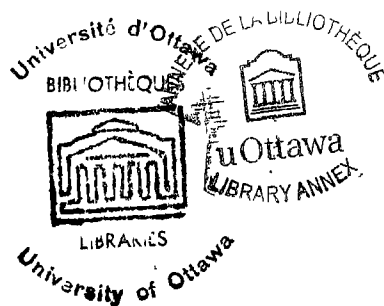


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AN EXPERIMENTAL STUDY OF
AUDITORY DOMINANCE AND
CEREBRAL LANGUAGE LATERALITY

by Christiaan D. Roode

Thesis presented to the School of
Psychology and Education of the
University of Ottawa in partial
fulfillment of the requirements
for the degree of Doctor of
Philosophy



Ottawa, Canada, 1963

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CURRICULUM STUDI ORUM

Christiaan D. Roode was born in Boshof, South Africa, October 19, 1935. He received the Bachelor of Arts degree in Psychology and Music from Potchefstroom University, South Africa, in 1955. He received the Honns. B.A. degree in Psychology in 1956, and the Master of Arts degree in Psychology from the Potchefstroom University in 1959. The title of his thesis was Eksperimentele Onderzoek na die Invloed van Musiek op Verstandsprestasie, (Experimental Investigation of the Influence of Music on Mental Performance).

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INTRODUCTION

For many years varying degrees of importance have been attached to the incidence of left-handedness in cases of stuttering. Laterality testing has become routine procedure, not only with some psychologists, but also with most speech pathologists. As the relationship between handedness and speech disabilities has never been adequately demonstrated, this practice has fallen into neglect.

However, a new electronic device for speech therapy has been developed in France recently and it is stressed by the manufacturers that therapy for the right-handed individual should be given through the right ear and for the left-handed individual through the left ear. As no adequate explanation was provided, it was decided to perform a study to determine the relative importance of this statement. As conventional cerebral dominance theory is the only theory to justify such a statement, the study was approached from this point of view.

It was further decided to avoid using speech disability cases because of different etiological factors involved. Therefore, normal subjects were taken and a temporary interference, in the form of binaural and monaural delayed auditory feedback, was introduced into the vocal output. The amount of speech disturbance caused by the

different ears then served to evaluate the importance of the statement mentioned.

The first chapter of the report presents the review of the literature. It is divided into four sections where cerebral dominance and language function are discussed, followed by a section on the importance of auditory monitoring in speech output, and another section on the attempts to demonstrate the existence of auditory dominance. A last section provides rationale and hypotheses for the investigation.

The second chapter deals mainly with the design of the study where the sample, the instrumentation for the experiment, the testing procedure, the analysis of speech samples and the statistical design are discussed.

Chapter III presents the results of the experiment and chapter IV attempts an adequate interpretation of the results.

In the last section, a summary and conclusion is given and the possible implications, for future research, are suggested.

CHAPTER I

REVIEW OF THE LITERATURE

The fact that an individual usually shows a functional preference for one hand over the other has long been a source of interest in the literature. Similar functional preferences have been shown to exist for at least eyes and feet. These observations have been related in various ways to a cerebral dominance of the hemisphere contralateral to the preferred organ. In turn, cerebral dominance has been accounted for in various ways, varying between extremes like Blau's¹ viewpoint that handedness is determined culturally, and Bauer and Wepman's² opinion that left hemisphere dominance is innate and that any deviation from this, in the occurrence of left-handedness or ambidexterity, is a sign of inadequate development of dominance and not of innate right cerebral dominance. In a comprehensive survey of the literature regarding lateral preference in man, Dayhaw³ has pointed out

1 A. Blau, "The Master Hand", Research Monographs, No. 5, New York, 1946, 206 p., quoted by Harold Goodglass and F.A. Quadfasel, "Language Laterality in Left-handed Aphasics", Brain, Vol. 77, 1954, p. 526.

2 Robert W. Bauer and Joseph W. Wepman, "Lateralization of Cerebral Functions", Journal of Speech and Hearing Disorders, Vol. 20, 1955, p. 172.

