A DEVELOPMENTAL STUDY OF EAR ASYMMETRY IN CHILDREN

A Dissertation

Presented to

the Faculty of the Graduate School

University of Houston

In Partial Fulfillment

of the Requirements for the Degree

Doctor of Education

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by

Ronald L. Taylor

August, 1975

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AN ABSTRACT

Research in the area of neuropsychology and child development suggests that the human brain undergoes a process of lateralization in which cognitive, speech and motor functions become "dominant" in one of the hemispheres. Further investigation suggest that this process occurs at a different rate for different individuals and could have an effect on their learning abilities. Such views are consistent with recent theories of "developmental dyslexia" and other disabilities attributed to a neurological or maturational lag.

The present study was undertaken to determine the effects of several independent variables on ear asymmetry in children. Ear asymmetry has been used as a measure of hemispheric lateralization by many researchers. Specifically, a dichotic listening procedure (simultaneous auditory stimulation) was used to determine the effects of sex, age,socioeconomic status and intelligence on childrens' ear asymmetry scores.

Eighty-four children were used as subjects. They were divided into three age groups (5-8-11) and further grouped by sex and socioeconomic status. A dichotic listening task and the Peabody Picture Vocabulary Test were individually administered to each child.

The results of the study indicated that age was the only significant variable for right ear scores ($F=4.448$; $p < .05$). There was no significant variable for left ear scores. Furthermore, a stepwise regression analysis indicated that age was the best and only significant predictor of right ear scores. Conversely, IQ was the best predictor of left ear scores. Also important was the finding that the difference between the right and left ear scores were significant for all age groups and that the difference became larger with age. This increased ear asymmetry with age was partly attributed to the use of dichotic tapes of different complexity with different age groups.

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CHAPTER I

INTRODUCTION

It is widely documented that the human brain undergoes a process of lateralization in which complex cognitive, speech and motor skills become dominant in one of the hemispheres (Lenneberg, 1967). Evidence suggests that language or speech skills are largely located in the left hemisphere. This conclusion is for the most part based on studies of aphasic or brain damaged adults (Zangwill, 1960).

Few studies have focused on the actual development of this lateralization phenomenon. Variables such as age, sex, handedness and socioeconomic status have all been considered salient features of the process. Studies in these areas, however, have been for the most part contradictory and somewhat inconclusive.

Recently, a technique termed dichotic listening has been used to study the lateralization phenomenon (Kimura, 1963). In such a paradigm, a subject receives simultaneous auditory stimulation via stereo headphones. In one ear is presented a series of digits or words; in the other ear a different series of digits or words are presented. The subject is then asked to recall, in any order, the digits or words presented. In non-neurologically impaired adults, the subject will recall more digits or words presented to the right ear (contralateral to the "dominant" left hemisphere for speech). The explanation for this ear asymmetry phenomenon is based on experimental studies which demonstrate that the contralateral auditory pathways are stronger than the ipsilateral pathways which connect the hemispheres to the ears (Rosenzweig, 1951).

When the dichotic listening procedure is administered to children, however, the results are not as predictable. Age, sex and socioeconomic status among other variables have been shown to affect children's performance on dichotic listening tasks. The implication of these findings is that these variables could have an effect on the lateralization of the brain in children. If these variables can, in fact, be demonstrated to have an association with a neurological lag, it could lend support to recent evidence which suggests that a variety of "disabilities" noted in children are a result of maturation (Satz and Friel, 1973). More specifically, it could indicate that many of the "differences" seen in children of different sex of socioeconomic status could be due to a maturational lag.

Statement of the Problem

The present study will explore the lateralization phenomenon as it relates to the development of ear asymmetry in children. Specifically, three questions will be studied:

1) At what age does ear asymmetry take place for verbal material and does the magnitude increase developmentally with age?

2) Does ear asymmetry differ for boys and girls?

3) Does socioeconomic status have any effect on ear asymmetry?

The answers to these questions should give meaningful insight into the area of child development. Moreover, it will offer added understanding into the neurological development of cognitive and language abilities in children.

Definition of Terms

The following terms have specialized meanings for this study and may be unfamiliar to the reader.

Cerebral Dominance

Cerebral dominance pertains to the phenomenon in which certain cognitive, language and motor skills are largely located in either the left or the right hemisphere. It is assumed that in approximately 97% of the adult population there is left dominance for speech skills (Lenneberg, 1967).

Contralateral

Contralateral actually means "other side". It is used in this study referring to the ear contralateral to the left hemisphere (the right ear).

Dichotic Listening

This term refers to a task in which a series of digits are simultaneously presented to a subject (e.g. 5, 18, 1 to the right ear and 9, 13 and 2 presented to the left ear). The subject is then asked to recall in any order the digits he heard.

Ear Asymmetry

In a normal adult population, there is a tendency for right ear to more accurately "hear" verbal material which is simultaneously presented to both ears. This phenomenon is termed ear asymmetry.

Ipsilateral

This term refers or pertains to the "same side" of the body.

Lateralization

This refers to a gradual process in which certain skills become dominant in one of the hemispheres. Accordingly, the lateralization process begins somewhere between the ages of three and five, and is usually completed by puberty (Lenneberg, 1967).

Somesthetic

This term pertains to sensations and sensory structures of the body.

CHAPTER II

REVIEW OF RELATED LITERATURE

Lateralization of function in the hemispheres of the brain is a phenomenon which is unique to man and is represented by the asymmetrical specialization of complex cognitive and language skills (Satz, 1970). The cerebral specialization of speech and language skills, primarily within the left hemisphere, represents the most hierarchically advanced demonstration of laterality in human primates (Satz, 1970) and, in fact, operationally defines the traditional concept of "cerebral dominance" (Lenneberg, 1967). Furthermore, evidence exists that the organization of higher integrative functions in man undergoes considerable differentiation and specialization during childhood.

One method which has been employed recently to study this phenomenon is the analysis of the performance of the two ears under complex auditory stimulation. This technique is termed dichotic listening and was initially developed by Broadbent (1954) to study short term memory. In this paradigm, subjects were simultaneously presented with different lists of digits to each ear (via stereo headphones) and were asked to recall the digits they heard after each trial. Broadbent found that each subject tended to report all the digits heard from one ear before reporting any from the other ear.

Kimura (1961a) employed a similar procedure and observed that her subjects demonstrated superior free recall for those digits presented to the right ear. One explanation for this occurrence has been postulated by Rosenzweig (1951) and Kimura (1961b). They found in experimental studies that each ear has connections with the auditory receiving area in each hemisphere, but that the pathways connecting the ears to their opposite hemispheres are stronger and more effective than the ipsilateral pathways. Thus if the left hemisphere is dominant for speech, the ear contralateral to this hemisphere would be more likely to "hear" the stimuli under simultaneous auditory presentation. Several variables have been studied to determine their relationship to this lateralization phenomenon.

Age

The lateralization phenomenon has been widely documented in the clinical literature (Semmes, 1968). The process of the development of this functional asymmetry has not been widely studied, however. Lenneberg (1967) suggested that the degree of unilateral speech representation increased in childhood until puberty at which time brain maturation stabilized.

Kimura (1963) employed the dichotic listening procedure with a group of children of varying ages and found a right ear superiority as early as age five. This study was replicated by Kimura (1967) using children from a lower socioeconomic background. She again found a right ear superiority at age five, although this was true for girls only. This finding also suggests a lag in the development of left hemisphere dominance for males. Sex differences are studied in depth in the next section.

