	10.14	10.86	.70
Arithmetic	9.86	12.0	2.17*
Vocabulary	10.57	10.64	.07
Digit Span	10.07	11.57	2.15*
Performance Scale			
Pict. Comp.	11.57	11.0	.62
Pict. Arr.	11.21	10.57	.66
Bl. Des.	10.14	10.93	.73
Obj. Ass.	10.50	9.43	.94
Coding	10.43	9.79	.77
Mazes	10.50	10.29	.18
Maze Sec.+	30.07	21.48	1.99x

+ This is an additional measure of performance devised by the author and is not scaled for age.

* $p < .05$, 2 tailed test
x $p < .1$, 2 tailed test

recorded for each subject (maximum seven minutes) and it was found that the boys tended to be faster at this task, but not significantly so (see Table 4).

By taking the percentage of the total scores expressed as percentage of age of maximum accuracy scores on each dichotic listening test it was possible to use the total digit score percentage as an additional test of verbal ability and the total environmental sounds score percentage as an additional non-verbal test. Percentages were taken in order to allow comparisons between both types of test. A two way analysis of variance, mixed design, demonstrated no significant difference between girls and boys in overall performance in the dichotic listening tests (see Table 5). The overall performance of the subjects was significantly better in the environmental sounds than in the digits, however the tests were not matched for degree of difficulty. There was no significant sex by test interaction.

Table 4

Mean Scores of Thurstones' Fluency and Space Test for Girls and Boys

Test	Sex		
	Girls (n = 14)	Boys (n = 14)	t
Fluency	27.5	24.9	.73
Space	15.8	15.9	.14
Space:Time (min.)*	6.2	5.7	1.08

* This is an additional measure of performance devised by the author, but not used in scoring the original test.

Table 5

Mean Percent Accuracy of the Dichotic Digits Test and the Dichotic Environmental Sounds Test for Girls and Boys

Sex	Totals	
	Digits	Environmental Sounds
Girls (n = 14)	47.64	60.07
Boys (n = 14)	46.64	57.85

Summary of analysis of Variance

Sex:	F = 0.48	d.f. (1,26)	
Test Type:	F = 25.93	d.f. (1,26)	$p < .001$
Sex X Type:	F = 0.07	d.f. (1,26)	

Hemispheric Specialization

In the dichotic listening tests a score was taken for each ear of each subject. Since the same material was presented to each ear and was tested on this material during the course of the dichotic listening sessions, direct comparisons between ears can be made.

A two-way analysis of variance, mixed design, was performed on the raw accuracy scores of the dichotic digits test with sex as the between subject variable and ear score as the within subject variable. There was no main effect of sex, however there was a main ear effect, that is the right ear was significantly better at this task than the left ear. The sex by ear interaction was not significant (see Table 6). However since one of the *a priori* questions of the study was to determine if there is a sex difference in hemispheric specialization for processing cognitive material, separate t tests were performed on each sex group. A t test for dependent means reveals that the girls show a significant right ear superiority but that the boys do not (girls; $t = 3.01$, $p < .025$; boys; $t = 0.30$, d.f. 13.).

Table 6

Mean Ear Accuracy Scores* on the Dichotic Digits Test

for Girls and Boys

Sex	Ear	
	Left	Right
Girls (n = 14)	97.71	125.79
Boys (n = 14)	107.29	110.50

Summary of analysis of Variance

Sex:	$F = 0.22$	d.f. (1,26)
Ear:	$F = 5.76$	d.f. (1,26), $p < .05$
Ear X Sex:	$F = 3.01$	d.f. (1,26), $p < .1$

* Maximum score per ear = 234

That the boys did not show the expected right ear superiority is noteworthy. This is likely due to the fact that the individual groups are relatively small and one or two subjects who display the reversed pattern of asymmetry could cause this result. One right-handed male subject who had the highest total accuracy score of all the subjects, had a left ear superiority. The variance of the right-handed boys left ear scores was significantly larger than the variance of their right ear scores as revealed by a t test for differences in variance, ($t = 3.35$, d.f. 6 $p < .025$). No other sub group for either dichotic test showed such a difference. It would appear that the scores of one or two boys were enough to negate the right ear effect.

It should be noted here that 64.2% of all the subjects showed a right ear superiority. A break-down by sex reveals that 71.4% of the girls and 57.1% of the boys show right ear superiority in the digits task.

Since the environmental sounds test was new and untested an additional analysis was performed on the accuracy scores of this test. Half of all the subjects showed a right ear superiority and half showed a left ear superiority for environmental sounds. The proportion of boys showing a left ear superiority was 57.1%. The girls had 57.1% showing a right ear superiority in this particular task.

Although an equal number of subjects scored better with their right ear than with their left ear in the environmental sounds, it should be noted that the magnitude of the right ear superiority for these subjects was much smaller than the magnitude of the left ear superiority for the left ear superior subjects. The mean R-L difference for the "right eared" group is 5.93, whereas the mean R-L difference for the "left eared" group is -14.5. The absolute difference between the ear scores for the "left eared" group is significantly higher than the absolute difference between the ear scores for the "right eared" group (see Table 7).

The data for the environmental sounds dichotic listening test were analysed according to a two-way analysis of variance, mixed design. There was no main sex difference, but there was a significant ear difference. The sex by ear interaction was not

Table 7

Mean Absolute Difference Between Ears on Dichotic Environmental Sounds Test for Left Ear Superior Group and Right Ear Superior Groups

	Ear Superiority		
	Left (n = 14)	Right (n = 14)	t
Absolute Difference	14.5	5.9	3.12*

* $p < .025$, 2 tailed test

significant (see Table 8). Individual t tests performed on each sex group for the right versus left ear differences reveal that the boys have a significant left ear superiority for environmental sounds. but the girls do not show any ear superiority for this task. (boys; $t = 2.33$, d.f. 13, $p < .05$: girls, $t = 0.33$, d.f. 13.).

