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# Left-right differences in the auditory perception of verbal material by children ages eight and fourteen

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# LEFT-RIGHT DIFFERENCES IN THE AUDITORY PERCEPTION
# OF VERBAL MATERIAL BY CHILDREN,
# AGES EIGHT AND FOURTEEN

By

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# CHAPTER I

# INTRODUCTION AND BACKGROUND

## Introduction

Recently, there has been considerable interest displayed concerning auditory perception in the normal human being. It is interesting to note that, although we receive for the most part essentially the same sensory information with both right and left ears, there is some evidence to suggest that our perception of the information received differs with reference to the two ears. That there is a difference has been recognized for some time, but its nature has been quite uncertain until recently.

Perhaps it is worthwhile at this point to cite several views on perception and to differentiate it from sensation or reception. Andreas (1, p. 270) relates perception to sensation in saying that "perceptions often seem to be either a synthesis or an analysis of sensations . . ." Eisenson (13) states that

> . . . perception is the intellectual process by which meaning is derived from a given stimulus situation. It is the organizational process through which the individual is able to understand the significance of what goes on about him. Sense perception is the process of interpretation of sensory stimuli.

Strauss and Lehtinen (26) further define perception as

> . . . an activity of the mind intermediate (if one may academically separate processes which are psychologically simultaneous) between sensation and thought. It is the mental process which gives particular meaning and significance to a given sensation and therefore acts as the preliminary to thinking. It is the means by which the individual organizes and comes to understand the phenomena which constantly impinge upon him.

A large volume of material has been written about perception and it is felt that, for the purposes of this study, an exhaustive research of the literature in that area is not necessary. However, Solley and Murphy (24) set forth some conditions for perception which are pertinent to the present investigation. (1) Perception is inferred from behavior. (2) Before perception can occur a physical stimulus must be present and excite some sense receptor or receptors. They state further that a sense receptor may be stimulated without perception, but that perception never occurs without prior sense receptor stimulation. (3) Some observable overt response which cannot be made equally well in the absence of the stimulus must be present. In other words, it is difficult to determine if perception has taken place, if meaning has been given to the stimuli, in the absence of a response which can be observed.

The authors cited above attempt to define perception for us and distinguish it from other processes which are taking place within the organism. Perhaps the most workable definition of perception for the present study is an operational one, defined in terms of the responses received from the subjects. Operationally, then, perception is inferred from the verbal recorded responses of the subject.

Recent research has led to some conclusions with regard to differences in right-left perception in the adult human. Some investigation has also attempted to gain information on whether these differences also occur in children, to what extent they occur, and whether right-left differences in auditory perception change with age. Children are indeed more difficult subjects than adults in terms of motivation for the experimental situation and selection of appropriate stimulus material. As early as 1963, however, Kimura (18) presented spoken digits to children in such a way that different digits arrived simultaneously at the two ears. She felt that her study demonstrated a right-ear superiority in terms of accuracy of report for both boys and girls as early as age four. Kimura found a decrease in the difference between ears in the older groups which she explained as probably due to the higher overall efficiency of the older subjects on the test; that is, because of a relatively easy task, there was less scope for a difference between ears as subject increased in age. Yet, she still reported significant differences in favor of the right ear through age nine, the oldest age group tested, although she felt that the difference between ears was accentuated in the very young children. Differences found may have been somewhat inflated due to the fact that Kimura instructed her subjects to report what they heard, in any order they liked. Bryden (10) stated as a result of his 1963 study that left-right differences obtained by instructing order of report are much smaller than those obtained with free recall. This aspect of studies dealing with left-right differences in auditory perception of verbal material will be discussed more extensively in the Procedure portion of this paper.

Bakker (2) has more recently investigated right-left differences in auditory perception of verbal and non-verbal material by children, ages six to twelve. He found that retention of digit series was not significantly better by the right than by the left ear, but that retention of sound patterns was significantly better by the left ear than by the right. Perhaps the major difference between this study and that of Kimura was that the stimuli were presented to each ear separately. Bakker (2, p. 335) felt that his finding of no difference for verbal material may have been due to the fact that

> . . . the verbal material (digit series) was too simple compared with the nonverbal material (sound patterns) so that too small an appeal was made to the assimilation mechanisms responsible for ear asymmetry.

Although his data for verbal material was not statistically significant, Bakker's apparent finding of separating trends for ear dominance at approximately age 10 is felt to be pertinent to this study. He found indications that between the ages of 10 and 11 the left ear shows increasing dominance for nonverbal material while the right appears to take over for verbal stimuli. It is difficult to assess this finding objectively since Bakker reported only medians which may not adequately represent the actual distribution of results obtained. It is also difficult to correlate this study with that of Kimura as the age groups studied only partially overlapped. However, literature in the area of cerebral dominance does indicate that a transition from "equipotentiality" of the two hemispheres for language to a dominant language hemisphere takes place sometime during childhood. Brain (4, p. 29) suggests that

> Either hemisphere can function alone for language if the other is severely damaged early in life; . . . Hence, at birth, it would seem that the two cerebral hemispheres possess an equal potentiality for the localization of the speech functions, but there is a natural tendency, presumably inherited, for the large majority of individuals in the course of learning to speak to establish their speech centres in the left cerebral hemisphere. . . .

Lenneberg (19, p. 158), in discussing the development of language acquisition, notes that

> Between the ages of three and the early teens the possibility for primary language acquisition continues to be good; the individual appears to be most sensitive to stimuli at this time and to preserve some innate flexibility for the organization of brain functions to carry out the complex integration of subprocesses necessary for the smooth elaboration of speech and language. After puberty, the ability for self-organization and adjustment to the physiological demands of verbal behavior quickly declines. The brain behaves as if it had become set in its ways and primary, basic language skills not acquired by that time, except for articulation, usually remain deficient for life.

From data regarding hemispherectomies presented by Basser, Lenneberg (19, p. 158) infers that "*language learning* can take place, at least in the right hemisphere, only between the age of two to about thirteen." He indicates that this is probably also true of the left hemisphere from observations on language development in the retarded and in those who acquire deafness during early childhood. From a discussion on physical maturation, Lenneberg (19, p. 168) points out that all of the parameters of brain maturation studied (biochemical, structural and neurophysiological) show that by the time primary language acquisition comes to be inhibited, the brain also has reached its mature state, and cerebral lateralization is irreversibly established.

One basic difficulty with Lenneberg's discussion is that he fails to define the parameters of "primary language acquisition" and hence it is difficult to assess his statement that language learning can occur only between the ages of two and thirteen. In spite of this, however, it is felt that Lenneberg has presented some information which may be utilized in discussing cerebral dominance for verbal stimuli. Bakker's (2) indication of a critical age of ten years for cerebral dominance in the perception of verbal stimuli is not entirely consistent with evidence presented by Lenneberg. Further, Lenneberg's data would indicate that any study assessing cerebral dominance for perception of verbal stimuli should include subjects into the early teens to adequately assess the break at approximately age thirteen which he feels does exist.