Nagufuchi (1970), employing a similar dichotic listening paradigm, found that as early as age three, spoken word material was more accurately reported with the right ear than the left.

Several experiments have contradicted these findings, however, Bever (1970) used the dichotic listening task with a large sample of children from age three to five. Bever found no clear right ear superiority for his sample with many of his subjects demonstrating left ear or symmetrical ear preference.

Another apparent contradiction can be found in Kimura's (1963) study. Although she found right ear superiority at an early age, this asymmetrical speech representation decreased with age. This clearly violates the findings of increased lateralization (Lenneberg, 1967; Basser, 1962) reported in the clinical literature. An explanation for this apparent contradiction is offered by Satz, Bakker, Goebel, and Van der Vlugt (1973). The stated

> This conclusion, which has been implicitly accepted for the past decade, could in part be explained as an artifact of the stimulus procedures used in the Kimura (1963) and Knox and Kimura (1970) studies. The fact that the stimulus lists were composed of one-, two-and three-pair trials suggests that the task became increasingly easier for the older children, particularly on the one- and two-trial pairs. This bias would tend to increase overall recall for both ears in the older age groups which, in turn, would decrease the magnitude of the difference in recall between ears. (p. 2-3)

Studies of children suffering brain injuries to the left hemisphere are also at variance with Kimura (1963) and Nagufuchi (1970). These studies (Basser, 1962) indicate that the child's brain is capable of radical re-organization if damaged. Children recover the use of language much faster than adults who sustain similar injuries. This suggests that the lateralization of speech functions tends to shift to the right hemisphere and is not totally lateralized at an early age. Kimura (1963), however, stated that her data suggest that the left hemisphere is probably prepotent for speech long before language is lateralized and thus is not at variance with Basser's (1962) findings.

Sex

There have been conflicting reports as to the difference in males and females with respect to hemispheric lateralization. Kimura (1967) employing a dichotic listening procedure found a sex difference in the development of cerebral lateralization. Her data suggested a right ear superiority for females at an earlier age than male subjects.

This finding is consistent with the literature in the general area of language development. Terman and Tyler (1954) noted that girls excel boys in about all speaking skills in the early years. McCarthy (1930) also suggested that girls go through the language developmental cycle faster than boys, eventually arriving at the same level. Likewise Ghent (1961) found a lag in the development of somesthetic asymmetry in boys.

Bryden (1970) and Nagufuchi (1970) also found a poorer right ear performance in boys than girls at an early age using the dichotic listening paradigm.

Several studies, however, have found no sex differences on dichotic listening tasks. Bakker, Satz, Goebel and Van der Vlugt (1973) and Berlin, Hughes, Lowe-Bell and Berlin (1973) both reported no significant differences in sex on the ear asymmetry task. Kimura (1963) likewise found no significant sex difference with regard to speech lateralization. Kimura (1967) later explained that the apparent contradiction in her studies regarding sex differences could be due to several other factors such as intelligence level, home background and verbal ability.

<u>Handedness</u>

When variables such as handedness are introduced the concept of cerebral differentiation and lateralization is confounded. Evidence suggests that in right handers, speech and language functions are more often located in the contralateral left hemisphere, and visually guided skills located in the ipsilateral right hemisphere (Satz, 1970; Zangwill, 1960). The evidence for hemispheric specialization in non-right handers is not as clear. The amytal studies (Branch, Milner and Rasmussen, 1964; Milner, Branch and Rasmussen, 1966) suggest that there is more variability in the cerebral specialization of speech in left handers. These studies along with Satz et al (1967) and Zangwill (1962) suggest that a connection exists between handedness and cerebral organization of speech.

The latter study (Zangwill, 1960) demonstrated that a much lower incidence of aphasia was noted in right handers after sustaining right hemisphere damage.

Curry (1970) tested 25 left handed and 25 right handed subjects on three dichotic listening tasks-two verbal and one non-verbal. He found that the mean right ear score was higher than the mean left ear score for both handedness groups on both of the verbal dichotic tasks. This was significant for both dichotic tasks for the right handers, but for only one task for the left handers. He also found that more left handed subjects had ear preferences which were the reverse of that found for the groups as a whole. This difference between the handedness groups, however, was statistically significant on only one of the dichotic tests.

Further studies by Bryden (1965) and Curry and Rutherford (1967) resulted in similar conclusions. In each study, both left and right handed subjects demonstrated superior recall for digits presented to the right ear. However, the difference score between ears was smaller for left handers (i.e. more left handed subjects recalled digits with the left ear). These studies also suggest that the degree of hemispheric equipotentiality for speech may be greater for left than right handed subjects.

Many studies attempting to relate handedness and lateralization have received procedural criticism. Most of these studies (Bryden, 1965; Curry and Rutherford, 1967) used self reports of hand preference to correlate with the ear asymmetry scores. Satz, Achenbach and Fennell (1967) utilizing a multivariate assessment of manual dexterity in a large group of self classified left and right handers clearly demonstrated the unreliability of self reports of handedness. They found that approximately 40% of the self classified left handers demonstrated equal or superior performance with the non-preferred hand. These findings are similar to those of Benton, Myers and Polder (1962) who used a manual dexterity test to assess hand preference.

It seems evident from the present discussion that the literature is unclear as to the relationship of handedness to lateral speech dominance. Whatever the relationship, however, it seems that handedness (or the unreliable estimates of handedness) could lead to inaccurate conclusions on dichotic listening tasks unless it is carefully assessed or controlled.

Socioeconomic Status

The majority of this review will study the relationship of language development and socioeconomic status (SES). It is widely documented in the educational literature (John, 1963; Hess, 1970) that a functional relationship exists between SES and the development of verbal behavior. Rhiengold and Bayley (1959), in fact, postulated that it is possible that the verbal behavior young children is more sensitive to changes in the social environment than are other classes of behavior.

The majority of the literature in this area indicates a different rate and type of verbal development in lower and middle class children (Hess, 1970; McCarthy, 1930). Schatzman and Strauss (1955) in studying lower and middle class children reported a "considerable disparity" in the types and degree of verbal communication.

One of the major functions of speech is to aid in communication, both interindividual and intraindividual. Such a view considers language as a system of symbolic mediators that facilitates not only communication between individuals but also thinking and action for the individual himself (Carroll, 1964). Bernstein (1958) indicated that language in the lower class is not as flexible a means of communication as in the middle class. Khater (1951) reported that lower class children appear to be more withdrawn in verbal interactions than their middle class counterparts.

Not all the literature agrees, however, that social class is a salient feature of language development. La Civita, Kean, and Yamamoto (1966) found no social class differences when studying the relationship between SES and the acquisition of grammar of children in grades two, four, and six. Other researchers (Brown and Frazer, 1964) criticize the studies of social class and verbal behavior, and contribute the conflicting results in this area to the measures commonly used in the experiments.

These studies raise two important questions regarding social class and language development. First, does a relationship exist between the two, and second, what are the explanations for a difference in language functioning between social classes, if a difference does in fact exist?

Milner (1951) attributed lower class children's poorer performance on language activities directly to the economic aspects of the environment. For instance, these children possess fewer books, and the parents are usually not as well educated. Furthermore, Milner (1951) indicated that in lower class homes, adults do not read to their children as much as middle and higher class families. John (1967) pointed out that the middle class child has an advantage on tasks requiring precise and somewhat abstract language. These skills evidently are developed by the opportunity to learn to categorize and integrate information which requires specific feedback and careful tutoring. John (1967) further points out that such attention is not often as available in lower class families.