As previously stated the variance of the ear scores for the sub groups were not significantly different in the environmental sounds test. It appears that the lack of a left ear superiority in the girls is not the result of subject variance.

Birth Stress

It was possible to assess 22 sets of birth records since only 22 of the total 28 children were born in the Hamilton area. There were 12 left-handers and 10 right-handers in this group. Each child's birth records were examined with regard to two types of factors; birth stress factors and evidence of possible oxygen deficit. Although birth stress factors can lead to oxygen deficits, the are not necessarily precipitated by birth stress factors. There were no instances of severe cyanosis or resuscitation observed

Table 8

Mean Ear Accuracy Scores* on the Dichotic Environmental Sounds Test for Girls and Boys

Sex	Ear	
	Left	Right
Girls (n = 14)	60.64	59.50
Boys (n = 14)	61.57	54.14

Summary of analysis of Variance

Sex:	F = 0.29	d.f. (1,26)
Ear:	F = 6.26	d.f. (1,26), $p < .025$
Sex X Ear:	F = 3.36	d.f. (1,26), $p < .10$

* Maximum score per ear = 100

In spite of the fact that there are fewer right-handers in this particular sample than left-handers the incidence of birth stress factors in both groups is almost equal, and the incidence of possible oxygen deficits is equal for both groups. It should be pointed out that there is no evidence to indicate that any perinatal anoxia occurred at all, only possibly, in this subject population.

Effects of Handedness

Comparisons between scores for left-handers versus right-handers within a sex groups were made on tests assessing, 1) level of cognitive abilities and, 2) hemispheric lateralization of cogitive skills.

Level of Cognitive Abilities

Girls

The mean scores of the two handedness groups did not differ significantly in Full Scale WISC IQ (see Table 10). Nor do they differ significantly on verbal IQ or performance IQ as revealed by a two-way

Table 9

Incidence of Birth Stress and

Oxygen Deficit Factors

Observed in Handedness Groups

Factors	Hand Preference	
	Left (n =12) 12	Right (n=10) 11
Birth Stress		
1. Low birth weight, under 5 pounds	1	0
2. Prolonged labour, over 10 hours	6	1
3. Breech birth	0	1
4. Caesarean Section	0	1
5. Mother over 30 years old	4	5
6. Premature Birth	1	1
7. Umbilical cord around infant's neck	0	2
Oxygen Deficit	7	7
1. Apgar rating less than 7	2	1
2. Mild cyanosis	3	5
3. Slowness in breathing and crying	2	1

analysis of variance, mixed design (see Table 11). There is a trend for the performance component of the test to be superior to the verbal component, but not a significant one. The handedness by test interaction is not significant.

Although the left-handed girls scored higher on ten of the eleven subtests than the right-handed girls, their superiority was not statistically significant except marginally so in the Picture Arrangement subtests. The right-handed girls scored higher than the left-handed girls only on the Arithmetic, but not significantly (see Table 12. The difference in Maze times between the two handedness groups again favoured the left-handed girls, but not reliably (see Table 12).

The data from the Thurstone Test also revealed no significant differences between left-handed and right handed girls. (see Table 13).

Table 10

Mean Scores of Full Scale IQ (WISC-R)

for Left and Right Handed Girls and Boys

	Handedness		
Sex	Left	Right	t
Girls	106.43 n = 7	98.14 n =7	1.54
Boys	101.57 n = 7	105.29 n = 7	0.5

Table 11

Mean Scores of Verbal and Performance IQ (WISC-R)

for Left-and Right-Handed Girls

Handedness	Scores	
	Verbal	Performance
Left (n = 7)	101.86	110.57
Right (n = 7)	96.29	101.57

Summary of analysis of Variance

Handedness:	F = 2.20	d.f. (1,12)
Test Type:	F = 4.33	d.f. (1,12), $p < .1$
Handedness X Test Type:	F = 0.26	d.f. (1,12)

Table 12

Mean Scaled Scores of Verbal and Performance Subtests (WISC-R) for Left-and Right-Handed Girls

Subtests	Handedness		
	Left (n = 7)	Right (n = 7)	t
Verbal			
Information	9.43	8.71	.73
Similarities	11.0	9.29	1.37
Arithmetic	9.57	10.14	.39
Vocabulary	11.57	9.57	1.77
Digit Span	10.14	10.0	.13
Performance			
Pict. Comp.	12.57	10.57	1.74
Pict. Arr.	12.42	10.0	2.04*
Bl. Des.	10.42	9.85	.59
Obj. Ass.	11.28	9.71	.83
Coding	11.0	9.85	1.29
Mazes	11.42	9.57	1.09
Mazes sec.+	26.04	34.09	1.07

+ This is an additional measure of performance devised by the author and is not scaled for age.

* $p < .1$, 2 tailed test.

Table 13

Mean Scores of Thurstones' Fluency and Space Tests

Left-and Right-Handed Girls

Test	Handedness		
	Left (n = 7)	Right (n = 7)	t
Fluency	9.57	25.43	.69
Space	16.43	15.29	.59
Space:Time* (Min.)	6.6	5.9	1.93

* This is an additional measure of performance devised by the author, but not used in scoring test.

The two groups could not be differentiated in overall performance on either the dichotic digits test or the dichotic environmental sounds test (see Table 14).