## Background

A discussion of cerebral dominance and auditory perception necessitates a review of some relatively early research in the area of physiology concerned with representation of the two ears at the auditory cortex. Rosenzweig reported a study in which electrophysiological responses from the auditory cortex of anesthetized cats were obtained when the ear was stimulated with an auditory click (22). Responses of the auditory cortex were recorded at both cerebral hemispheres when acoustic clicks were delivered to first one ear and then the other. At each hemisphere, the response to stimulation of the contralateral ear was significantly larger in amplitude than the response of the ipsilateral ear. Although Rosenzweig pointed out that anatomical and functional differences between the anesthetized cats and the awake person are too great to be ignored, he indicates that clinical observations involving humans provide evidence that the representation of each ear is also greater in its contralateral hemisphere. Experiments in perception show that (1) stimulation of one ear can be discriminated from stimulation of the other ear, and (2) the experience caused by stimulation of one ear is affected by stimulation of the other ear; that is, there is binaural interaction (25, 29).

Rosenzweig further suggested that, at the auditory cortex of both cerebral hemispheres, each ear is represented by a population of "cortical units." The population representing the contralateral ear is larger than the population representing the ipsilateral ear. The two populations overlap; that is, some units belong to both populations. This notion of overlapping cortical units has also been postulated by Kimura (17) and will be discussed later in this chapter.

Thus, by the early 1950s it had been fairly well established that stimulation of one ear resulted in a more efficient response of the contralateral hemisphere than of the ipsilateral hemisphere. It remained to be discovered, however, that this response varied depending on the perceptual nature of the stimulatory material (i.e. linguistic vs. nonlinguistic) and on whether the stimuli were presented monaurally or dichotically with a simultaneous competing signal going to the opposite ear.

In 1961, Kimura (16) hypothesized that in subjects with speech represented in the right hemisphere, recognition of verbal material arriving at the left ear should be more efficient. Identification of the dominant hemisphere for speech was achieved by the injection of sodium amytal into the internal carotid artery of one side, thereby temporarily disrupting the functions of that hemisphere. The right and left sides were injected on different days, with contralateral hemiplegia and hemianopsia resulting from each injection. Dysphasia, however, occurred only after injection of the hemisphere dominant for speech. Kimura utilized a procedure whereby digits were presented through earphones simultaneously to the two ears and the subject reported everything he heard, in any order he liked. The results indicated that when speech is represented in the left hemisphere, the right ear is more efficient, and when speech is represented in the right hemisphere, the left ear is more efficient. Kimura also found that approximately 90 per cent of the subjects with speech represented on the left were right-handed and 75 per cent of the subjects with speech on the right were left-handed. However, the ear opposite the dominant hemisphere was found to be significantly more efficient, irrespective of handedness.

Kimura (16) discussed the postulation that under normal hearing conditions, both cochleas receive the same stimuli and there is no competition between the neural pathways from the two ears, perhaps explaining why the greater efficiency of the right ear for speech sounds had so far gone undetected. Another reason for lack of prior detection may be that, in normal subjects, both pathways are very efficient and only material of a certain level of difficulty will permit the detection of a difference between ears.

In 1957, Broadbent (6) indicated that subjects tend to be more accurate in identifying material from the first channel (ear) reported and that the longer they wait to report material in the other channel, the more likely they are to forget it. Bryden (10) noted that, in some of his work, most subjects tended to report the material from the right ear before giving that from the left. He felt it possible that right-ear dominance indicated in previous studies resulted from this preference for reporting the material from the right ear first. He subsequently studied this hypothesis by controlling the order of report so that each channel was reported first equally often, stating that any remaining right-ear preference could then be attributed to a true perceptual difference. Significant right-ear dominance was found to exist even when the order of report of digits presented simultaneously to the two ears was controlled; however, differences reported were smaller. Bryden presented a further postulation from his results, indicating that

> . . . material presented to the right ear would more actively excite appropriate trace systems in the cortex. As a result, the traces of material presented to the right ear would take longer to fade below response threshold, and thus could be more accurately reported toward the end of the response sequence than could material presented to the left ear /10, p. 105/.

Broadbent and Gregory (9) became concerned with the effect of method used in previous studies and its influence on results obtained. They felt that perhaps different results could be obtained if recognition rather than recall of digital material were required. Using a technique of auditory recognition after dichotic stimulation, they found convincing evidence of the superiority of the right ear in that there was no indication that recognition as opposed to recall reverses the advantage of the right ear; it did, however, seem to make the difference in favor of the right ear smaller.

Up to this point, we have considered solely the perception of verbal stimuli. Another area of concern is the perception of nonverbal stimuli. Although the study proposed herein will not investigate auditory perception of nonverbal stimuli, background material in this area is presented to more specifically define a difference between the ears with regard to auditory perception. Prior to 1962, the view, based on clinical studies of "amusia," was that the left hemisphere, particularly the left temporal lobe, was the area most concerned with music functions (14). Kimura (17) indicated that most of these studies suffered from two disadvantages: first, of an incomplete knowledge of the lesion, and second, of an inadequate testing of musical function contaminated by verbal factors in instruction, naming, and so on. In her 1964 study, Kimura added a melodies test. The melodic patterns from various concertos were used in devising melodies of 4 sec. duration. For each set of four melodies, two were first played simultaneously to the two ears, followed by a 4 sec. silence and then the playing of the four melodies in sequence. Results indicated that the score for the left ear was significantly superior to that for the right; a digits test run along with the melodies test indicated the usual significant superiority for the right ear. Kimura concluded that due to the

> . . . greater effectiveness of the crossed auditory pathways, melodies arriving at the left ear are more efficiently transmitted to the right temporal lobe, an area most important for their perception, than are melodies arriving at the right ear [17, p. 357].

An auxiliary finding in a study reported by Chaney and Webster (11) indicated that the right ear provided faster and more accurate response times when the stimuli were speech sounds, and that the left ear was faster and more accurate when the stimuli were sonar signals. They indicated that the techniques used in their study might provide a useful method for further investigation of the phenomenon of ear preference as a function of signal type. Milner (20) noted that performance in the Seashore tests is not affected by the addition of Heschl's gyrus to a standard temporal lobectomy, suggesting that the difference in auditory function between right and left temporal lobes, at least for musical ability, does not depend on a difference between the primary auditory areas.