In considering the child's daily environment as an influence, Deutsch (1963) postulated that the overall "signal to noise ratio" influences their language. This means that the child's environment is characterized by a high noise level and the child will have a tendency to inattend to both meaningless and meaningful stimuli as an attempt to decrease the noise level.

Another factor regarding the environment of the lower class is one which often arises out of necessity. Deutsch, Jenson and Katy (1968) noted that the child rearing duties in lower class homes often are assumed by a number of persons, both adults and older children. This could have effects on the child's language development. Rhiengold and Bailey (1959), for instance found that children who had a single mothering experience excelled those children who had six to eight mother surrogates in the area of vocalization.

The other major area of research dealing with social factors and language development concerns the pattern of parent-child interaction. Jensen (1968) indicated that the relatively undivided attention of the mother during the first two to four years of a child's life is a prime factor in language development. He further stated that if the mother's time is more divided in the lower class family the results of verbal testing are clearly predictable. Likewise, Stewart (1964) attributed much of language development to the influence of peers. One classic study in this area was performed by Luria and Yudovich(1959). Their study involved a pair of twins who had severely retarded language as a result of spending almost all their time exclusively with each other. When the twins were separated and given appropriate verbal stimulation and training, their verbal behavior became more characteristic of the "normal" child. Apparently this lack of an appropriate language model has its effects on verbal development and is more commonly found in the lower class home.

Another interesting characteristic of parent-child interaction reported in the literature pertains specifically to the style of communication used in the home. Bernstein (1958) suggested that social class differences in childrens' cognitive (including verbal) functioning resulted in social class linked differences in the modes of communication. Kamii and Radin (1967) indicated that there is less inclination for the lower class parent to communicate verbally with her child, resulting in less exposure to models and less corrective feedback. Jensen (1968) noted that this lack of differential reinforcement resulted in poorer auditory discrimination which facilitates language acquisition.

The majority of these and other studies have not considered race or ethnic background as a separate independent variable. Several studies, however, have dealt with both social class and race, resulting in interesting meaningful conclusions. Lesser, Fifer and Clark (1965) examined language (as measured by vocabulary) in terms of patterns and relative levels of first grade students from four ethnic backgrounds, each divided into lower and middle social class subgroups. The results indicated that ethnic background affected the pattern of verbal activities, while social class affects the level of scores on verbal activities. John (1967) found that there was a linguistic lag for both lower class black children and lower class white children. It would seem imperative that any study concerning language development and social class should either consider race or ethnic background as an independent variable or should systematically exclude it to avoid the possibility of confounding effects.

Social Class and Dichotic Performance

Could the factors mentioned in the previous section (or other factors) have an effect on the maturational process of children from differing social classes? Recently, several studies have demonstrated that children from lower socioeconomic areas show less of a right ear effect on dichotic listening tasks than do children from higher socioeconomic areas (Kimura, 1967; Knox and Kimura, 1970). These results led Kimura (1967) to hypothesize that lower SES children may be at an earlier stage of development of cognitive (including language functions) as compared to higher SES children. This hypothesis is based on receptive language ability, while most studies have dealt with expressive language abilities (e.g. vocabulary tests).

Geffner and Hochberg (1971) specifically studied socioeconomic level as a variable within a dichotic listening paradigm. Their findings generally agree with those reported by Kimura (1967). They found that although children from low socioeconomic areas do demonstrate right ear superiority for verbal stimuli, the degree of this superiority is less than that observed for children from middle socioeconomic areas. Geffner and Hochberg (1971) point out that one explanation for poorer performance on the dichotic listening task by the lower SES children could be malnutrition which "has been shown to be a significant factor affecting the general growth and development of children in all impoverished areas".

Geffner and Hochberg's findings, however, must be interpreted with caution. They point out that socioeconomic differences frequently include intellectual and racial differences. These factors alone could have contributed to the difference in asymmetry scores. Dorman and Geffner (1974) in a later study specifically state that one nonenvironmental variable which may have affected the outcome was that the large proportion of the children in the low socioeconomic group was black. They state "conceivably the delayed lateralization of speech found for the low SEC population may have been a racial effect interacting with socioenvironmental variables". Dorman and Geffner attempted to clarify the effects of race by using both black and white subjects from low and middle socioeconomic classes. Their data indicate that all groups evidenced a significant right ear advantage, and that the magnitude of this advantage did not differ as a function of race or socioeconomic class. This suggests that low SES subjects achieve left hemisphere specialization for speech at the same rate as higher SES subjects.

Another explanation for the difference in outcome between the Dorman and Geffner (1974) and the Geffner and Hochberg (1971) studies could have been due to the difference in the population sampled. Dorman and Geffner (1974) argue that their subjects did not come from as "deprived" an environment as those in the earlier study. Geffner and Hochberg (1971) argue that their "abnormal rearing conditions" resulted in a retarded rate of cerebral lateralization. Dorman and Geffner offer an alternative explanation

> ....abnormal rearing conditions engender Ss who function at very low cognitive and motivational levels...... it would appear necessary to present four

> and five year old very low SEC Ss with a relatively simple dichotic test (e.g. dichotic syllables) in a situation which would maximize the Ss motivational level.

Summary

The development of the dichotic listening procedure has added a new dimension to the area of child development. It allows an investigator to study a correlate of a physiological process, and more importantly the effects of various independent variables on that process. Thus far, the majority of research has dealt with this latter problem. Ultimately, this knowledge can be used for prediction and remediation of various behaviors. Recent evidence exists, in fact, which suggests that dyslexia could be a result of neurological lag. Satz and Sparrow (1970) postulated that developmental dyslexia is not a unitary syndrome but rather a lag in the maturation of left hemisphere which delays those skills which are in primary ascendancy at difference chronological ages.

Another area relates to the development of receptive language in children. This has been the focus of the present review. Several questions and problem areas have been delineated in the process. It is to these questions that this study will address itself. These are:

1) At what age does ear asymmetry take place for verbal material, and does the magnitude of the ear asymmetry increase developmentally with age?

2) Does the ear asymmetry differ for boys and girls?

3) Does socioeconomic status have any effect on ear asymmetry?

The answer to the first question, based on the majority of research in this area, indicates that the lateralization process takes place early in childhood, possibly as early as age three. These findings, however, must be interpreted with caution considering the possible procedural artifacts which account for the contradictory findings of decreased lateralization with age. With regard to the second and third questions, the literature is even more contradictory. About half of the research supports a lag in lateralization in boys and in lower SES subjects. The other half show no differences in lateralization when looking at sex and SES as independent variables. It was pointed out that other variables such as intelligence, race, and home background could account for these conflicting results.

There is a need to reexamine these questions making appropriate procedural changes and being rigorous in subject selection. By using sufficient task complexity (in the stimulus procedures), proper developmental changes can be studied. By considering the variables of intelligence and race, their effects, if any, can be assessed.

CHAPTER III

METHOD

Subjects

Twenty-eight subjects (14 boys and 14 girls) were selected at each of three age levels (5-8-11), resulting in a total population of 84. The children were selected from the Lamar Elementary school in the Goose Creek Consolidated Independent School District. The boys and girls selected at each grade level were approximately the same age chronologically (± 4 months). The subjects included in the study were white, right handed, and from both a lower and a middle socioeconomic level. Any subject with a history of neurological and/or hearing problems was eliminated from the study.

Initially a pool of subjects was established who met all the criteria. The experimental subjects were randomly selected from the pool.