Boys

The right-handed boys and the left-handed boys did not differ significantly in Full Scale WISC-R IQ (see Table 10). Handedness does not appear to affect verbal IQ scores or performance IQ scores as shown by a two-way analysis of variance, mixed design (see Table 15). Although the left-handed boys are the only sub group who do better on the verbal component, the handedness by test interaction is not reliable statistically.

There were no reliable differences between the left-and right-handed boys on any of the verbal subtests (see Table 16). The left-handed boys low performance score may be attributable to their low scores on the Picture Arrangement and Object assembly (see Table 16). The Picture Arrangement score for the left-handers is significantly lower than the right-handers score. There are no other significant differences between the groups.

Table 14

Mean Percent Accuracy Totals of the Dichotic Digits Test and the Dichotic Environmental Sounds Test for Left-and Right-Handed Girls

Totals	Handedness		
	Left (n = 7)	Right (n = 7)	t
Digits	48.0	47.29	.18
Environmental Sounds	64.36	55.79	1.56

Table 15

Mean Scores of Verbal and Performance IQ (WISC-R)

for Left-and Right-Handed Boys

Handedness	Scores	
	Verbal	Performance
Left (n = 7)	104.42	97.71
Right (n = 7)	103.0	106.57

Summary of analysis of Variance

Handedness:	F = 0.30	d.f. (1,12)
Test Type:	F = 0.30	d.f. (1,12)
Handedness X Test Type:	F = 3.24	d.f. (1,12)

Table 16

Mean Scaled Scores of Verbal and Performance Subtests (WISC-R) for Left-and Right-Handed Boys

Subtests	Handedness		
	Left (n = 7)	Right (n = 7)	t
Verbal			
Information	9.86	8.29	1.29
Similarities	10.86	10.86	0
Arithmetic	11.71	12.29	-.39
Vocabulary	10.57	10.71	-.08
Digit Span	10.71	12.42	-1.71
Performance			
Pict. Comp.	11.0	11.0	0
Pict. Arr.	8.85	12.28	-3.20*
Bl. Des.	10.57	11.28	-.35
Obj. Ass.	8.57	10.28	-1.38
Coding	9.57	10.0	-.29
Mazes	9.85	10.71	-.55
Maze Sec.+	20.71	22.23	-.35

+ This is an additional measure of performance devised by the author and is not scaled for age.

* $p < .025$, 2 tailed test.

The Thurstone test showed no reliable differences between the two groups (see Table 17).

In the dichotic listening tests handedness does not appear to have any effect on overall performance (see Table 18).

Hemispheric Specialization

Girls

A two-way analysis of variance, mixed design, was used to assess any possible ear superiority for right-and left-handed girls in the dichotic digits task. There was a main effect for ear but not for handedness, nor was there a handedness by ear interaction of any significance (see Table 19). Further analysis reveals that the right-handed girls exhibit a significant right ear superiority for this material but that the left-handed girls do not. (Right-handed girls; $t = 2.62$,d.f. 6. $p < .05$; Left-handed girls; $t = 1.63$, d.f. 6).

In the dichotic environmental sounds test, a two-way, mixed design analysis of variance shows there is no handedness, ear or handedness by ear effect (see Table 20).

Table 17

Mean Scores of Thurstones' Fluency and Space Test for Left-and Right-Handed Boys

Test	Handedness		
	Left (n = 7)	Right (n = 7)	t
Fluency	22.42	27.43	1.29
Space	16.14	15.71	.20
Space:Time (min.)*	5.9	5.6	.31

* This is an additional measure of performance devised by the author, but not used in scoring the original test.

Table 18

Mean Percent Totals of the Dichotic Digits Test and the Dichotic Environmental Sounds Test for Left-and Right-Handed Boys

	Handedness		
Totals	Left (n = 7)	Right (n = 7)	t
Digits	43.43	49.86	1.88
Environmental Sounds	58.5	57.21	.25

Table 19

Mean Ear Accuracy Scores* on the Dichotic Digits Test for Left-and Right-Handed Girls

Handedness	Ear	
	Left (n = 7)	Right (n = 7)
Left (n = 7)	100.14	124.71
Right (n = 7)	95.29	126.86

Summary of analysis of Variance

Handedness	$F = 0.02$	d.f. (1,12)
Ear:	$F = 6.89$	d.f. (1,12), $p < .025$
Handedness X Ear:	$F = 1.65$	d.f. (1,12)

* Maximum score per ear = 234.

Table 20

Mean Ear Accuracy Scores* on the

Dichotic Environmental Sounds Test

for Left-and Right-Handed Girls

Handedness	Ear	
	Left (n = 7)	Right (n = 7)
Left (n = 7)	66.17	62.57
Right (n = 7)	55.14	56.43

Summary of analysis of Variance

Handedness	F = 2.31	d.f. (1,12)
Ear:	F = 0.01	d.f. (1,12)
Handedness X Ear:	F = 0.55	d.f. (1,12)

* Maximum score per ear = 100.

Boys

The dichotic digits test data do not differentiate right-and left-handed boys when analysed. The two-way analysis of variance performed indicates there is no ear difference, handedness difference or, handedness by ear interaction (see Table 21).

The environmental sounds test data show an ear effect but no handedness or handedness by ear interaction (see Table 22). Neither the right-handed or the left-handed boys show the ear effect strongly enough independently to be significant. (Right-handed boys; $t = 1.97$, d.f. 6, $p < 1.$: Left-handed boys; $t = 1.50$, d.f.6.).