Kimura also indicated in her 1964 study that the asymmetries observed occur only under conditions of dichotic stimulation. She noted, in an unpublished study, that when the Timbre test of the Seashore battery was presented to a group of subjects one ear at a time, no difference between the ears was found. She indicated that similar results are found for digit presentation. Kimura felt one reason may be that dichotic listening puts more demands on the system than does monaural listening; however, she felt that another factor was probably involved. Mentioned earlier was the fact that Rosenzweig (22) suggested that the auditory system is arranged in such a manner that some central units in each half of the brain fire upon stimulation of the ipsilateral ear, some with the contralateral ear, and some with both. More units are activated by contralateral stimulation than by ipsilateral, and in those units which fire to both, the contralateral connections occlude the ipsilateral. Thus the greater effectiveness of the contralateral pathways should become more apparent when both ears are stimulated but with different material. Kimura suggests that when only one ear is stimulated at a time, the difference between the ears may not be great enough to permit detection of a difference; however, when different information travels along these pathways, those units which fire to both ears will be taken up by the contralateral pathway. She indicates that, in this way, dichotic stimulation may enhance the difference between the two pathways.

Recently, Shankweiler and Studdert-Kennedy (23) did a comparison of identifications of dichotically presented pairs of synthetic CV syllables and pairs of steady-state vowels presented to right-handed subjects. These were prepared on the Haskins Pattern Playback, a device for producing controlled synthetic speech stimuli which photoelectrically converts hand-painted patterns, modeled on spectrograms, into sound. The CV syllables included the voiced and unvoiced stop consonants /b-p, d-t, g-k/, each followed by the vowel /a/. Also used were five, equal duration steady-state vowels /i, ɛ , æ , a, u/. The results indicated that syllables presented to the right ear were identified with significantly greater accuracy than were those presented to the left by 14 of the 15 subjects. The right ear advantage occurred unreliably on the vowel test, with only slightly over half of the subjects showing up better on the right ear. The experimenters note that this last finding is probably due to the fact that the neutral status of the steady-state vowels places them about midway between speech and music. They indicate that further research is needed in this area.

# CHAPTER II

# PROBLEM AND PROCEDURE

## Problem

The task we were faced with was to investigate left-right relationships in the auditory perception of verbal material by children, taking into account some of the problems previously mentioned which may have obscured or left untapped some differences which do seem to exist. In this study, we attempt to demonstrate the phenomenon of development of a right-ear superiority for the auditory perception of verbal stimuli and subsequently compared the results with previous research findings. Significant data obtained at the peripheral level may be of some value in discussing prognosis for the development of verbal skills in those children who have been brain-injured while in the process of developing language; results from this study may also be of consideration in making decisions concerning amplification for the child with a hearing handicap.

A survey of the relevant literature reveals lack of sufficient data and consistency of the results that have been reported with regard to left-right differences in the auditory perception of verbal material by children between the ages of eight and fourteen. Both Kimura and Bakker found fault with their results in terms of the tests they used to demonstrate such differences, Kimura (18) with children through age nine and Bakker (2) with children through age eleven. Since Lenneberg (19) feels that developmental changes in cerebral dominance for language may still be taking place to approximately age thirteen, this writer found it desirable to attempt to demonstrate the existence of such differences by an auditory test including subjects through age fourteen. The hypotheses investigated were twofold and are stated in the null form as follows: (1) Neither ear will be significantly more efficient in responding to verbal dichotic stimuli presented simultaneously to the two ears. (2) In response to verbal dichotic stimuli presented simultaneously to the two ears, no significant difference will be found in ear efficiency as a function of age when investigating female children at ages eight and fourteen.

## Procedure

Subjects for the present study consisted of 60 female children selected from the Missoula Public Schools, including 30 each at ages eight and fourteen. For the purposes of this study, it was not felt necessary to include the intervening ages, since what was desired was a knowledge of whether or not a significant efficiency in favor of the right ear has occurred by age eight; the children at age fourteen were included as a control group to be investigated if in fact the changes had not occurred by age eight. The age of the child was defined as that of her nearest birthday; that is, if the child was born December 10, 1954, and was tested November 21, 1968, her age was recorded for purposes of this study as fourteen years.

The decision to use only females was prompted by the desire to eliminate, as much as possible, maturational factors. Since girls generally mature earlier on a variety of aspects than boys, it is conceivable that the performance of a fourteen-year-old boy may be more like that of a twelve-year-old girl than of a girl at his own age level and thus any existing phenomenon of changes in ear preference by age may be obscured by maturational factors. Kimura (18) found no significant differences in the relative ear preference of males and females at any particular age level, but her study only included children through age nine.

The sample was also selected with reference to the following criteria: (a) Children found to have a hearing impairment following a preliminary audiometric screening test were not included. A Maico protable audiometer equipped with otocups was used and children were screened at 1000 Hz and 4000 Hz using a level of 20 dB ISO as a pass-fail criterion. The subjects were not screened at 500 Hz because of the possible interference of ambient noise in gaining accurate results at this frequency, since testing was carried out in the schools. (b) Any prospective subject demonstrating left-handedness upon being asked to write his name was not included in the study. Kimura (16) found that left-handed subjects had speech represented in the right hemisphere approximately 75 per cent of the time. However, her results were based on a pathological population. Milner _et al_. (21) found, as a result of bilateral intra-carotid injections, that left-handed or ambidextrous normals had right hemisphere speech representation 20 per cent of the time, while none of his right-handed normals had similar speech representation. Although handedness is recognized as a somewhat inadequate indication of dominance, elimination of left-handed subjects was on additional effort contributing to the homogeneity of the sample.

A dichotic (differing stimuli presented binaurally) message which could be presented in such a manner as to be perceived as simultaneous was used. The most commonly used message material for this type of study has been digits (7, 8, 9, 16, 17, 18). Digits are not by any means ideal as simultaneously presented stimuli (lack of phonemic similarity being one main objection); however, because it seemed desirable to relate results of the present study as closely as possible to past literature, digits were retained as the message. Although many of the previously noted authors have utilized simultaneously presented digits, the manner of simultaneous construction and presentation has not been reported in the literature in sufficient detail so as to be replicated. Kimura (16, 17, 18) refers to the techniques of simultaneous presentation employed by Broadbent in his 1954 and 1956 studies. In these studies, Broadbent (8, p. 194) reports that

> . . . material was recorded on the two tracks, so that one digit arrived at one of Ss ears and another digit simultaneously at the other ear.

Correspondence with D. E. Broadbent (30) indicated a procedure utilizing a metronome and warning signals in order to produce simultaneous dichotic digits. Broadbent explained that for experimental purposes, asynchrony of the size thus created may be inadequate for some of the questions one would wish to ask. Bryden (10) and Craik (12) also report having used simultaneous digits but do not elaborate on procedures for making such digits arrive at the two ears simultaneously. Techniques of simultaneously presented dichotic stimuli have been reported elsewhere (23, 28) but were not felt to be practicable for the purposes of this writer. Broadbent (30) indicated in his letter that Bell Telephone Laboratories was producing synchronous digit material by computer, and this writer was successful in gaining their assistance in the production of tapes needed for this study. The following procedure was followed to construct a master recording sent to Bell Telephone Laboratories.