3 Lawrence T. Dayhaw, "De la preference laterale chez l'homme", excerpt from Revue de l'Universite d'Ottawa, April-June 1951, 33 p.

various investigations regarding hand-, foot-, eye-, and ear-preferences and the many conflicting viewpoints in accounting for these findings. At present there is still much confusion in the literature.

1. Cerebral Dominance and Language Function.

The picture becomes even more confusing when we turn to this aspect of laterality. Goodglass and Quadfasel, in discussing the relation between laterality and developmental disorders of speech and reading, said:

The observation has been made repeatedly by Orton (1937), Pearson (1940), Harris (1947), and many others that stammerers and poor readers show a greater-than-average incidence of left-handedness, ambidexterity, and mixed hand and eye preferences. This relationship must now be accepted as a fact to be explained.⁴

However, they added that although an increased incidence of mixed or left-sided preference is a repeatedly verified finding for stutterers without any known brain damage and with an above average verbal intelligence, this interference seems to be more on the level of speaking than on the level of language as a symbolic function. Also, it appears to be a generally accepted finding that mixed or left-sided hand-eye preference is not a causal factor towards a deficiency

⁴ Harold Goodglass and F.A. Quadfasel, "Language Laterality in Left-handed Aphasics", Brain, Vol. 77, 1954, p. 532-533.

in language acquisition, but much rather a symptom. Since the present study is not concerned with any particular lateral preferences as related to speech or reading problems, no attempt is being made to survey the literature more thoroughly on this point.

However, the aspect of cerebral dominance and language function that has considerable importance for the present investigation is attempts to localize the speech centre in the brain and investigations concerning relationships between the occurrence of left or right hemiplegia and aphasia.

Penfield and Roberts,⁵ in reviewing the literature on handedness and cerebral dominance, note that handedness was not mentioned in the literature prior to 1865. They say that Marc Dax found lesions of the left hemisphere in forty cases in which there had been a speech disturbance during life. When Broca published his first case in 1861, this fact was still unknown in Paris. In 1863, Broca mentioned that nineteen out of twenty cases with aphemia had left hemisphere lesions. However, he was cautious and did not make any generalizations beyond this statement. Later, when Dax's lecture was again presented in 1863, it led Bouillaud

⁵ Wilder Penfield and Lamar Roberts, Speech and Brain Mechanisms, Princeton, New Jersey, Princeton University Press, 1959, p. 89-90.

to explain the occurrence of aphasia with lesions of the left cerebral hemisphere, on the grounds that most people are right-handed. When Broca later reported the case of a woman that had had right hemiparesis since infancy with no speech disturbance, it was assumed that speech had been subserved by the right hemisphere. At autopsy a large lesion was found in the distribution of the left middle cerebral artery. This woman was left-handed and on these grounds it was concluded that the right hemisphere is dominant for speech in left-handed individuals. Penfield and Roberts state:

Thus was created the dogma that the right cerebral hemisphere is dominant for speech in the left-handed in the same way that the left cerebral hemisphere is supposed to be for the right-handed.⁶

However, in the light of more recent findings and by observing all the cases that were mentioned in the literature, Broca's statement can no longer be accepted. A summary is given of cases mentioned in the literature that seem to contradict the belief of right hemisphere dominance for speech in the left-handed. Goodglass and Quadfasel⁷ collected 110 cases from the literature and added thirteen new cases of left-handers with unilateral lesions of the language area and found that language was disturbed in fifty-three per

6 Penfield and Roberts, Op. Cit., p. 69.

7 Goodglass and Quadfasel, Op. Cit., p. 546.

cent of all left-handers with lesions of the left hemisphere.

They also collected ten cases from the literature and added two new cases of left-handers with extensive right hemisphere damage of the speech areas without any aphasic involvement. It seems safe to judge that these left-handed cases had speech represented also on the ipsilateral hemisphere, i.e. the left hemisphere. Although Penfield and Roberts⁸ object to some of the so-called negative cases in the literature on grounds that some of their cases have later developed dysphasia, this does not significantly change the picture. As a matter of fact, they agree with the findings of Goodglass and Quadfasel after similar investigation and addition of their own cases. They state:

Adding our cases to those in the literature, there are 144 left-handers with dysphasia - 55% involving the left hemisphere and 45% involving the right. And there are one and one-half times as many negative cases (left-handers without dysphasia) involving the right hemisphere (33) as the left (21).⁹

Looking at these findings objectively the statement of Ettlenger et.al. is acceptable:

⁸ Penfield and Roberts, Op. Cit., p. 95.