Table 21

Mean Ear Accuracy Scores* on the Dichotic Digits Test for Left-and Right-Handed Boys

Handedness	Ear	
	Left (n = 7)	Right (n = 7)
Left (n = 7)	100.86	102.0
Right (n = 7)	113.71	119.0

Summary of analysis of Variance

Handedness:	F = 3.61	d.f. (1,12) $p < .1$
Ear:	F = 0.08	d.f. (1,12)
Handedness X Ear:	F = 0.03	d.f. (1,12)

* Maximum score per ear = 234.

Table 22

Mean Ear Accuracy Scores* on the

Dichotic Environmental Sounds Test

for Left-and Right-Handed Boys

Handedness	Ear	
	Left	Right
Left (n = 7)	62.9	54.1
Right (n = 7)	60.3	54.1

Summary of analysis of Variance

Handedness:	F = 0.06	d.f. (1,12)
Ear:	F = 5.19	d.f. (1,12). $p < .05$
Handedness X Ear:	F = 0.15	d.f. (1,12)

* Maximum score per ear = 100.

CHAPTER IV

DISCUSSION

Sex and Hemispheric Specialization for Cognitive Abilities

The sex factor and the pattern of hemispheric specialization as inferred from the dichotic listening data present an interesting picture. The overall performance of the boys and girls did not differ on either the digits test or on the environmental sounds test. One might have expected the girls to have been better than the boys on the digits test since this was a verbal test, and girls are often better than boys on such tests (Maccoby, 1966). It would also be expected that the boys would perform better than the girls on the environmental sounds test since this was a non-verbal test on which boys are often superior to girls.

The lack of a sex difference in overall performance on the environmental sounds test is noteworthy in that it is inconsistent with the findings of the study of Knox and Kimura (1970) who found a male superiority in their environmental sounds test. The Knox and Kimura test differed from this test in several aspects.

Knox and Kimura presented single pairs of sounds for a duration of four seconds and required a verbal response from their subjects. Their subjects heard each of the twelve pairs of sounds once only and then made the identification of the sounds. The present study required repeated recognition of the stimuli which were of a markedly shorter duration (200 msec.), distorted, less verbalizable, and truly dichotic. Also two pairs of stimuli were presented and the subjects reported by pointing to pictures. Because of these differences between the two tests it is difficult to speculate as to why there should be a sex difference in overall score in the Knox and Kimura study but not in the present study. One possibility is that the present study, prior to testing, required each subject to know what each stimulus was, therefore, both sexes were possibly more equally familiar with the sounds at the time of testing resulting in the manifestation of no overall differences in recognition.

A left ear advantage for environmental sounds occurred for the boys but there is no evidence of this for the girls. This suggests that the sounds were processed better by the boys right hemisphere than by their left hemisphere but the girls hemispheres may be equally involved in performing this particular task. Put another way, the boys may process non-verbal material in a more unilateral fashion and the girls may process this material in a more bilateral fashion. This is similar to what Witelson (1976) found for spatial material in the tactual mode. However it is not what Knox and Kimura (1970) found for girls. Knox and Kimura (1970) showed that the girls as well as the boys showed a left ear advantage in recognition of environmental sounds. The previously stated differences in the test used by Knox and Kimura and the test used in the present study cannot account for the differences found in the results of the two studies since the boys in both studies show a left ear advantage. This means that both environmental sounds tests require right hemisphere processing in spite of the fact that both tests differ. The fact that the present study found no asymmetry in ear scores in the girls, but Knox and Kimura did, may only be explained by further research. Nevertheless, in the present study, it appears that sex may be related to cerebral organization of processing some auditory non-verbal material.

The relationship of bilateral and unilateral organization on non-verbal and spatial abilities appears to be negligible. The "unilaterally" organized boys are no better at non-verbal and spatial tasks than are the "bilaterally" organized girls. This finding is a variance with the general view that males are better than females at certain spatial tasks (Maccoby, 1966). Why this should happen in this study will be discussed below. However, the hypothesis that unilateral processing by the right hemisphere of non-verbal and spatial material is better than bilateral processing of this material cannot be supported by these data.

The dichotic digits test data show a right ear advantage for girls but not for boys. The lack of ear score asymmetry in the boys is difficult to explain since boys as well as girls have a right ear advantage for verbal material in most other studies (Ingram, 1975; Kimura, 1963).

One right-handed boy in this study had the highest single ear score for the whole sample and it was in his left ear. Since the subject population was not large it is possible that this could have caused the lack of a right ear effect in the boys.

The two sexes did not differ substantially in Verbal performance on the WISC-R or on the Thurstones' Fluency test. The boys' significantly better performance on the Arithmetic and Digit Span subtests is interesting in light of the fact that the verbal dichotic listening test deals exclusively with remembering numbers. Yet the boys as a group did not show a unilateral organization of the left hemisphere for processing digits as did the girls who were not as good as the boys in Arithmetic and Digit Span.

That the girls did not perform better on the Verbal tests than the boys and the boys did not perform better on the spatial and non-verbal tests than the girls as might be expected by previous studies (Maccoby, 1966; McGlone and Davidson, 1973) is somewhat disconcerting. There are four possible explanations for why these results occurred. The first and most obvious explanation is that there were not enough subjects tested to yield reliable differences between groups. Only large differences between the two sex groups would be discernible with a sample as small as the one tested. But small differences between the cognitive abilities for boys and girls may not yield much useful information about sex differences in cerebral organization since small differences could be due to many and varied factors. For example, if 10,000 boys are significantly better than 10,000 girls on a particular spatial task by five percent, what does that say about cerebral organization? A difference of five percent could be attributable to a host of environmental factors. On the other hand, if a particular spatial test shows that boys are qualitatively different from girls then one questions whether or not there are factors causing the differences which are basic to a particular sex, such as hormonal influences, or possibly a different cerebral organization. And if a cognitive difference is qualitative rather than quantitative then it should appear in small groups as well as in large groups.