The digits "one" through "nine" were recorded at 15 ips on an Ampex (PR10) tape recorder by a male speaker; the speaker monitored his voice by use of the V.U. meter on the tape recorder in order to maintain, as nearly as possible, a constant recording intensity. "Seven" was omitted as it was the only two-syllable number in the sequence and thus would have been difficult to match for simultaneity with the other digits. After the digits were recorded satisfactorily, they were subsequently isolated from the tape by cutting vertically. The location on the tape for the vertical cuts was determined by passing the tape back and forth across the playback head of the recorder until the position for a cut had been selected by use of auditory monitoring and the V.U. meter. The resulting portions of tape were edited so as to make them the same length, in the process omitting a portion of the acoustic stimulus of one digit or another while still maintaining its intelligibility. For example, to make "two" and "three" of the same duration, it was possible to cut off a portion of the /i/ on the end of "three" without reducing its intelligibility as the numeral "three." The portions of tape thus edited were spliced together in sequence and were rerecorded at 7½ ips as there were indications that the heads on the Ampex tape recorder were misaligned so as to cause difficulty in playback on another recorder. The resulting tape, along with specification for the exact sequence and pairing of the digits (Appendix B), were sent to Bell Telephone Laboratories for production of two tapes (see explanation later in this chapter) consisting of 30 sequences of stimuli on each tape with a pause of ten seconds after each sequence for subjects' response time.

Admittedly, there are difficulties with this technique. For instance, it is possible that a portion of the acoustic information has been omitted from the tape by the initial editing procedure and the splicing necessary to make two digits the same length; the acoustic event has admittedly been altered somewhat but whether the alteration is significant in terms of intelligibility of the stimulus is another matter. No reduction in intelligibility was apparent in several preliminary observations. Hirsh (15) states that a separation time of between 15 and 20 msec. is required for a listener to report correctly which of two sounds preceded the other; however, it is difficult to evaluate this evidence in terms of the present study since Hirsh's stimuli were mechanically produced sounds of known rise time and duration. The technician at Bell Telephone Laboratories who assisted in preparation of the tapes supplied waveform plots of the digits and from examination of these waveforms it appears that the digits differed in duration by 10 msec. or less; they did not differ technically as to onset since a starting point, being that point at which the waveform changed to indicate the beginning of the auditory stimulus, was selected in reference to the waveform plot of each digit. However, some of the actual rise time and duration of the stimulus may have been lost during splicing, a factor which this writer is not able to overcome at this time.

Digits produced as explained above were presented dichotically and simultaneously in sequence with other digits at the rate of one pair per one-half second, as suggested by Broadbent and Gregory (9). Research suggested that average memory span for successive presentation of digits for children between the ages of eight and fourteen varies from five to six digits (28); however, there appears to be no evidence as to the corresponding memory span for digits when presented simultaneously and dichotically. Studies by both Broadbent and Kimura have typically used three simultaneous dichotic digit pairs before a response is required; however, these studies utilized adults as subjects and it was felt that this task might be too difficult for children. The problem appeared to be one of devising a task which was of sufficient difficulty to demonstrate any differences which may exist but not so difficult as to be an impossible feat for the child. Two sets of stimuli were constructed (see Appendix B), one consisting of a series of digit pairs presented to one ear with competing pairs of digits presented simultaneously to the opposite ear. The other consisted of a series of three digits presented to one ear with a competing digit triplet simultaneously presented to the opposite ear (see Figure 1 for illustration). It was felt that perhaps the former set might be needed for the eight-year-old subjects; however, an informal pilot study including four children in each age group indicated that the three-pair set could be used for each group. Although the accuracy of response varied from subject to subject, all children tested were able to perform using the three-pair set.

Five of the three digit sequences were used for unscored practice trials as it had been determined from the pilot study mentioned earlier that five preliminary trials served to aid in instructional purposes and also were necessary to minimize practice effects. The five trials

| Set 1 |  | Set 2 |  |
|---|---|---|---|
| Channel 1 | Channel 2 | Channel 1 | Channel 2 |
| 2-3 | 1-4 | 3-2-6 | 4-9-8 |
| 3-8 | 4-9 | 4-3-5 | 8-9-6 |
| 3-6 | 8-9 | 5-4-6 | 2-1-9 |
| etc. | etc. | etc. | etc. |

Fig. 1.--Two sets of stimuli constructed

were followed by fifteen sequences to be scored. Using a table of random numbers, three variables were assigned for each subject: reference ear, channel, and tape. The reference ear (the ear reported first) was randomly assigned for the first run, with the opposite ear being the reference ear for the second run. To counterbalance any differences which might have existed between the two channels, they were randomly assigned to the two ears for each subject. Tapes 1 and 2 (Appendix C) were made to differ as to order of presentation of the digital stimuli.

Each subject was initially screened for hearing and handedness and was then given instructions by the experimenter as to the nature of the task before him (Appendix D). It was determined from the pilot study that the children, particularly those at age eight, approached the task more favorably if the instructions were spoken to them rather than being read. Thus, there were minor deviations in wording of the instructions from subject to subject. There were none, however, which were felt to contribute significantly to deviations in subjects' performance on the task. After each subject completed the first run of five trials followed by fifteen scored sequences, she was given further instructions (Appendix D) and then finished the task. She listened to the tape over stereophonic head phones connected to a Sony Stereo Tapecorder 260. Her responses were recorded manually by the experimenter and at the same time were recorded on a Califone 70-TC tape recorder.

The instructions included the stipulation that the subject report the digits she heard in one ear followed by those she heard in the other ear. Bryden (10) found that left-right differences obtained by instructing order of report are much smaller than those obtained with free recall; this is reportedly due to the fact that subjects tend to report material arriving at the right ear first and forget the material presented to the left ear before they have a chance to report it.

Although each subject's total response from both ears was recorded, only the first three digits reported were considered in determining correctness of response; these digits were considered as those which she heard in her reference ear. In addition, each digit scored was counted as a correct response only if it was reported in the appropriate order in the sequence. For a particular sequence, each subject was given a score of from 0 to 3, according to the number of digits correctly identified from the reference ear.

One subject at the eight-year-old level and three at the fourteen-year-old level were eliminated from the study and alternate subjects were run to retain the original number for the study. The eight-year-old subject and subject nine in the fourteen-year-old group responded in such a way that their data were unscorable; the other two subjects at the fourteen-year-old level indicated that they had not understood nor followed the instructions for all or part of the task. The data for these subjects is presented in Appendix E.