Materials

Subtest two of the Harris Tests of Lateral Dominance (See Appendix A) was used to determine handedness. Also, the free lunch lists, parent occupations and teachers' recommendations were used to determine socioeconomic level. The parent occupations for those children classified lower SES can be found in Appendix B. The Dichotic Listening Test (Satz, 1975), a Sony Dual Channel Tape Recorder and a Koss AV-19 stereo headphone set were used to collect the ear asymmetry scores. The Peabody Picture Vocabulary Test (Dunne, 1959) was routinely administered to all subjects to obtain added information.

Recording Method

The following describes the recording method used in developing the dichotic listening tapes (Satz, 1975). Twelve digits were selected from 1 to 20, with 2 digit numbers balanced between channels. The three syllable "eleven" was omitted, as was 6, 7, 16, 17, 19, and 20. The remaining digits were first recorded using a female voice in a soundproof chamber using a Revox A77 stereophonic tape recorder. Punch cards were then prepared which specified the desired stimuli, list length, number of trials, presentation rate, intertrial interval, unilateral channel delays, number of trials/channel delay, and order of channel delay. This information was fed into a computer program developed by Schultz Electronics, Gainesville, Florida. The master tape sequences were subsequently generated via an 1800 IBM computer back onto the Revox recorder to form the experimental tape. This computer program produces very sophisticated and electronically sound tapes. Optimal synchronization in stimulus onset (simultaneity ±2msec.) can also be achieved with this program. After the three digit pair tape was developed, a second tape was prepared which consisted of only two digit pairs. This was achieved by carefully re-recording the first tape and erasing the final digit pair.

Procedure

All subjects were tested in a small, quiet room in the school that was used for hearing and eye tests. The subjects listened to the digit sequences presented by the stereophonic tape recorder via the stereo headphones. Thirty series of three digit pairs were presented at the rate of two pairs/second and at an intensity level of approximately 70db. The three digit tape was administered only to the older children (8, 11). The two digit tape was administered to the younger children. In addition, five series of digit pairs were presented to each subject as practice, and was not included in the final analysis. Each subject was asked to remember as many digits as possible in any order (See Appendix C). The subjects' responses were recorded on a standard scoring sheet (See Appendix D). The headphones were reversed midway throughout the experimentation to counterbalance any effects of digit complexity. The dependent variable in this study was the total recall (correct) per ear. Each individual score for the younger children was multiplied by 3/2.

Statistical Analyses

The data was analyzed by a method similar to that used by Satz et al (1974). This method is called the stepwise regression model. In such a model, the experimenter formulated hypotheses about the data in terms of mathematical models, analyzed these using regression equations and compared them to their relative efficiency in predicting the data. The analysis gave insight into the relative strengths of the relationships between proposed independent variables and a dependent variable.

This method generated a coefficient of determination (R^2) for each model. This statistic is the square of the multiple correlation coefficient and gave an indication of the percentage of the total variance accounted for by each model. Thus any two models could be compared for predictive accuracy by comparing the difference of their R^2s with F tests.

The advantage of using such an analysis is that the experimenter could tailormake specific statistical tests, and avoid the limitations or conformity of the types of analyses generated by standard statistical procedures. The disadvantage is that it gives no indication of statistical significance. Therefore, in addition to the stepwise regression, an analysis of variance was performed to determine the significance of sex, socioeconomic status and age on the right and left ear scores. Also, all the possible interactions of these variables were studied.

CHAPTER IV

RESULTS

The analysis of the data from the 84 subjects is presented in this chapter. The presentation of the data is centered around three basic questions. These are

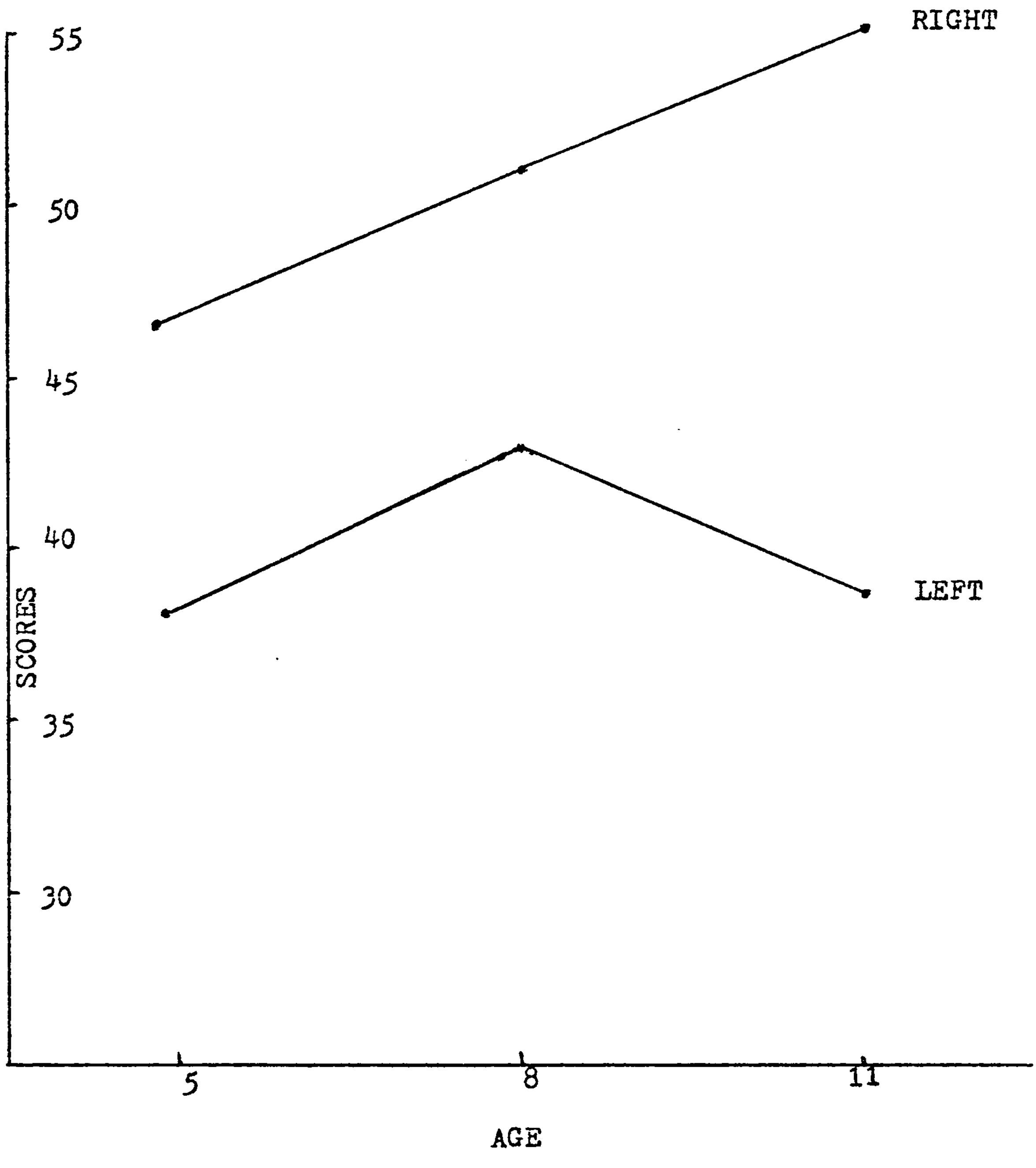
1) What is the relationship between age and ear asymmetry?
2) What is the relationship of sex and ear asymmetry?
3) What is the relationship of socioeconomic status and ear asymmetry?

Also, the effects of I.Q., if any, are considered. Three separate analyses are discussed relating to these questions. The first is simply an inspection of the means for all the groups. Secondly the results of the ANOVA is presented, and finally the results of the stepwise regression is shown.