Therefore the lack of sex differences in cognitive skills in this study may be due to the fact that the previously reported sex differences in the tests used in this study (notably Thurstones' Space and Fluency Tests) are quantitative and not qualitative. However, other kinds of cognitive tests may yield differences of qualitative nature. Unfortunately it would appear they were not used in this study.

A second reason why the typical cognitive sex differences reported were not found in this study could be that the group tested was somewhat atypical.

Although this could be a possibility it is rather doubtful because of the fact that the Full Scale IQ scores are very close to the norms established for the WISC-R. As a group they are very average across all of the subtests as well.

A third possible expanation for the lack of cognitive differences found in this study could be that girls and boys are not reared as they were a generation ago, with different interests pushed on each sex, but more alike with the individual child being allowed to pursue his or her own interests. Previously perhaps boys "choices" of activities such as sports, and model building, or toys given to them such as train sets, mechano sets, and Leggo sets, predisposed them to have a more "spatial outlook" than girls whose activities and toys seemed to be more related to motherhood than anything else. It is possible that today's children are not so restricted in their choices of activities and the boys no longer have a spatial advantage and girls no longer a verbal advantage. Of course this explanation is contingent upon whether or not cognitive sex differences are environmentally induced. It also depends on whether or not there really has been a change in parent's attitudes towards their children's activities.

The fourth and last possible explanation which will be offered to show why there are no typical cognitive sex differences is that the tested subjects were too young to show any reliable differences in cognitive level. Baker and Ehrhardt (1974) report that consistant cognitive sex differences do not appear until after age 10 or 11. Since the mean age of the groups tested was 10.6 years, it is indeed possible that the children were not mature enough to show the usual cognitive differences. Why age should affect sex differences in cognitive abilities is open to environmental as well as hormonal explanations.

Handedness and Birth Stress

In both the right- and left-handed groups there were birth stress factors present (see Table 9), but these factors did not result in major instances of perinatal anoxia. It would appear that the reporting of birth stress factors *per se* does not necessarily allow one to assume that anoxia must follow. Granted there were several instances of possible oxygen deficit but none requiring any artificial respiration, at least as noted in the records. There was a high incidence of prolonged labour in the left-handed group, half of them, but it is difficult to determine the effects of this until birth. At birth these subjects appeared no more anoxic than did the right-handers. It would seem that if the theory that birth stress resulting in perinatal anoxia can alter predisposed hand preference is correct, then it must also be stated that this theory does not account for all cases of left-handedness.

The theory proposed by Bakan is in need of further scrutiny. Part of his theory originates from a study he did based on birth order data (1971). Bakan defined those who were first born or fourth born or more as being high risk for birth stress, and those who were second and third born as being low risk for birth stress. In surveying 648 university students he found that out of 95 left-handed subjects 58.9% were in the high risk group and 41.1% were in the low risk group. Of the 553 right-handers surveyed 45.2% were in the high risk group and 54.8% were in the low risk group. He found that there were proportionally more left-handers than right-handers in the high risk group. From this he concluded that high risk birth order was a contributing factor in causing left-handedness.

A similar study by Hubbard (1971), did not replicate Bakan's results. Hubbard surveyed 974 university students of whom 141 were left-handed and 833 were right handed. He found there were proportionally more left-handers (56.0%) in the low risk group than in the high risk group (44.0%). He also found that 53.4% of the right-handers surveyed were in the high risk group and 46.6% in the low risk group. Hubbards analysis revealed that there were proportionally more right-handers than left-handers in the high risk group. Hubbard stated that since his data were based on a larger subject population than Bakan's, Bakan probably made a sampling error and that high risk birth order was not a factor related to left-handedness.

Both of these studies seem to have overlooked one very important factor and that is, what is the proportion of first and fourth born or more birth order in the population at large? Since all families have a first born, logic dictates that the largest birth order group would be the first born group due to single child families. Combining this group with the group that is fourth-plus may well yield a higher proportion of people than the combination of second and third born would yield. Therefore, there may be more people with high risk birth order as defined by Bakan than people with low risk birth order in the general population.

A study by Belmont and Morolla (1973) on intelligence and birth order provides the necessary information. Belmont and Morolla obtained data from 400,000 19 year old males in the Netherlands. There were 56.2 percent high risk, (first or fourth born or more), subjects and 43.8 low risk (second and third born) in their population. But in Bakan's study, 47.1% of his 648 subjects, regardless of hand preference, were in the high risk group and 52.9% of them were in the low risk group. Using a 2 x 2 chi squared analysis to compare Bakan's proportions of high and low risk with those of Belmont and Morolla it is revealed that Bakan's ratio of high to low risk subjects is indeed different from that of Belmont and Morolla ($\chi^2 = 21.18$: d.f. 1, $p < 0.00001$). In Hubbard's study, 52.1% of the 974 subjects surveyed were classified as high risk and 47.9% as low risk. A 2 x 2 chi squared analysis comparing Hubbards ratio of high to low risk birth order with Belmont's and Morolla's high to low risk birth order reveals that Hubbard's ratio is also significantly different from that of Belmont and Morolla

($\chi^2 = 6.73$: d.f. 1, $p < 0.001$). Since neither Bakan's nor Hubbard's ratios of high to low risk birth order are the same as what one would expect to find in the general population as based on the Belmont and Morolla study, it is likely that Bakan and Hubbard surveyed atypical groups. If this is so then Bakan's conclusions regarding hand preference and birth order may be based upon an atypical subject population and hence may not be correct. Furthermore Hubbard's conclusions may be similarly incorrect. Clearly, more research is needed in order to resolve this problem.