# CHAPTER III

## RESULTS

The data from this study were analyzed with the F-ratio and t-test. Values for F were computed by utilization of a treatments x subjects design as illustrated in Table 1. The difference in performance between age groups (B), difference in efficiency between the two ears under the experimental conditions set forth (A), and interaction between ear preference and age level were all found to be significant at the .05 level.

Table 2 presents the mean scores for right- and left-ear performance at the two age levels investigated. The t-test was used for comparison of mean scores for the two ears at each age level; the difference between right- and left-ear performance at each age level was significant at the .05 level. The hypotheses investigated in this study, stated in the null form, were: (1) Neither ear will be significantly more efficient in responding to verbal dichotic stimuli presented simultaneously to the two ears. (2) In response to verbal dichotic stimuli presented simultaneously to the two ears, no significant difference will be found in ear efficiency as a function of age when investigating female children at ages eight and fourteen. It can be seen, then, that the null hypotheses can be rejected in both cases as the results indicate that the right ear is significantly more efficient under the prescribed conditions and that the significantly greater right-ear efficiency occurring at both age levels was in fact of higher significance at the eight-year-old level. Implications of the latter finding will be discussed later in this paper.

## TABLE 1

## TREATMENTS X SUBJECTS DESIGN

| Source | df | Sums of Squares | Mean Squares | F-Ratios Obtained |
|---|---|---|---|---|
| Between-Subjects | N-1 = 59 | $ss_S = 6,760$ | | |
| B | b-1 = 1 | $ss_B = 1,920$ | $ms_B = 1,920$ | 23.0 |
| error (b) | N-b = 58 | $ss_{error\ (b)} = ss_S - ss_B = 4,840$ | $ms_{error\ (b)} = 83.4$ | |
| Within-Subjects | N (a-1) = 60 | $ss_{wS} = ss_T - ss_S = 2,731$ | | |
| A | a-1 = 1 | $ss_A = 464$ | $ms_A = 464$ | 77.3 |
| AB | (a-1) (b-1) = 1 | $ss_{AB} = 48$ | $ms_{AB} = 48$ | 8.0 |
| error (w) | (a-1) (N-B) = 58 | $ss_{error\ (w)} = ss_{wS} = ss_A - ss_B = 347$ | $ms_{error\ (w)} = 6$ | |
| Total | aN-1 = 239 | $ss_T = 9,491$ | | |

## TABLE 2

## MEAN SCORES FOR RIGHT- AND LEFT-EAR PERFORMANCE

| Age | Right Ear | Left Ear | Mean Score for Each Age |
|---|---|---|---|
| 8 | 30.5 | 25.3 | 27.9 |
| 14 | 37.3 | 34.6 | 35.9 |
| Mean Score for Each Ear | 33.9 | 30.0 | |

# CHAPTER IV

# DISCUSSION

It is felt that the demonstration of a significant right-ear preference in the eight-year-old group under the experimental procedure utilized is an important addition to the current literature in the area of right-left differences in the auditory perception of verbal material. Kimura (18) found a right-ear superiority at age eight; however, it was smaller than what she found at the four-year-old level. Kimura felt that the task she used was perhaps too easy for the older children; subjects were required to repeat simultaneously presented dichotic digits, some in two- and others in three-digit sequences. They also were instructed to repeat them in any order they liked; Bryden (10) found that differences obtained by instructing ear order of report are much smaller than those obtained with free recall. Stimuli for the present study consisted of simultaneous dichotic digits in three-digit sequences only and each subject was instructed as to first ear of report before she began the task. Thus, the differences found in this study were demonstrated in response to a more difficult task than used by Kimura and in addition would be expected to be smaller than those she found since subjects were instructed to report in a predetermined order. Bakker found no significant dominance of either ear for digit series at any of the age levels examined (stimuli were presented to the ears separately), while this study demonstrates a significant right-ear superiority for verbal material at both of the age levels investigated. Support is thus given to previous research that indicates the need for a dichotic simultaneous stimulus in investigating differences in efficiency between the two ears in response to verbal stimuli. To this time, significant differences have not been found with use of a monotic listening task. In the absence of significant data, Bakker felt that there was a trend toward increasing dominance for verbal stimuli by the right ear between ages ten and eleven; the data resulting from this study do not support Bakker in this area.

From a survey of the relevant literature, one could reasonably expect children at age fourteen to show at least an equal right-ear efficiency as compared with those children at age eight, unless, like Kimura's experience, the task became too easy as the age level increased. It is felt that the difference demonstrated between age levels is at least in part a function of the test used. For example, a number of the fourteen-year-old subjects achieved the maximum possible score of 45 in one ear or the other, while still a greater number came very close to maximum scores in both ears; this phenomenon did not occur at the eight-year-old level (see Appendix F). With reference to Figure 2, one cannot say with much assurance that the performance for the children at age fourteen has reached its peak as there was only one less subject falling into the 81-90 score category than into the one immediately preceding it. However, the curve for the eight-year-old subjects appears to have assumed a definite downward trend, suggesting that the task used allowed these subjects to perform to their maximum capabilities; this was apparently not the case with reference to the older group of subjects. The fourteen-year-old subjects should show at least a comparable, if not greater, right-ear efficiency when responding to a task that tested the outer limits of their skill in this area.

As noted in the <u>Procedure</u> section of this paper, the master recording of digits was controlled for intensity before being sent to Bell Telephone Laboratories. However, in production of the dual channel recording of simultaneous digit sequences, a quality difference occurred between the two channels, causing one to be perceptually louder than the other when balanced for intensity by use of an artificial ear. Thus, before running the subjects, the tapes were balanced for perceptual equality in loudness