Figure 1 is a representation of the overall means for each age group for both the right and the left ears. There is an almost linear relationship for the right ear, demonstrating increasing right ear scores with age. Conversely, the left ear scores form a curvilinear relationship with the zenith at the eight year old level. The distance between the right ear and the left ear scores are very similar for the five and the eight year olds, but increases for the eleven year olds. This is indicative of a greater ear asymmetry for the eleven year olds.

FIGURE 1

Right and Left Ear Scores by Age



The right and left ear scores for the boys and girls are depicted in Figure 2. Right ear scores were consistently higher than the left ear scores for both boys and girls. Differences were shown, however, principally at the five and the eleven year old level. The boys at age five had higher right ear scores and lower left ear scores. At age eight, the right and left ear scores were almost identical for both sexes. At the eleven year old level, there was a reverse of what was seen at the five year old level with the girls showing higher right ear and lower left ear scores.

Ear asymmetry scores for the middle and low socioeconomic subjects are presented in Figure 3. An inspection of these means for each age level would prove beneficial. At the five year level, the higher SES subjects recalled more digits with the right and the left ear than did the lower SES subjects. However, the difference between the right and the left ear scores are very similar; the higher SES children simply recalled more digits. At the eight year old level, the lower SES subjects recalled more digits with the right ear and fewer with the left ear than did the higher SES subjects. At the eleven year old level, however, the higher SES children scored higher with the right ear and lower with the left ear than the lower SES subjects.

A three way analysis of variance was performed to determine the effects of the following variables on right and left

FIGURE 2

Right and Left Ear Scores by Sex

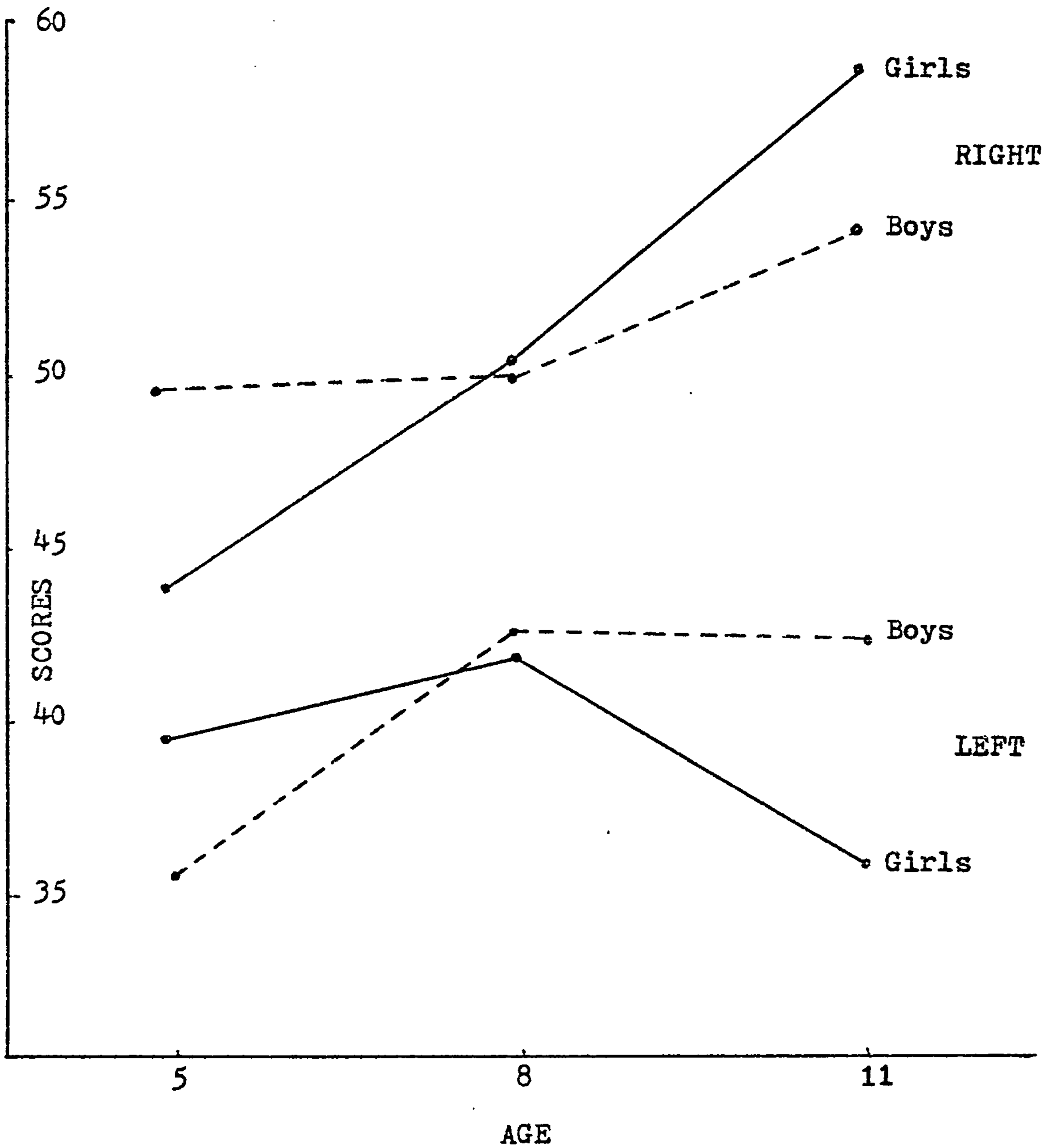
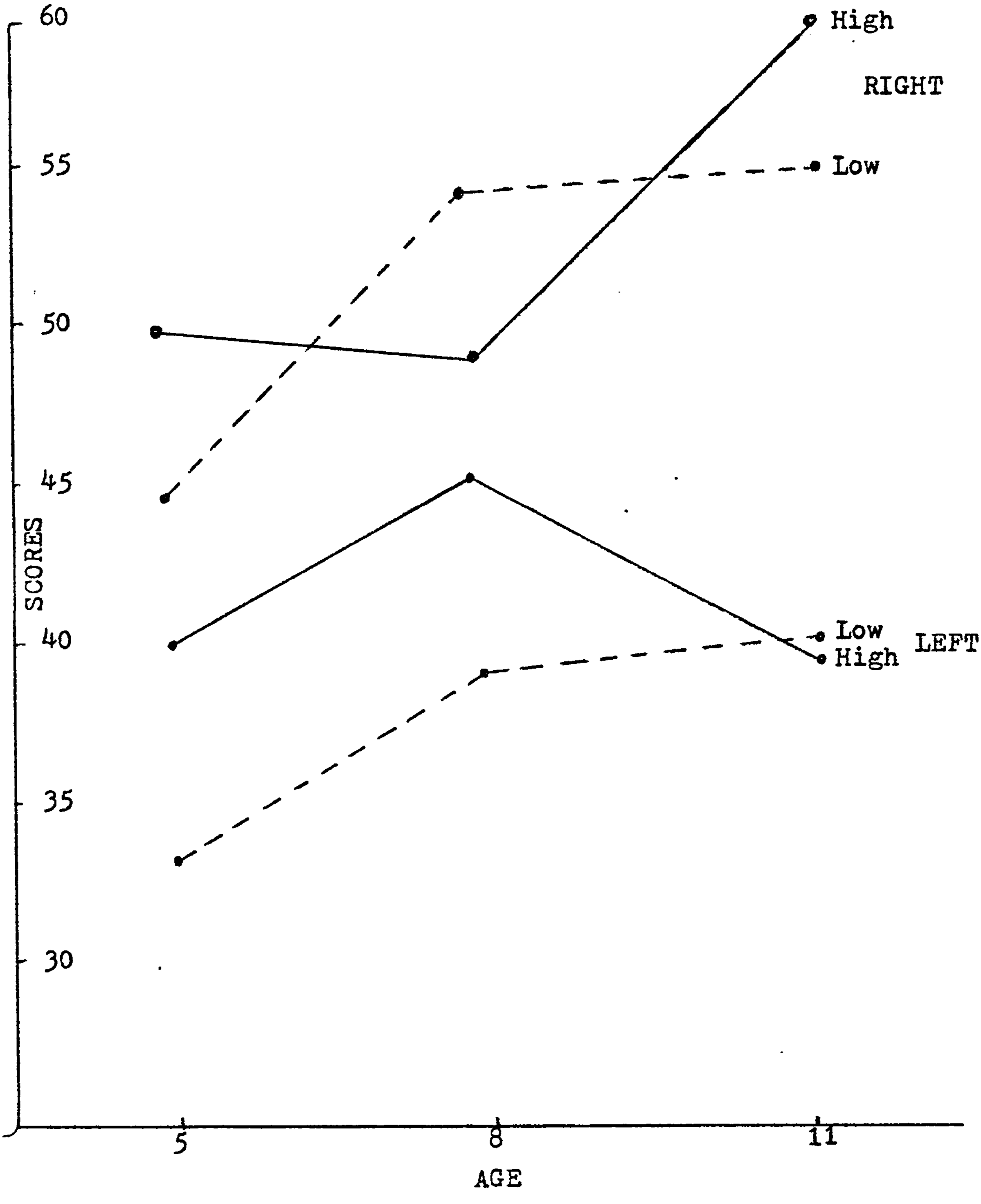