⁹ Ibid., p. 97.

No longer can it be accepted that right cerebral dominance is the rule in left-handed individuals or that aphasia resulting from a left-sided lesion in a left-handed patient is in any way exceptional (...) indeed "left-brainedness" might well appear to be the more prevalent form of cerebral organization in left-handed individuals.¹⁰

However, looking at the literature, the incidence of left hemiplegia with an aphasia, especially in left-handers, is striking and similarly rules out the possibility of a complete left-sided localization of speech functions. Goodglass and Quadfasel¹¹ mention fifty cases altogether of left-handers with aphasia and right cerebral lesions, and eight negative cases of left-handers without aphasia and left cerebral lesions. The conclusion is that in some cases there undoubtedly is some, or full representation of speech in the right hemisphere. Penfield and Roberts¹² report that 136 cases have been mentioned in the literature with aphasia and lesions on the right hemisphere, of whom fifty-three were right-handed, forty-two left-handed, twenty-three predominantly left-handed and eighteen unknown. Ettliger et. al., in discussing cerebral dominance in left-handers, note:

¹⁰ George Ettliger, C.V. Jackson, and O.L. Zangwill, "Cerebral Dominance in Sinistrals", Brain, Vol. 79, 1956, p. 369.

¹¹ Goodglass and Quadfasel, Op. Cit., p. 540-543.

¹² Penfield and Roberts, Op. Cit., p. 90.

Taken together, these findings provide strong evidence for the existence of right hemisphere language laterality - in some sinistrals at least. We may, however, agree with Goodglass and Quadfasel (1984) that right hemisphere dominance is very much less common than left-handedness.¹³

Goodglass and Quadfasel interpret these findings to mean that the possibility should be considered of cerebral ambilaterality for speech, especially amongst left-handers. They perceive of it more in terms of a statistical distribution where right-brainedness and left-brainedness are two extremes on a sort of bimodal curve:

From the evidence presented it appears that the distribution curve of language laterality differs from that of handedness by being more one-sided, unimodal, and tapering off, with more people showing ambilaterality for speech than there are having a clear-cut right-sided dominance (...) see fig. 1 (...). This independence of distribution from that of handedness means that laterality for language is not identical with laterality for handedness. Handedness does not determine brainness.¹⁴

It has been seen that an exhaustive review of pertinent literature over the past hundred years emphasized three main points:

- a) that left hemisphere language laterality seems to be the most common occurrence by far, even for left-handers;

¹³ Ettlenger et. al., Op. Cit., p. 570.

¹⁴ Goodglass and Quadfasel, Op. Cit., p. 532.