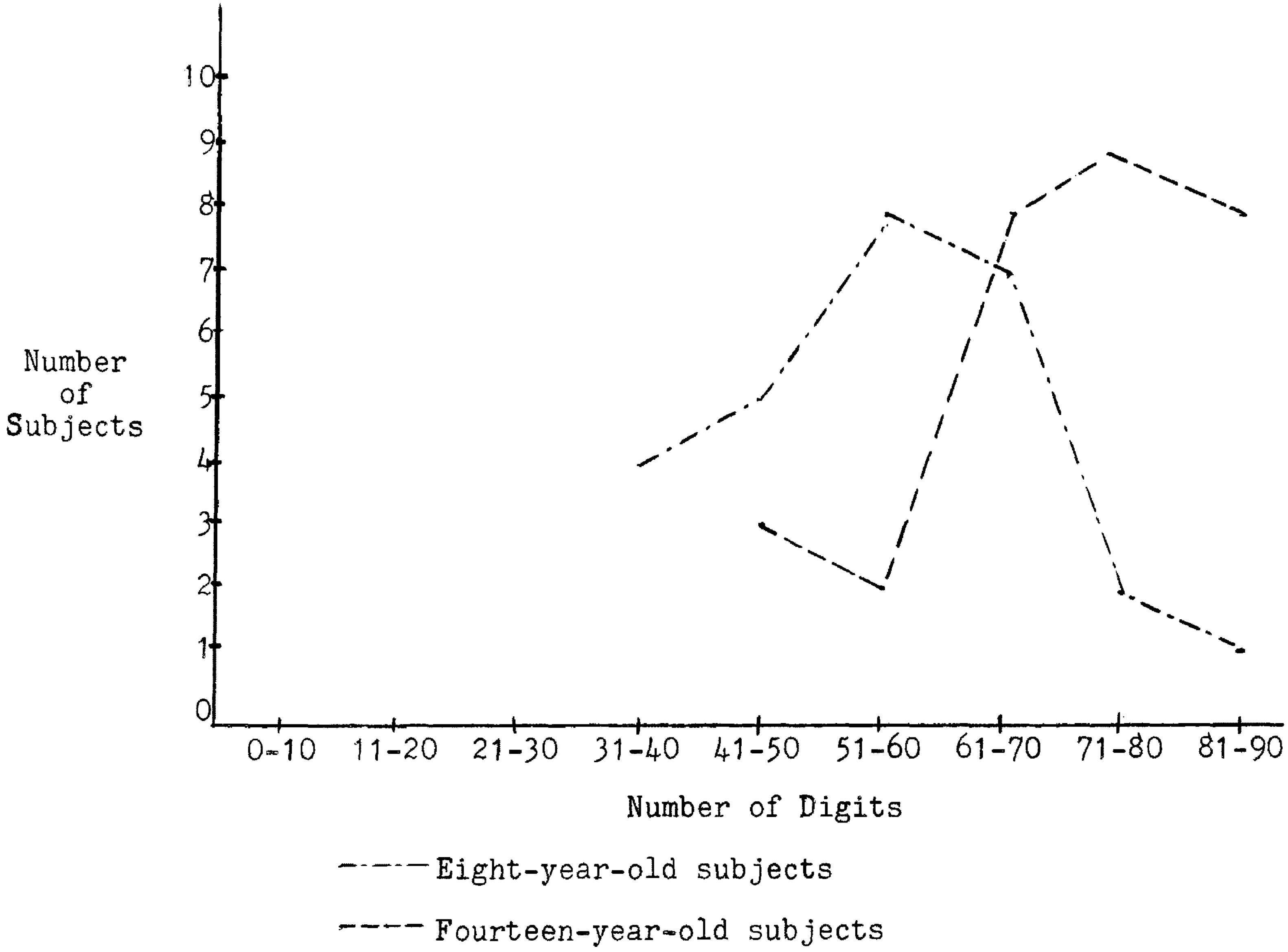

Fig. 2.--Total number of digits correctly reported as a function of age

by the examiner after several practice sessions in which the examiner checked her ability to perform this function with a fair degree of accuracy. Gain controls for the two channels were then set at the appropriate levels thus determined and were checked periodically to ensure that the controls remained at the predetermined setting. Periodic checks were also made by use of the stereo headphones to ensure that no equipment change had taken place so as to upset the channel balance. It was felt that any channel differences which remained after use of this technique would be taken care of by the random assignment of Channel 1 and 2 to the two ears for each subject.

Negative reactions to the testing situation may have interfered with performance on the task presented, particularly with regard to the fourteen-year-old group. Although instructions were prepared with the thought of putting the subject at ease, many subjects (largely the older ones) showed great concern with doing well and displayed their displeasure with their performance by verbal and vocal interjections, negative facial expressions, and, in one case, an apology accompanied by very moist eyes. It is felt that research with children, and particularly adolescents, should take into consideration this concern for "good" performance; the researcher should do everything possible to eliminate such apprehension by instructing subjects as completely as possible as to the purpose of the study, what is expected of them personally, what will be done with the responses they have made, and so on.

Since the present study failed to demonstrate a significantly greater efficiency in favor of the right ear for the fourteen-year-old subjects as compared with those at age eight, we are unable to say whether or not this phenomenon continues to develop beyond eight years of age. As noted in the introductory material, Lenneberg (19) feels that a dominant language hemisphere is not fully established until the early teenage years, and thus trauma to the language hemisphere during this developmental period has a better prognosis for recovery than that occurring later in life. While results of this study cannot support Lenneberg in this area to the extent this task represents language dominance, neither can they deny continued development of right-left differences in the auditory perception of verbal materials through the early teens, because of factors mentioned above which interfered with the performance of the older subjects.

Because the difference in performance between the two ears apparently cannot be demonstrated except in a controlled situation with the use of competing stimuli, one might assume that any difference which does exist is thus so small as to be virtually insignificant. Such an assumption, however, is not felt to be necessarily justified at this point. Most of our listening, unlike that of the clinical test setting, is in fact dichotic with the stimuli being competing signals which exist in the environment. Therefore, the differences which have been found in this study and others like it may point out a new area for consideration in aural rehabilitation. Suppose, for example, that we are treating a child with a bilateral loss of hearing essentially equal in both ears and the decision for amplification of right versus left ears is basically an arbitrary one. We do not know at this point what the long-term effects of placing the hearing aid on the ear which is somewhat more efficient in handling verbal stimuli might be. The importance of such a decision might very well be a pertinent question for further investigation in this area.

# CHAPTER V

## SUMMARY

The purpose of the present study was to investigate differences in the efficiency of the right and left ears of children in perceiving verbal stimuli. Although it has been quite well established that adults demonstrate a significant right-ear efficiency in response to verbal material, the research with respect to children shows both insufficient data and inconsistency of results in this area.

Stimuli for this study were taped digits prepared, with the aid of Bell Telephone Laboratories, so that they arrived dichotically and simultaneously to the two ears of each subject. Sixty female subjects, thirty each at ages eight and fourteen, were selected from the Missoula Public schools. All subjects were given an audiometric screening test with a pass-fail criterion of 20 dB at 1000 Hz and 4000 Hz ISO. In addition, left-handed subjects were eliminated from the study. Subjects listened to the taped digits over stereophonic head phones and reported the digits they heard after each sequence of three digits presented to one ear with a competing digit triplet presented to the opposite ear. Two runs consisting of five trials followed by fifteen sequences to be scored were presented to each subject; she was instructed to report first those digits she heard in either her right or left ear on the first run, with the opposite ear being reported first on the second run. She was also instructed to report the digits in the order in which she heard them. Only the first three digits reported were considered in determining correctness of response. These digits were assumed to have been heard in the ear which the subject had been instructed to report first. For a particular sequence, each subject was given a score of from 0 to 3, according to the number of digits correctly identified from the reference ear.