FIGURE 3

Right and Left Ear Scores by Socioeconomic Status



ear recall scores; age, sex and socioeconomic status. Also, the interaction of these independent variables were examined to determine their possible significance in affecting right and left ear scores. Table 1 displays the summary table for the analysis of variance using the right ear scores as the dependent variable. Significant differences were found between the different age groups with regard to right ear scores, $F(2, 72) = 4.448$; $p < .05$. No other variable yielded a significant difference.

TABLE 1

ANOVA Summary Table for Right Ear

Source	df	F	p
Within Cells	72	-	-
Age	2	4.448	$< .05$
Sex	1	.139	n.s.
SES	1	.056	n.s.
Age *Sex	2	.648	n.s.
Age *SES	2	1.274	n.s.
Sex *SES	1	2.781	n.s.
Age *Sex *SES	2	.251	n.s.

The analysis of variance indicated that there was a significant difference between the three age groups for right ear recall but did not specify which age group was significantly different from the others. For this information a confidence interval following the analysis of variance (scheffe test) was conducted (Lathrop, 1969). Results from this test indicated that while there was considerable difference between ages five and eight and ages eight and eleven, the only significant difference was between ages five and eleven.

Table 2 shows the results of the analysis of variance using the left ear scores as the dependent variable. As can be seen, there was no signifcant differences of the scores using sex, age and socioeconomic status as the independent variables.

TABLE 2

ANOVA Summary Table for Left Ear

Source	df	F	p
Within Cells	72	-	-
Age	2	1.198	n.s.
Sex	1	.273	n.s.
SES	1	1.607	n.s.
Age *Sex	2	1.099	n.s.
Age *SES	2	1.087	n.s.
Sex *SES	1	.281	n.s.
Age *Sex *SES	2	.293	n.s.

Since age did have a significant effect on the right ear scores, but not the left ear scores, it was decided to study the right and left ear scores for each age group separately. Therefore, an analysis of variance was conducted within each age group comparing the right and the left ear scores. Table 3 is a summary of the analysis within the 5 year age old group. This analysis showed a significant difference, $F(1, 55) = 6.193$; $p < .05$, between right and left ear scores.

TABLE 3

ANOVA Summary Table for Five Year Olds:
A Comparison of Right and Left Ear Scores

Source	df	F	p
Between	1	6.193	$< .05$
Within	54	-	-

Tables 4 and 5 summarize the analysis of right and left ear scores for the eight and eleven year olds, respectively. There were significant differences for the eight year old group, $F(1, 54) = 6.236$; $p < .05$ and the eleven year old group, $F(1, 54) = 21.342$; $p < .001$. The F statistic increased with age demonstrating a greater difference between right and left ear scores as age increased.

TABLE 4

ANOVA Summary Table for Eight Year Olds:
A Comparison of Right and Left Ear Scores

Source	df	F	p
Between	1	6.236	$<.05$
Within	54	-	-

TABLE 5

ANOVA Summary Table for Eleven Year Olds:
A Comparison of Right and Left Ear Scores

Source	df	F	p
Between	1	21.342	$<.001$
Within	54	-	-

A stepwise regression analysis was next performed to promote insight into the relative strengths of the relationships between proposed independent variables and the dependent variable. This analysis first found the single variable model which produced the largest R^2. For each of the other independent variables it calculated an F statistic reflecting that variables contribution to the regression model were it to be included. Variables were added one by one until no variable produced a significant F. A correlation matrix as well as a summary table for those variables included and not included in the final regression equation were produced.

Table 6 is a display of the correlation matrix of all the variables included in the regression analysis. The correlations can be interpreted as Pearson Product Moment Correlations. Of interest are the following correlations: right ear and age, .321, left ear and age, .092, IQ and socioeconomic status, -.363, IQ and right ear, .052, IQ and left ear, .252, and right and left ear, -.420.

TABLE 6

Correlation Matrix

Variable	Age	Sex	SES	Right Ear	Left Ear	IQ
Age	1.000					
Sex	.000	1.000				
SES	.029	.024	1.000			
Right Ear	.321	-.037	-.021	1.000		
Left Ear	.092	-.065	-.132	-.420	1.000	
IQ	-.011	-.087	-.363	.052	.252	1.000

The regression analysis first determined the best predictive model using one variable for the right ear scores. The significance level for inclusion into this model was .05. Next, the regression analysis added the other variables one by one to the best one variable model to find the best two, three and four variable model. Again, inclusion of a variable in a model was dependent on its satisfying the .05 level of significance. In other words, for a variable to be included in a model, it had to add significantly to the predictive accuracy.

The best single model for the right ear scores was shown to be age. The age model in fact had a R^2 of .3209 (see Table 7), indicating that this model accounted for approximately 33% of the total variance. The age model had an F statistic of 9.412 (1, 82) or a significance of .0029 for inclusion. When other variables were added to this model, however, there was no significant increase in predictive accuracy. Table 8 shows a summary of the variables not included in the final regression equation.

TABLE 7

Variables Included in the Final Equation: Right Ear

Variable	Partial Correlation Coefficient	Partial F Value	Significance Level	R^2
Right Ear	.628			
Age	.321	9.412	.0029	.3209

TABLE 8

Variables Not Included in the Final Equation: Right Ear

Variable	Partial Correlation Coefficient	Partial F Value	Significance Level
IQ	.0581	.274	.602
Sex	-.0323	.125	.725
SES	-.0321	.083	.773

A stepwise analysis was also performed using the left ear scores as the dependent variables. Again, only the one variable model was significant and included in the final regression equation. The one variable model for predicting left ear scores as IQ, which accounted for approximately 25% of the variance. (See Table 9)

TABLE 9

Variables Included in the Final Equation: Left Ear

Variable	Partial Correlation Coefficient	Partial F Value	Significance Level	R^2
Left Ear	.193			
IQ	.252	5.563	.0207	.252

The partial correlation, F value and significance level for those variables not included in the final regression equation are shown in Table 10.