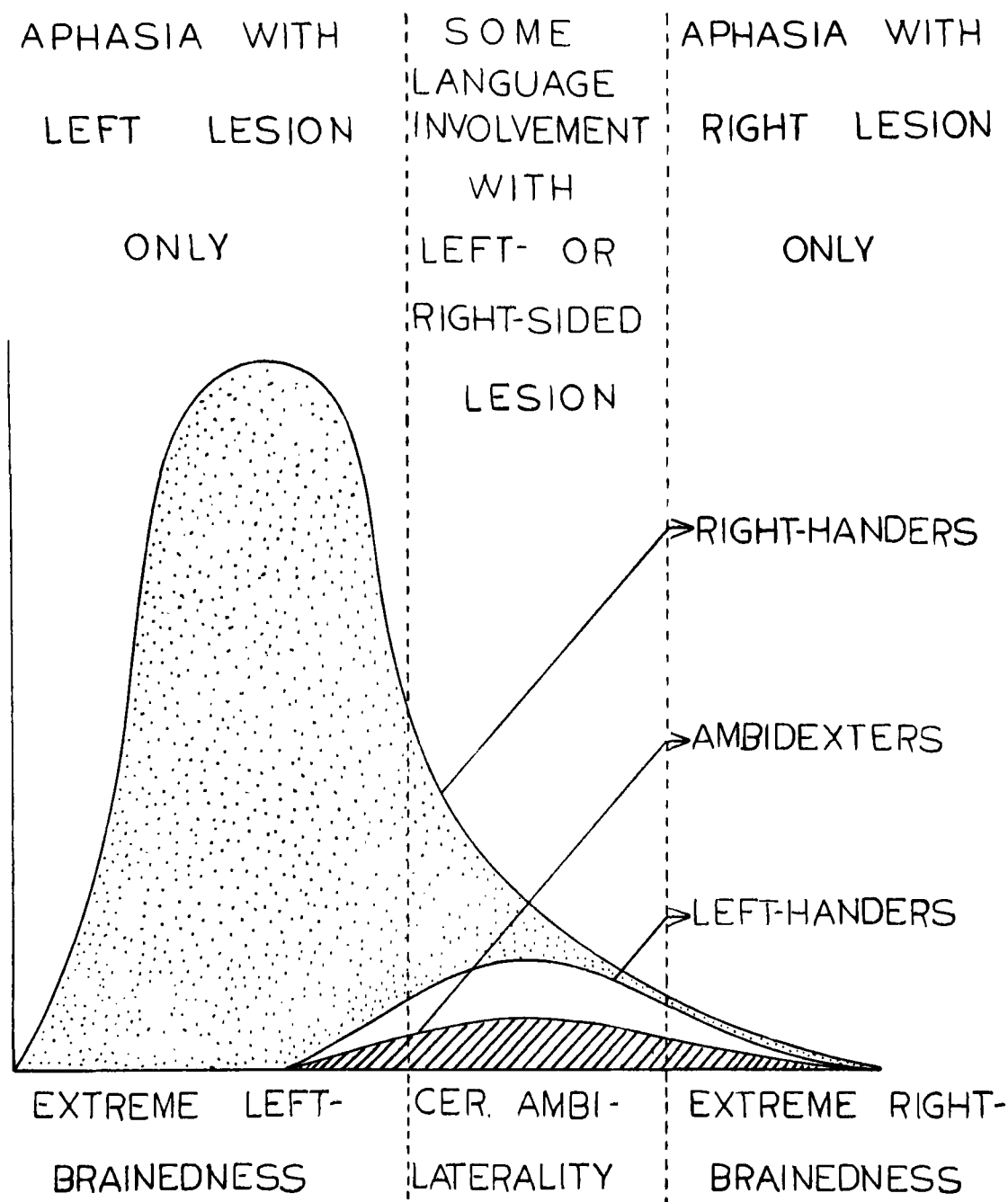


Figure 1. Hypothetical distribution of cerebral laterality among right-handers, ambidexters, and left-handers as inferred from the frequency of aphasia after unilateral lesions.

a Goodglass and Quadfasel, Op. Cit., p. 532.

- b) that right hemisphere language laterality seems to be an extremely rare occurrence, and if it does occur, the odds are about twelve to one that the individual is a left-hander and only one to fourteen that he is a right-hander;
- c) that the possibility of bilateral speech representation, especially in left-handers, cannot be ruled out.

Penfield and Roberts therefore conclude:

In almost one hundred years, only about 140 cases have been reported with aphasia and involvement of only the right hemisphere. It seems clear that the left hemisphere is usually dominant for speech, regardless of handedness. The reason why the right hemisphere is sometimes dominant for speech remains unclear, but it is not related solely to handedness.¹⁵

One of the striking things in most of these reports is the failure to state precisely what tests of laterality have been used in determining the handedness of the patient. It appears that in most cases the preferred hand for most activities is used as an indicator of laterality in general. Left-handers who do not write with their left hands, but who do most other things left-handedly, are usually classified as predominantly left-handed and are therefore included in most investigations. Also, in very few investigations mentioned has there been any attempt to test for eyedness

¹⁵ Penfield and Roberts, Op. Cit., p. 102.

and footedness. Ettliger et. al¹⁶ mentioned the lateral preferences for foot and eye of their ten left-handers under discussion. Only two of them showed consistent left-preference (cases 3 and 9) and neither of them used his left hand for writing and drawing. However, of the two cases with inferred right hemisphere dominance for speech, case 3 was one of them. It has been pointed out repeatedly that the more tests of laterality used, the fewer become the number of purely right- or left-sided. It could therefore very well be that most so-called left-handed cases were actually cases with mixed dominance, and the same could apply to at least some of the right-handed cases. This undoubtedly will confuse the present picture.