One other source of possible support for Bakan's theory is also questionable. This is the idea that brain damage can alter hand preference since certain groups with early brain damage show a higher incidence of left-handedness than does the normal population. It has been reported that these brain damaged groups have an incidence of left-handedness of 18 percent compared to the normal population's incidence of 8 percent (Bakan, Dibb, and Reed, 1973; Satz, 1973). However, the figure of 8 percent for left-handedness in the normal population may well be too low. Both Bakan (1971) and Hubbard (1971) report that the incidence of left-handedness (based on subjects' report) in their randomly selected populations of university sutdents was 14 percent. A recent study conducted in Taiwan reports that although there are very few left-handers in their sample, 18 percent of the right-handed subjects reported being pressured to write with their right hand (Teng, _et al_ 1976). Also, a survey of 100 undergraduates conducted by the author revealed that 20 percent of the subjects reported being left-handed. If the true incidence of left-handedness in the general population is close to the 18 percent reported for the brain damaged groups then brain damage may have no effect on hand preference except in extreme cases. Therfore the mechanism which Bakan has proposed for altering hand preference may be invalid.

Handedness and Hemispheric Specialization of Cognitive Abilities

The data from the dichotic listening tests show that the right-handed girls are the only sub group who display any significant ear asymmetry, and that is in the dichotic digits task only. No hand sub group has an ear asymmetry for environmental sounds, in spite of the fact that the boys as a total group display a left ear advantage for this material. Since there were only seven subjects in each hand sub group it is likely that the conservative influence of the small number per group in the statistical analysis outweighed the possible differences in ear scores.

However, even if one could assume that the lack of ear asymmetry in the dichotic digits task meant that bilateral linguistic processing was taking place, it wouldn't be possible to make any conclusions about bilateral versus unilateral left hemisphere processing of linguistic material and its relationship to spatial abilities. This is due to the finding that only one hand sub group, the left-handed boys, may have showed any lower spatial abiltity. This was on the Picture Arrangement subtest of the WISC-R, where the left-handed boys scored markedly lower than the right-handed boys. Yet the left-handed girls and the right-handed boys displayed a similar "bilateral" processing organization for linguistic material and their spatial abilities were not impaired relative to their verbal abilities. Furthermore, the left-handed girls who would be expected to perform worse than any sub group in spatial or non-verbal tests (McGlone and

Davidson, 1973) since they would have a high degree of bilateral language being female and left-handed, had the best Performance score on the WISC-R than any other sub group. Their performance on the Picture Arrangement sub test showed a trend to be higher than the right-handed girls, the only group who could possibly have been called "unilateral" processors of linguistic material.

This study has not proven or disproven the hypothesis that bilateral linguistic processing impairs spatial ability.

At this point it should be pointed out that it can be misleading to say that an ear effect, either right or left, was found in a dichotic listening experiment. For example, in the digits test in this study there was a significant right ear advantage for the entire subject population tested, 28 subjects. Yet only 18 of the subjects actually had a right ear advantage, and only one sub group, the right-handed girls demonstrated the right ear effect significantly. Similarly, an overall left ear effect was found in the environmental sounds test, but only half of the subjects had a left ear advantage and no one sub group reliably showed the left ear effect. Although, the absolute difference between ears data (see Table 7) is relevant here because it does establish the fact that the left ear effect was more pronounced than was the right ear effect. Still, it seems that some caution should be exercised when interpreting data of this kind, especially when global inferences tend to be made about the neurological meaning of ear effects.

REFERENCES

Annett, M. The binomial distribution of right, mixed and left handedness. Quarterly Journal of Experimental Psychology, 1967, 19, 327-333.

Bakan, P. Handedness and birth order. Nature, 1971, 229, 195.

Bakan, P, Dibb, G., and Reed, P. Handedness and birth stress. Neuropsychologia, 1973, 11, 363-366.

Baker, S. W. and Ehrhardt, A. A. Prenatal androgen, intelligence and cognitive sex differences. 53-76 in Sex Differences in Behavior, Freidman, R. C., Richart, R. M. and VandWiele, R. L. eds., New York, John Wiley and Sons, Inc. 1974.

Basser, L. S. Hemiplegia of early onset and the faculty of speech with special reference to the effects of hemispherectomy. Brain, 1962, 85, 427-460.

Belmont, L. and Morolla, F. Birth order, family size and intelligence. Science, 1973, 182, 1096-1101.

Benton, A. L. The 'minor' hemisphere. Journal of the History of Medicine and Allied Sciences, 1972, 27, 5-14.

Branch, C., Milner, B. and Rasmussen, T. Intercarotid sodium amytal for the lateralization of cerebral speech dominance. Journal of Neurosurgery, 1964, 21, 399-405.

Bryden, M. P. Order of report in dichotic listening. Canadian Journal of Psychology, 1962, 16, 291-299.

Bryden, M. P. Tachistoscopic recognition, handedness and cerebral dominance. Neuropsychologia, 1965, 3, 1-8.

Butters, N. and Barton, M. Effects of parietal lobe damage on the performance of reversible operations in space. Neuropsychologia, 1970, 8, 205-214.

Carmon, A. and Gombos, G. M. A physiological vascular correlate of hand preference: Possible implications with respect to hemispheric cerebral dominance. Neuropsychologia, 1971, 8, 119-128.

Critchley, M. The Parietal Lobes, New York: Hafner Publishing Co. 1953.

Dennis, M. and Kohn, B. Comprehension of syntax in infantile hemiplegics after cerebral hemidecortication: Left hemisphere superiority. Brain and Language, 1975, 2, 472-482.