TABLE 10

Variables Not Included in the Final Equation: Left Ear

Variable	Partial Correlation Coefficient	Partial F Value	Significance Level
Age	.0975	.772	.380
SES	-.0454	.167	.684
Sex	-.0448	.163	.588

The stepwise regression analysis demonstrated that for the right ear, age alone was the best single model for prediction. IQ, sex and SES in that order added minimally to the predictive accuracy. Conversely, IQ was the best single model in predicting left ear scores with age, SES and sex adding minimally to the regression model.

Because IQ could have affected many scores and in fact accounted for 25% of the variance of left ear scores, an analysis of variance was performed to determine if the IQ scores of each age group were significantly different. If this were the case, the differences in ear asymmetry of the three groups could have been due to IQ. The results of this analysis are summarized in Table 11.

TABLE 11

ANOVA Summary Table for IQ

Source	df	F	p
Between	2	1.0966	$< .05$
Within	81	-	-

The three age groups were not significantly different with respect to IQ.

Chapter V

DISCUSSION

The vast amount of literature regarding dichotic listening studies demonstrate the presence of a right ear advantage when verbal material is presented (Kimura, 1961; Nagafuchi, 1970). The present findings confirm these results. If, in fact this right ear advantage for dichotically presented material can be interpreted as a result of speech lateralization of the brain, the results lend strong support for left hemisphere dominance for speech.

The right ear advantage in dichotic listening is not new. The principle objective of the present study was to experimentally explore the development of the ear asymmetry phenomenon with regard to several parameters. Specifically, the effects of age, sex, IQ and socioeconomic status on ear asymmetry scores were studied. As was reported in Chapter III, this was accomplished by administering the dichotic listening tasks (Satz, 1975) to 84 children. The children were divided into three age groups and subgrouped by sex and socioeconomic status. A rough estimate of the child's intellectual functioning was also established. Of particular importance in the present study was the use of a less complex (2 digit) tape with the younger children and a more complex (3 digit) tape with the older children. This was done in an attempt to eliminate the ceiling effect seen in many dichotic studies (Kimura, 1963; Knox and Kimura, 1970). The ceiling effect has resulted in an increase in overall recall for both ears which could be misinterpreted as a decrease in lateralization with age.

Summary of Findings

The statistical treatment of the data revealed the following:

1) The means for the various age groups demonstrate that there was an increase in right ear scores with age. Conversely, the left ear scores stayed approximately the same. If a greater disparity between ear scores can be interpreted as increased lateralization, these results clearly substantiate the idea of increased lateralization with age. Furthermore, these results indicate that the use of dichotic tasks of different complexity can eliminate the ceiling effect and give more credence to the analysis of other developmental parameters.

2) A comparison of the means for boys and girls indicates that contrary to much of the literature (Kimura, 1967; Bryden, 1970), the boys demonstated higher right ear and lower left ear scores at an early age. The girls, however, eventually caught up (age 8) and ultimately reversed the trend (age 11). This finding suggests that boys show a greater ear asymmetry at an early age but do not change dramatically as they get older. On the other hand, the girls started slower but had increasingly higher right ear and lower left ear scores with age.

3) A comparison of the means for higher and lower socioeconomic children showed somewhat puzzling results. As demonstrated by Dorman and Geffner (1974) there was very little difference in the two groups at age five. However, the lower SES children actually scored higher on right ear and lower on left ear than did the higher SES children at age eight. This clearly violates the findings of Geffner and Hochberg (1971) who showed a reverse trend. However, at age eleven, there was this reverse with the higher SES children demonstrating greater ear asymmetry.

4) Of the three independent variables studied to determine the effects on right ear scores, only age was significant. These results agree with the majority of the literature (Nagafuchi, 1970; Kimura, 1961a) regarding increased ear asymmetry with age. Likewise, these results confirm the findings of Berlin, Hughes, Lowe-Bell and Berlin (1973) and Dorman and Geffner (1974) concerning sex and SES respectively. The present findings are somewhat at variance with Kimura (1967) and Geffner and Hochberg (1971). The correlations between right ear scores and sex and SES were both negative (-.037 for sex, -.021 for SES). The correlation between right ear scores and age was +.321.

5) There was a significant difference between right ear and left ear at every age level studied. This suggests that as early as age five, speech lateralization has at least been partially developed. This finding agrees with both Kimura

(1963) and Nagafuchi (1970) who noted a definite right ear superiority at early ages.

6) There was no significant difference on left ear scores for the sex, SES or age groups. Again, the correlations between left ear scores and sex and SES were negative (-.065 and -.132 respectively). The correlation between left ear scores and age was slightly positive (+.092).

7) The correlation between right ear and left ear scores was -.420. This suggests that as the right ear scores increase, the left ear scores decreased. This adds support for the use of different dichotic tasks for different age groups. When using the same dichotic task, an increase in right <u>and</u> left ear scores is often noted.

8) The regression analysis revealed that age was the best single predictive model for right ear scores. Furthermore, the addition of no other variable added significantly to the predictive accuracy. Age, in fact, accounted for 33% of the total variance of the right ear scores. Conversely, IQ was the best predictor of left ear scores, accounting for 25% of the total variance.

9) The IQ scores for the different age groups were not significantly different. This eliminated the possibility of the ear asymmetry differences being due to IQ.

Implications

The results of the present study generally agree with the literature regarding right ear advantage in dichotic studies. Furthermore, the results substantiate the findings of Kimura (1967) and Nagafuchi (1970) that this right ear advantage occurs as early as age five. However, significant right ear advantage at age five should not imply complete unilateral hemispheric lateralization. This problem must be examined within a developmental context. Ultimately, a study should be undertaken which answers the question"At what age, if any, does the ear asymmetry asymptope?" This question has been felt by some to represent a more substantive problem than age of onset (Satz, 1974). If, for example, the magnitude of the ear asymmetry did not increase and was at its maximum at onset, it would seriously question the validity of a brain maturation model and the reports of recovery from aphasia after brain injury (Satz et al, 1974; Lenneberg, 1967; Basser, 1962). As reported in Chapter II, many studies have demonstrated a decrease in ear asymmetry with age. These studies, however, were shown to have procedural artifacts which could have accounted for the unexpected findings.

The present findings, however, clearly demonstrate the increase of ear asymmetry with age and points to the efficacy of using dichotic tasks of different complexity with various age groups. Also, assuming greater asymmetry denotes increased lateralization), the present results do not disagree with the aphasic studies (Basser, 1962) which show that as a child gets older it becomesmore difficult for the right hemisphere to assume speech functions. Furthermore, by showing a predictable developmental increase with age, the possibility of confounding effects when studying other variables will be greatly decreased.

The finding of no significant sex differences on dichotic performance agrees with Kimura (1963) but disagrees with her later study (Kimura, 1967). The present study also took intelligence into account, a variable which Kimura stated could have affected her contradictory findings. The IQ levels were similar for both boys and girls, suggesting that intelligence could not account for the lack of significance.

With regard to socioeconomic status, the present study disagrees with Geffner and Hochberg (1971) but agrees with Dorman and Geffner who found no significant difference between differing socioeconomic levels. Geffner and Hochberg auggested that racial and intellectual differences could have accounted for the differences in their groups' performance on dichotic tasks. The present study eliminated race as a variable and took into account intellectual ability. Interestingly, the lower SES children had significantly lower IQ's overall yet did not perform significantly lower on the dichotic tasks. This actually tends to strengthen the position that SES has no effect on the ear asymmetry phenomenon.