Furthermore, without a single exception, these observations have been made on hospitalized patients under treatment or surgery for lesions in the language area. In most of the cases the exact onset of the lesion is not known, so that at the time of investigation language functions could very well have been transferred, or partially transferred, to the opposite hemisphere. Even the presence of a lesion in the language area is enough to confuse the picture. The method of electrical interference and -stimulation of the speech areas, as developed by Penfield and described by

16 Ettliger, et.al., Op. Cit., p. 582.

Penfield and Roberts,¹⁷ yielded similar results as those already reached; namely, that the left hemisphere is dominant for speech, regardless of handedness. This method, however, was also employed when the patient was under surgery, usually for removal of an epileptoid lesion. The language area, as such, was not affected in all the cases investigated, but there is no data available as to eye- and foot preferences of the patients.

These findings therefore should be interpreted as relating to handedness in the strict sense of the word, and not to sidedness where there is a more uniform preference for hands, feet and eyes. And it should also be kept in mind that existing hand preference and the presence of aphasia could be influenced by the lesion to such an extent that generalizations of findings to the normal non-hospitalized population would be unjustified. Finally, in attempts to localize the speech area, handedness and the occurrence of aphasia have been used as main criteria. No reference was made to a possible contribution of auditory dominance. Since audition is so closely linked with the speech process in terms of a cybernetical nervous system, it appears to justify further investigation into this area.

The preceding discussion has been mainly concerned with studies that attempted to correlate cerebral language

¹⁷ Penfield and Roberts, Op. Cit., p. 103-118.

laterality with handedness. The following section will try to emphasize the importance of audition as a monitor for moment-to-moment-speech and the possible implications thereof for the problem under investigation.

2. Auditory Monitoring of Speech.

The publication of Wiener's¹⁸ classic on cybernetics in 1948 has brought new insights and techniques of many disciplines to bear on problems of control and communication. Thus has developed what is known as a servomechanism, where information regarding the performance of a machine is fed back to the device which is error-sensitive and can take steps to compensate, if necessary. This principle is applied widely in fields of engineering, e.g. in computers, anti-aircraft guns, traffic control systems, heating and ventilating systems in homes and in many other areas.

Two types of control systems are usually applied, the open loop system and the closed loop system. In the first, a number of steps is carried out regardless of the performance of the device at any particular stage. An example of this type of control system is found in most automatic washers where the machine goes through a number of cycles, regardless of the degree of dirtiness of the clothes. In

¹⁸ Norbert Wiener, Cybernetics, New York, Wiley, 1948, xvi-212 p.

the closed loop system, or servosystem, information is continuously fed back to the device, which can pick up any errors that may be present in the performance, and take steps to correct them. This type of servomechanism is important in the discussion of any form of nervous system organization, that depends upon sensory feedback regarding the performance of the organism at any particular stage. An example of this type of servomechanism in the nervous system is found in the general posturing activities of the body, where elaborate feedback systems allow us to know the relationship of the body to gravitational axes, and serve to keep us in an upright position.¹⁹ These applications of closed loop control systems in human behaviour have led Grant Fairbanks²⁰ to develop a servosystem theory of the speech mechanism, where auditory intake serves as the sensory feedback channel to monitor vocal output. He reviewed, without discussion, five diagrams of communication systems, one dating back as far as 1930. These models where the message is returned to the brain of the speaker via the ears, at the same time that it is

19 Alfred A. Strauss and Newell C. Kephart, Psychopathology and Education of the Brain-Injured Child, Vol. II. Progress in Theory and Clinic, New York, Grune and Stratton, 1955, p. 6.