The hypotheses investigated, stated in the null form, were: (1) Neither ear will be significantly more efficient in responding to verbal dichotic stimuli presented simultaneously to the two ears. (2) In response to verbal dichotic stimuli presented simultaneously to the two ears, no significant difference will be found in ear efficiency as a function of age when investigating female children at ages eight and fourteen. In analyzing the data with the F-ratio and t-test, significance was obtained at the .05 level and both null hypotheses were rejected. The right ear was found to be significantly more efficient under the prescribed conditions and the significantly greater right-ear efficiency occurring at both age levels was in fact of higher significance at the eight-year-old level. This latter finding was felt to be at least in part a function of the test used; it appeared to be too easy for the older subjects as compared with those at age eight and thus was not felt to test the outer limits of their skill in this area.

It is felt that the finding of a significant right-ear efficiency at age eight is an important addition to the literature in this area as this efficiency was demonstrated in response to a more difficult task than previously used; Kimura (18) felt that the task she used was perhaps too easy for children at this age level. Support was also given to previous research that indicates the need for a dichotic simultaneous stimulus in investigating differences in efficiency between the two ears in response to verbal stimuli.

Results of the present study were felt to be particularly pertinent for further investigation in the area of aural rehabilitation. The differences in ear efficiency, although small, might be of importance when considering long-term rehabilitative measures such as placement of hearing aids.

# APPENDIX A

## CORRESPONDENCE WITH D. E. BROADBENT

Date: October 21, 1968

To: Loreen C. Folsom

From: D. E. Broadbent, Director
Applied Psychology Research Unit
15 Chaucer Road
Cambridge, England

The method which I used for getting approximate simultaneity of my taped messages was as follows. I employed a two-track tape recorder which had the facility of being able to play back on one track while recording on the other. We then recorded one track, speaking in time with a metronome, and preceding each burst of test material with a warning signal on the next but one metronome beat before the stimulus itself. Having recorded one track complete, we then listened through headphones to this track playing back, while recording the second track. With a little practice, one can thus utter the test message on the second track, using the warning signal from the first track to trigger one's reaction, with reasonable accuracy. A check on the extent to which this has been achieved can be got by putting the tape recorder on play-back, and slowly pulling the tape past the heads. The onset of each message can be heard, actually rather low in pitch, but located reasonably precisely along the length of tape: one can locate it reasonably to about 1/8 inch, and at 7 1/2 inches a second tape speed this is of course about 15 milliseconds.

The synchronization obtained is unlikely to be much better than that with the method I have described: it may well on occasion range up to 100 milliseconds, although I have hardly ever known it to get worse than that. For some purposes, such as those in which I was originally interested this may be regarded as adequate: but there is no doubt that asynchrony of this size may be important for particular problems, and my original tapes would not be adequate for some of the questions one would wish now to ask experimentally.

The most advanced way of getting better synchrony is by storing the auditory material digitally in a computer, and generating them accordingly. This method has been used by Bell Telephone Laboratories but is a little flamboyant for most of us.

A good technique which I have recently heard from Harris Savin in the University of Pennsylvania is as follows. Prepare two loops of recording tape, slightly different in length. Record one of the two digits on each loop, and play the loops on two tape recorders. Sooner or later the two sounds will become simultaneous: then record them. I have not yet used this myself, but it sounds a most promising idea and ought to work quite nicely.

# APPENDIX B

## SPECIFICATION FOR SEQUENCE AND PAIRING OF DIGITS SENT TO BELL TELEPHONE LABORATORIES*

| Set 1 | | Set 2 | |
|---|---|---|---|
| Channel 1 | Channel 2 | Channel 1 | Channel 2 |
| 2-3 | 1-4 | 3-2-6 | 4-9-8 |
| 3-8 | 4-9 | 4-3-5 | 8-9-6 |
| 3-6 | 8-9 | 5-4-6 | 2-1-9 |
| 2-5 | 8-1 | 8-6-2 | 3-1-4 |
| 5-4 | 6-1 | 4-8-2 | 1-5-6 |
| 6-9 | 2-8 | 1-2-8 | 4-9-3 |
| 1-3 | 5-2 | 2-6-3 | 8-5-1 |
| 8-3 | 5-9 | 3-4-6 | 5-2-9 |
| 8-5 | 3-1 | 5-4-2 | 6-9-1 |
| 5-4 | 3-2 | 6-1-2 | 4-5-3 |
| 9-4 | 3-8 | 4-3-9 | 2-8-1 |
| 6-3 | 2-4 | 6-1-9 | 5-8-4 |
| 6-8 | 4-3 | 6-5-3 | 9-2-8 |
| 4-5 | 6-2 | 8-5-6 | 3-2-4 |
| 4-2 | 3-6 | 9-8-2 | 6-4-1 |
| 4-5 | 1-8 | 1-6-9 | 3-2-4 |
| 9-3 | 6-8 | 2-9-5 | 4-6-3 |
| 9-1 | 5-4 | 5-3-1 | 9-8-6 |
| 3-4 | 6-9 | 3-2-8 | 1-4-9 |
| 4-1 | 5-2 | 5-8-9 | 1-2-6 |
| 6-3 | 5-2 | 4-3-2 | 6-1-9 |
| 5-6 | 8-3 | 6-2-9 | 3-5-4 |
| 2-5 | 1-8 | 3-5-2 | 4-6-8 |
| 2-9 | 6-8 | 4-3-2 | 9-8-5 |
| 4-5 | 1-6 | 6-5-2 | 8-9-3 |
| 9-5 | 8-2 | 1-5-8 | 2-4-9 |
| 5-9 | 3-2 | 6-8-1 | 9-5-2 |
| 5-4 | 8-9 | 6-4-1 | 2-9-5 |
| 3-5 | 6-2 | 4-8-6 | 2-5-9 |
| 3-5 | 8-4 | 8-6-5 | 9-2-1 |

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*The digits were so sequenced and paired using a table of random numbers, with the specification that the same digit not occur twice in the same series and that "seven" not be included.