Geschwind, N. and Levitsky, W. Human brain: Left-right asymmetries in temporal speech region. Science, 1968, 161, 186-187.

Hannay, H. S. Real or imagined incomplete lateralization of function in females? Perception and Psychophysics, 1976, 19,(4),349.

Harris, L. J. Neurophysiological factors in spatial development.

Hécaen, H and Ajuriaguerra, J. de. Left Handedness. New York: Grune and Stratton, 1964.

Hubbard, J. Handedness not a function of birth order. Nature, 1971, 232, 276.

Ingram, D. Cerebral speech lateralization in young children. Neuropsychologia, 1975, 13, 103-105.

Jackson, J. H. On the nature of the duality of the brain. Brain, 1915, 38, 80-103. (original publication: Med. Press Circ., 1874, 17, 19, 41, 63).

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

Klein, D., Moscovitch, M. and Vigna, C. Attentional mechanisms and perceptual asymmetries. Neuropsychologia, 1976, 14, 55-66.

Kohn, B. and Dennis, M. Selective impairments of visuo-spatial abilities in infantile hemiplegics after right cerebral hemidecortication. Neuropsychologia, 1974, 12, 505-512.

Knox, C. and Kimura, D. Cerebral processing of non-verbal sounds in boys and girls. Neuropsychologia, 1970, 8, 227-237.

Lenneberg, E. H. Biological Foundations of Language. New York: John Wiley, 1967.

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

Maccoby, E. E. The Development of Sex Differences Stanford, Calif.: Stanford University Press, 1966.

McGee, M. Laterality, hand preference, and human spatial ability. Perceptual and Motor Skills, 1976 42, 781-782

McGlone, J. Sex differences in functional brain asymmetry. Research Bulletin #378, 1976, University of Western Ontario.

McGlone, J. and Davidson, W. The relation between cerebral speech laterality and spatial ability with special reference to sex and hand preference. Neuropsychologia, 1973, 11, 105-113.

McGlone, J. and Kertesz, A. Sex differences in cerebral processing of visuo-spatial tasks. Cortex, 1973, 9, 313-320.

McRae, D. L., Branch, C. L. and Milner, B. The occipital horns and cerebral dominance. Neurology, 1968, 18, 95-98.

Miller, E. Handedness and the pattern of human ability. British Journal of Psychology, 1971, 62, 111-112.

Milner, B. Visual recognition and recall after right temporal lobe exision in man. Neuropsychologia, 1968, 6, 191-209.

Newcombe, F. and Radcliff, G. Handedness, speech lateralization and ability. Neuropsychologia, 1973, 11, 399-408.

Paoluzzi and Bravaccio (1967). Cited in Subirana, A. Handedness and cerebral dominance. In Vinken, P. J. and Bruyn, G. W. Eds. Handbook of Clinical Neurology Amsterdam: North Holland Publishing Co. 1969, Vol.4: Disorders of Speech, Perception and Symbolic Behavior, pp. 248-272.

Peterson, J. M. and Lansky, L. M. Left handedness among architects: some facts and speculation. Perceptual and Motor Skills, 1974, 38, 547-550.

Ray, W. J., Morell, M., Fredient, A. W. and Tucker, D. Sex differences and lateral specialization of hemispheric functioning. Neuropsychologia, 1976, 14, 391-393.

Satz, P. Left-handedness and early brain insult: An explanation. Neuropsychologia, 1973, 11, 115.

Teng, E. L., Lee, P. H., Yang, K. S. and Chang, P.C. Handedness in a Chinese population: Biological, social and pathological factors. Science, 1976, 193, 1148-1150.

Wada, J., Clark, R. and Hamm, A. Cerebral hemispheric asymmetry in humans. Archives of Neurology, 1975, 32, 239-246.

Warrington, E. and Pratt, R. T. C. Language laterality in left-handers assessed by unilateral E.C.T. Neuropsychologia, 1973, 11, 423-428.

Witelson, S. F. Hemispheric specialization for linguistic and nonlinguistic tactual perception using a dichotomous stimulation technique. Cortex, 1974, 10, 3-17.