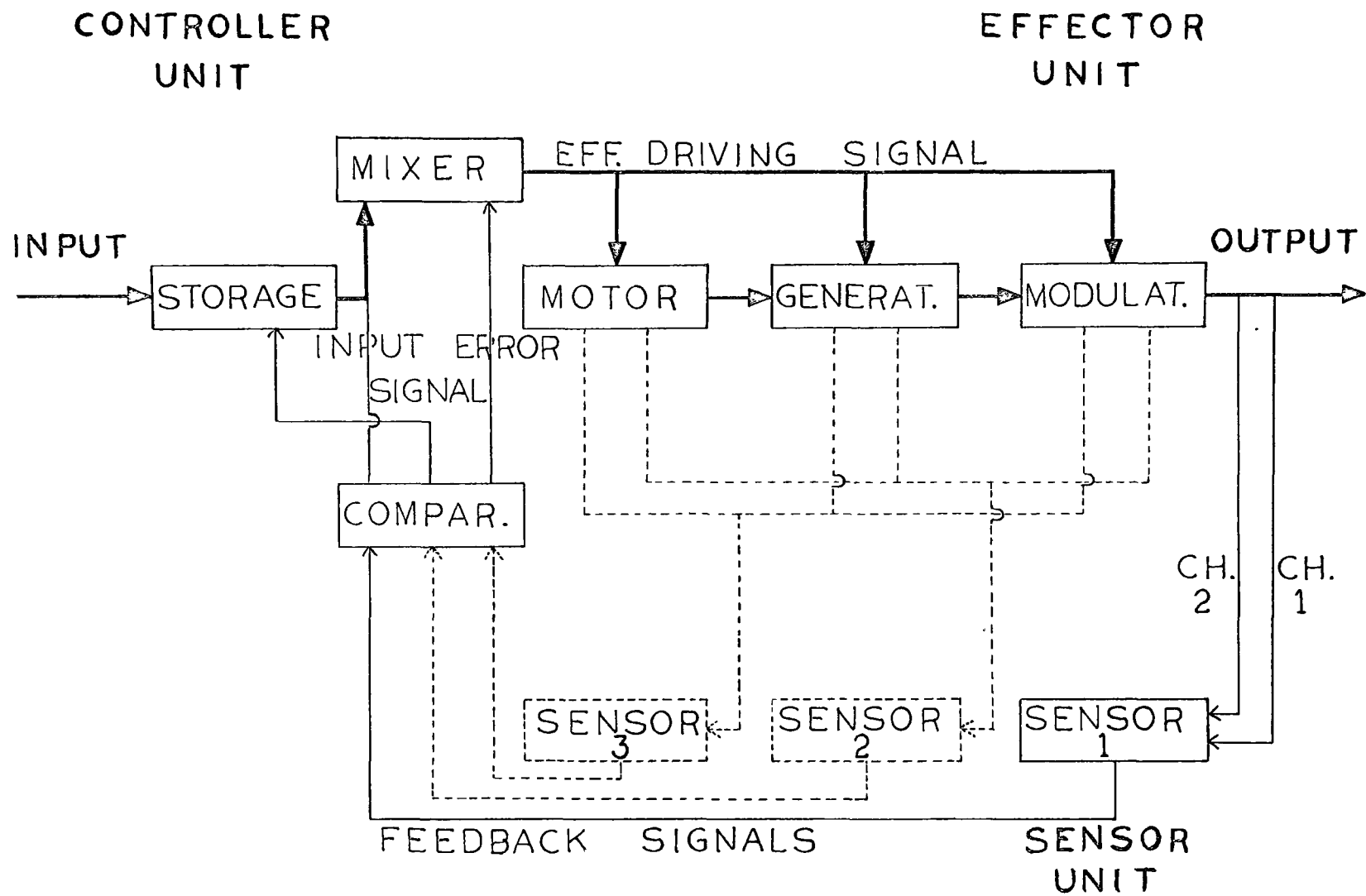
20 Grant Fairbanks, "Systematic Research in Experimental Phonetics: 1. A Theory of the Speech Mechanism as a Servosystem", Journal of Speech and Hearing Disorders, Vol. 19, 1954, p. 133-139.