# APPENDIX C

## SEQUENCE OF DIGIT SERIES UTILIZED

| Tape 1 | | Tape 2 | |
|---|---|---|---|
| Channel 1 | Channel 2 | Channel 1 | Channel 2 |
| Trials | | Trials | |
| 4-9-8 | 3-2-6 | 4-9-8 | 3-2-6 |
| 8-9-6 | 4-3-5 | 8-9-6 | 4-3-5 |
| 2-1-9 | 5-4-6 | 2-1-9 | 5-4-6 |
| 3-1-4 | 8-6-2 | 3-1-4 | 8-6-2 |
| 1-5-6 | 4-8-2 | 1-5-6 | 4-8-2 |
| Scored Digits | | Scored Digits | |
| 4-9-3 | 1-2-8 | 8-5-1 | 2-6-3 |
| 8-5-1 | 2-6-3 | 5-2-9 | 3-4-6 |
| 5-2-9 | 3-4-6 | 6-9-1 | 5-4-2 |
| 6-9-1 | 5-4-2 | 4-5-3 | 6-1-2 |
| 4-5-3 | 6-1-2 | 2-8-1 | 4-3-9 |
| 2-8-1 | 4-3-9 | 5-8-4 | 6-1-9 |
| 5-8-4 | 6-1-9 | 9-2-8 | 6-5-3 |
| 9-2-8 | 6-5-3 | 3-2-4 | 8-5-6 |
| 3-2-4 | 8-5-6 | 6-4-1 | 9-8-2 |
| 6-4-1 | 9-8-2 | 3-2-4 | 1-6-9 |
| 3-2-4 | 1-6-9 | 4-6-3 | 2-9-5 |
| 4-6-3 | 2-9-5 | 9-8-6 | 5-3-1 |
| 9-8-6 | 5-3-1 | 1-4-9 | 3-2-8 |
| 1-4-9 | 3-2-8 | 1-2-6 | 5-8-9 |
| 1-2-6 | 5-8-9 | 6-1-9 | 4-3-2 |
| Trials | | Trials | |
| 4-9-8 | 3-2-6 | 4-9-8 | 3-2-6 |
| 8-9-6 | 4-3-5 | 8-9-6 | 4-3-5 |
| 2-1-9 | 5-4-6 | 2-1-9 | 5-4-6 |
| 3-1-4 | 8-6-2 | 3-1-4 | 8-6-2 |
| 1-5-6 | 4-8-2 | 1-5-6 | 4-8-2 |

## Scored Digits

8-5-1
5-2-9
6-9-1
4-5-3
2-8-1
5-8-4
9-2-8
3-2-4
6-4-1
3-2-4
4-6-3
9-8-6
1-4-9
1-2-6
6-1-9

2-6-3
3-4-6
5-4-2
6-1-2
4-3-9
6-1-9
6-5-3
8-5-6
9-8-2
1-6-9
2-5-9
5-3-1
3-2-8
5-8-9
4-3-2

## Scored Digits

4-9-3
8-5-1
5-2-9
6-9-1
4-5-3
2-8-1
5-8-4
9-2-8
3-2-4
6-4-1
3-2-4
4-6-3
9-8-6
1-4-9
1-2-6

1-2-8
2-6-3
3-4-6
5-4-2
6-1-2
4-3-9
6-1-9
6-5-3
8-5-6
9-8-2
1-6-9
2-9-5
5-3-1
3-2-8
5-8-9

# APPENDIX D

## INSTRUCTIONS FOR TASK

This is another kind of hearing test. First I want you to listen and tell me what you hear (play first sequence at least once, or until identified as being <u>numbers</u> in <u>both ears</u>). I want you to listen and when the man stops talking, I want you to tell me what numbers you heard in both ears, starting with those you hear in this ear (point for eight-year-olds, use R-L for older children). I also want you to tell them to me in the order that you hear them. You probably won't be able to remember them all, so just do as well as you can. Do you understand? Let's try a few (give five practice trials, stopping and reinstructing if child appears to be having great difficulty). Do you have any more questions before we continue? (Play next fifteen sequences.)

Now I want you to continue to do what you have been doing but begin with those numbers you hear in this ear (your R-L ear for fourteen-year-olds). Let's try a few (give practice trials). Do you have any questions? (Play remaining fifteen sequences.)

## APPENDIX E

## DATA FOR SUBJECTS ELIMINATED

| Subject | Age 8 | | 14-8 | | 14-9 | | 14-13 | |
|---|---|---|---|---|---|---|---|---|
| | Right | Left | Right | Left | Right | Left | Right | Left |
| | 286 | 251 | 263 | 493 | 498 | 263 | 498 | 253 |
| | 529 | 329 | * | 853 | 256 | 346 | 263 | 326 |
| | 691 | 542 | 542 | 529 | 691 | 592 | 329 | 692 |
| | 645 | 645 | 653 | 541 | 453 | 643 | 691 | 653 |
| | 281 | 281 | 489 | 453 | 489 | 439 | 649 | 238 |
| | 584 | 568 | * | 281 | * | 619 | 239 | 589 |
| | 692 | 654 | * | 584 | 698 | 658 | 584 | 683 |
| | 856 | 283 | 356 | 928 | 324 | 856 | 629 | 356 |
| | 981 | 165 | * | 324 | 982 | 982 | 324 | 984 |
| Data | 169 | 295 | * | 942 | 321 | 169 | 621 | 164 |
| | 294 | 986 | 259 | 324 | 463 | 295 | 369 | 295 |
| | 981 | 123 | 531 | 463 | | 531 | 296 | 986 |
| | 129 | 129 | 328 | 536 | | 238 | 986 | 328 |
| | 589 | 498 | 586 | 349 | | 126 | 134 | 528 |
| | 649 | 439 | 432 | 526 | | 432 | 526 | 324 |
| | | 219 | | | | | | |
| | | 314 | | | | | | |
| | | 186 | | | | | | |
| Score | Unscorable | | 23 | 36 | Unscorable | | 24 | 23 |

*Response was unscorable.

# APPENDIX F

## RIGHT- AND LEFT-EAR SCORES FOR EACH SUBJECT

| Age Eight | | Age Fourteen | |
|---|---|---|---|
| Right | Left | Right | Left |
| 18 | 21 | 39 | 42 |
| 43 | 27 | 23 | 22 |
| 31 | 28 | 42 | 37 |
| 31 | 23 | 43 | 41 |
| 25 | 25 | 40 | 37 |
| 31 | 30 | 38 | 41 |
| 28 | 14 | 39 | 38 |
| 44 | 31 | 32 | 25 |
| 41 | 42 | 43 | 37 |
| 26 | 11 | 38 | 36 |
| 27 | 23 | 45 | 42 |
| 9 | 42 | 45 | 38 |
| 26 | 17 | 44 | 37 |
| 29 | 36 | 30 | 26 |
| 29 | 31 | 38 | 40 |
| 39 | 17 | 45 | 42 |
| 33 | 9 | 38 | 31 |
| 35 | 28 | 40 | 33 |
| 39 | 28 | 20 | 22 |
| 37 | 29 | 45 | 45 |
| 31 | 27 | 40 | 29 |
| 34 | 31 | 37 | 41 |
| 37 | 20 | 33 | 37 |
| 41 | 34 | 23 | 44 |
| 40 | 37 | 36 | 25 |
| 18 | 17 | 37 | 32 |
| 16 | 21 | 39 | 23 |
| 25 | 32 | 26 | 23 |
| 22 | 23 | 44 | 38 |
| 24 | 13 | 36 | 34 |

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