Another factor which should be discussed is the possible role of memory in this and other dichotic listening experiments. It seems logical that as a child gets older, his capacity for role memorizing digits should increase. This has led to the so called "ceiling effect" previously discussed. Hopefully the use of the different dichotic tapes will eliminate a larger portion of this problem. The apparent effect of memory in the present study was to increase the right ear recall and maintain the left ear recall. While this shows increased ear asymmetry, it still includes a greater number of digits recalled at ages eight and eleven. If then, one can assume that memory could play an important part in the total number of digits recalled, the relationship of sex and SES to memory could be established. While this was not the intention of this study, a glance at the data can suggest areas for further research. For example, there appears to be little difference in the total number of digits recalled between boys and girls. On the other hand, higher socioeconomic children tended to recall more digits than the lower SES children.

Out of the present study, several implications and applications emerge. First, the use of different dichotic tasks for different age groups accurately demonstrated the expected increase of ear asymmetry with age. This fact is consistent with the vast majority of the clinical literature on brain maturation (Lenneberg, 1967) and recovery from aphasia (Basser, 1962). It thus adds support to the uses of dichotic listening in studying the lateralization phenomenon. Secondly, because the study demonstrated the presence of a brain maturation process it allowed the investigator to empirically explore the effects of several independent variables on the maturational process. Specifically, it was shown that sex and socioeconomic status did not have any significant effect on the lateralization process. These results, when looked at in the light of the maturational/developmental theories of disabilities offers added information. While such "disabilities" as dyslexia, or receptive aphasia may be the result of a maturational lag, the present results suggest that certain characteristic groups are not more likely to have them. Satz et al (1974) succinctly stated

> Additional support for normative findings would certainly provide a more substantive context for the investigation of possible hemispheric lag mechanisms in children who are dyslexic or subject to marked cultural deprivation. (p.6)

Since the effects of several independent variables were assessed in the present study, it would be beneficial to apply this information to further research. The lack of significance of sex and SES and the apparently important role of age and IQ in the ear asymmetry phenomenon specifies the concerns that future researchers shold have. Such a future study might look at the ear asymmetry of readers vs. nonreaders, taking into account age and IQ. Also a study correlating reading measures with dichotic listening scores would prove beneficial. Such a study might lead to the use of the dichotic procedure for prediction of certain academic(e.g. reading) behaviors.

Satz and Friel (1973) attempted to use the dichotic listening procedure as a predictor of high and low risk children who ultimately developed reading problems. The study was carried out in the early phases of kindergarten before formal reading instruction had begun. They found that the total number of digits recalled were highly different ($p < .005$) between the two groups. It seems possible that a correlational study could be made comparing reading measures and several dichotic listening scores (total number of digits, right minus left ear scores, right minus left/total) to determine the most sensitive measure in predicting academic performance.

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APPENDIX A

SUBTEST TWO OF THE

HARRIS TESTS OF LATERAL DOMINANCE

SUBTEST TWO OF THE

HARRIS TESTS OF LATERAL DOMINANCE

Demonstrate your hand preference for each of these tasks:

1. Writing
2. Eating
3. Brushing teeth
4. Striking a match
5. Inserting a key in a lock
6. Throwing a ball
7. Combing hair
8. Shooting a rifle
9. Holding a tennis racket
10. Activating a small cigarette lighter

APPENDIX B

PARENT OCCUPATION FOR LOWER SES CHILDREN

PARENT OCCUPATION FOR LOWER SES CHILDREN

Subject number	parent occupation
1	iron worker
2	cook
3	waitress
4	baby sitter
5	derrickman
6	structural painter
7	waitress
8	waitress
9	roughneck
10	welder
11	iron worker
12	railroad engineer
13	laborer
14	night guard
15	insulater
16	roughneck
17	mechanic
18	oiler
19	driller
20	machinist
21	unemployed
22	steel worker
23	process technician
24	pipe worker
25	machinist
26	tire service
27	truck driver
28	steel worker
29	welder
30	housewife
31	cook
32	pipe fitter
33	cable splicer
34	machinist
35	maintenance
36	welder
37	paint and body man
38	roughneck
39	derrickman
40	mechanic
41	unemployed
42	waitress

APPENDIX C

SCORING SHEET

DICHOTIC LISTENING

Subject ____________

____

School ____________

E ____________

Instructions:

Start trials with left earphone (one with cord) on S's left ear. Reverse headphones after trial 15. Use red felt pen to strike out #s given

Tape recorder used # ________

RC 1-15 ________

RC 16-30 ________

LC 1-15 ________

LC 16-30 ________

RC total ________

LC total ________

RC - LC ________

RC + LC ________

1.	1	2	3	4	5	8	9	10	12	13	14	15	18
2.	1	2	3	4	5	8	9	10	12	13	14	15	18
3.	1	2	3	4	5	8	9	10	12	13	14	15	18
4.	1	2	3	4	5	8	9	10	12	13	14	15	18
5.	1	2	3	4	5	8	9	10	12	13	14	15	18
6.	1	2	3	4	5	8	9	10	12	13	14	15	18
7.	1	2	3	4	5	8	9	10	12	13	14	15	18
8.	1	2	3	4	5	8	9	10	12	13	14	15	18
9.	1	2	3	4	5	8	9	10	12	13	14	15	18
10.	1	2	3	4	5	8	9	10	12	13	14	15	18
11.	1	2	3	4	5	8	9	10	12	13	14	15	18
12.	1	2	3	4	5	8	9	10	12	13	14	15	18
13.	1	2	3	4	5	8	9	10	12	13	14	15	18
14.	1	2	3	4	5	8	9	10	12	13	14	15	18
15.	1	2	3	4	5	8	9	10	12	13	14	15	18

REVERSE HEADPHONES

16.	1	2	3	4	5	8	9	10	12	13	14	15	18
17.	1	2	3	4	5	8	9	10	12	13	14	15	18
18.	1	2	3	4	5	8	9	10	12	13	14	15	18
19.	1	2	3	4	5	8	9	10	12	13	14	15	18
20.	1	2	3	4	5	8	9	10	12	13	14	15	18
21.	1	2	3	4	5	8	9	10	12	13	14	15	18
22.	1	2	3	4	5	8	9	10	12	13	14	15	18
23.	1	2	3	4	5	8	9	10	12	13	14	15	18
24.	1	2	3	4	5	8	9	10	12	13	14	15	18
25.	1	2	3	4	5	8	9	10	12	13	14	15	18
26.	1	2	3	4	5	8	9	10	12	13	14	15	18
27.	1	2	3	4	5	8	9	10	12	13	14	15	18
28.	1	2	3	4	5	8	9	10	12	13	14	15	18
29.	1	2	3	4	5	8	9	10	12	13	14	15	18
30.	1	2	3	4	5	8	9	10	12	13	14	15	18

APPENDIX D

STANDARD SET OF INSTRUCTIONS

STANDARD SET OF INSTRUCTIONS

In just a minute I'm going to put these headphones on you and we are going to play a little game. You are going to hear different numbers in both of your ears at the same time. The tape may sound a little funny at first. I want you to remember as many numbers as you can and tell them to me. It dosen't matterwhat order you tell them to me. Do you have any questions? Good, lets begin.

(Give five practice trials cueing the response at the pause after each trial presentation.)