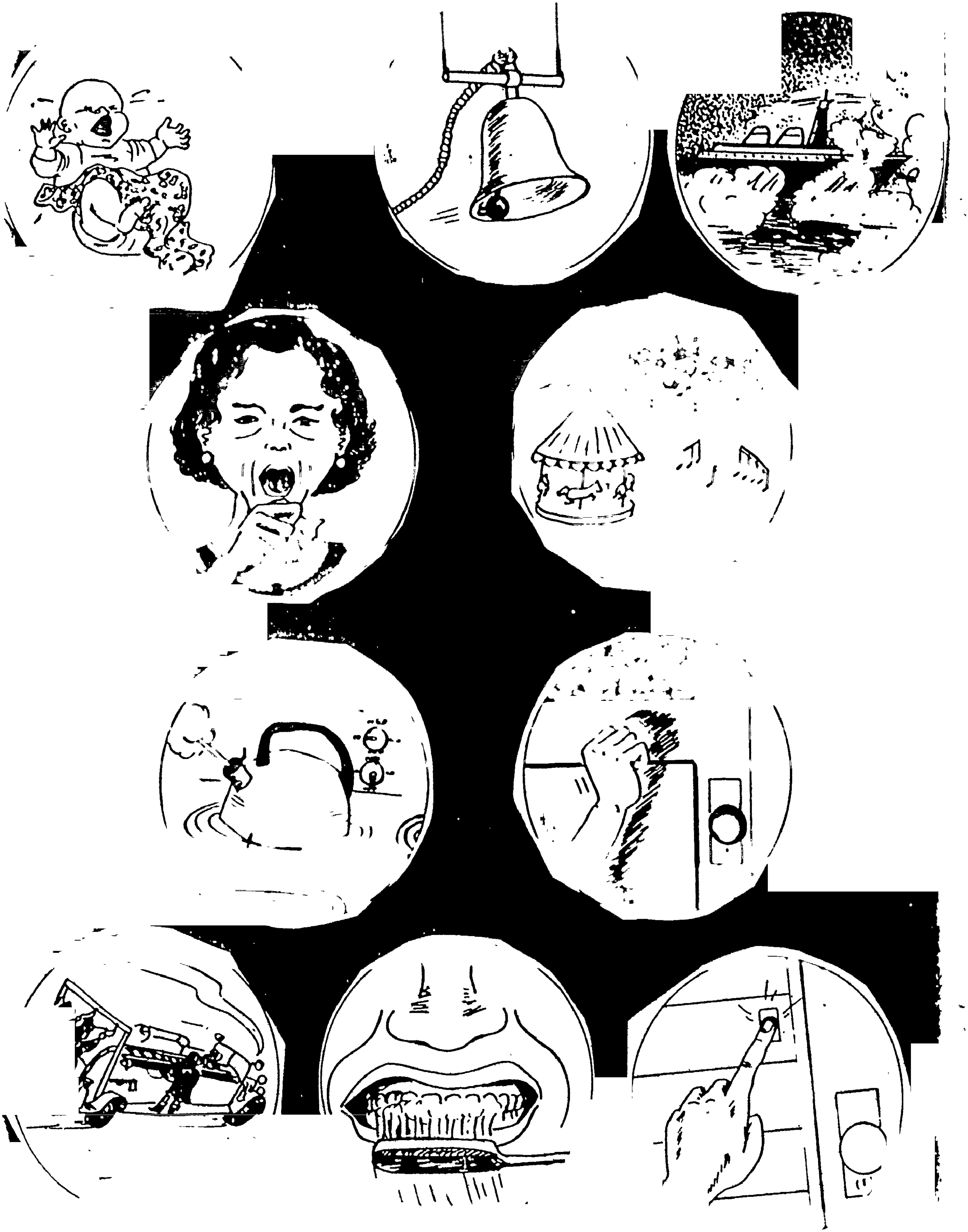
Witelson, S. F. Sex and the single hemisphere: Right hemisphere specialization and spatial processing. Science, 1976, 193, 425-427.

Witelson, S. F. and Pallie, W. Left hemisphere specialization for language in the human newborn: Neuroanatomical evidence of asymmetry. Brain, 1973, 96, 641-647

Witelson, S. F. and Rabinovitch, M. S. Children's recall strategies in dichotic listening. Journal of Experimental Child Psychology, 1971, 12, 106-113.

APPENDIX I

A sample of the arrays used in recognition of the environmental sounds in the environmental sounds test.



APPENDIX II

A copy of the handedness questionnaire used in this study.

NAME: ______________________ AGE: ________ SEX: ________

Relationship to ______________________
(subject's name)

Is there any reason that you are aware of that you use one hand instead of the other hand in performing a particular task? If so, please indicate the reason in this space: ______________________

____

____

____

Which hand do you use in performing the following tasks? Please indicate your answer on the line following each task. If you usually use either hand check off ambidextous.

	Left	Ambidextrous	Right
If someone asks you "are you right or left-handed" what do you reply?	____	____	____
Writing	____	____	____
Putting on make-up/shaving	____	____	____
Throwing	____	____	____
Cutting with scissors	____	____	____
Hitting (for example, which hand is used in table tennis?)	____	____	____
Ironing	____	____	____
Using a saw	____	____	____

R. MacFarlane
Enclosure #1

APPENDIX III

A copy of the letter sent to the parents of the subjects involved in this study.

McMASTER UNIVERSITY

DIVISION OF HEALTH SCIENCES

Department of Psychiatry

1400 Main St. West
Hamilton, Ontario

October 1974

Dear Parent,

I am a graduate student in Medical Science at McMaster University. For my thesis I am conducting research on certain factors concerning birth and the possible relationship to hand preference and the organization of the brain. In order to do this, I am testing ten year old children who are either left- or right-handed. I would like to include your child in my study which will be conducted in your child's school.

The testing of your child would take about two hours. Your permission is necessary to allow me to perform this research. I also need your co-operation in obtaining permission to examine the birth records of your child, and in filling out the enclosed forms concerning the hand preference to you, your spouse and other children.

I will be the only person conducting this project and the information obtained will be treated most confidentially. If you have any questions at all concerning this project please feel free to contact me. If you decide to allow your child to participate in this study would you please sign the enclosed forms and send them back to me as soon as possible.

Your co-operation in this study would be most appreciated. Thank you for your attention.

Robert MacFarlane

Robert MacFarlane, B.A.
Chedoke Hospital
Child and Family Centre

RMF:jps

Enclosures: 2

APPENDIX IV

A copy of the consent form sent to the subject's parents.

I give ______________________________ permission to participate
(child's name)

in the research project being conducted by Robert MacFarlane. It is my understanding that any information obtained concerning my child will not be disclosed to anyone.

________________ (Date)

________________________ (Parent's Signature)

AUTHORIZATION FORM

I ____________________________ give Robert MacFarlane permis-
(Mother's Signature)

sion to examine the birth records of my child ________________,

born on ____________________ at ____________________ Hospital.

Mr. MacFarlane may have access to this information between 15 October, 1974 until 30 June, 1975.

________________ (Date)

________________________ (Signature)

R. MacFarlane
Enclosure #2