transmitted to the ears of the listener, served as the starting point for his more elaborate model. He said:

The return of M_1 (message) to B_1 (brain) has often been referred to in such words as auditory monitoring, and interpreted as a sort of 'checking up' on what the speaking apparatus has produced. There is nothing wrong with this view of matters as far as it goes, but it seems to me that it mis-emphasizes the significance of self-hearing during speaking. It stresses the past. The essence of a speaking system, however, is control of the output, or prediction of the output's future. In this kind of system the significance of data about the past is that they are used for prediction of the future.²¹

His diagrammatic model (see figure 2) is based upon a closed loop control system where the input signal, originating in the brain (not shown), is at the left of the diagram and the eventual output signal in the form of audible speech, is at the right. The effective driving signal, originating in the brain, is fed through a motor, generator and modulator on his diagram, which are the respiratory, vibratory and resonance-articulatory structures, respectively. The sensor unit is shown at the bottom of the diagram where sensor 1 is the main channel for providing feedback signals to the comparator. This information is obtained through the two ears (channels 1 and 2 on the diagram) which are playing identical roles in providing the comparator with feedback signals. This is an important observation, since it will bear directly upon the problem that will be investigated in future chapters.

²¹ Fairbanks, Op. Cit., p. 134.



REVIEW OF THE LITERATURE

Figure 2. Model of a closed cycle control system for speaking.^a

^a Grant Fairbanks, *Op. Cit.*, p. 136.

Apart from sensor 1 the comparator is also provided with feedback signals through sensors 2 and 3, which are shown with dotted lines on the diagram. They symbolize the tactile and proprioceptive end-organs. They supply information about the mechanical operation of the effector unit but not of the output itself. This information is subsidiary. The comparator is only part of the whole controller unit indicated on the left of the diagram. This controller unit is an automatic device that issues specific orders to the effector. It should be noted that the message does not originate within the controller unit, but is received from the phensation centre and stored in the storage device. From here it goes as an input signal to both the mixer and the comparator. The comparator now is in possession of two signals, one that has been fed back through the sensor unit, and that is the result of final speech output, and another signal coming from the storage device and which is actually the original unit before it has been modified as an effective driving signal. The comparator now performs the function of comparing the end product with the original and unmodified signal. If the two are exactly alike then the error signal equals zero and no modification is instructed through the mixer device. However, the bigger the difference between the two units in the comparator, the bigger will be the error signal that is instructed to the mixer. In this way the controller unit is constantly

informed of the output and is trying to reduce the error signal to zero. When it is done, the storage device is cleared and the whole process is repeated. It should be kept in mind that this is a model and not a replica of sensory and neuro-muscular activities during the monitoring of speech.

This model explains speech disturbances that can be experimentally induced through delayed auditory feedback. When a subject's normal air conducted speech is returned to his ears with a delay in the feedback process, his speech is seriously disrupted. It is usually characterized by repetition of syllables and words, longer phonation time and increase in vocal intensity. Lee²² was the first to mention this in the literature during 1950 and since then vast amounts of research has been done in this field. The disruption of speech under these conditions is understandable in the light of Fairbanks' model. The return of the subject's vocal output to his ears, with the induced delay, leaves the comparator unsatisfied and a resulting large error signal in the controller unit. This explains why the subject slows down his speech and repeats syllables.

²² E.S. Lee, "Effects of Delayed Speech Feedback", Journal of the Acoustical Society of America, Vol. 22, 1950, p. 824-826.

In the preceding section it has been pointed out that the ears play an important role in monitoring the subject's vocal output. It has also been noticed that in Fairbanks' model the two ears play identical roles in the monitoring process. This is the reason why the cerebral language laterality has not been taken into account in this model. The following section will briefly survey the literature on studies dealing with auditory dominance.

3. Auditory Dominance.

The lack of well controlled research in this field is striking. Only a few references could be located that dealt specifically with this problem. The first investigation was carried out by Peterson²³ and reported during 1942. He used an earphone, mounted on an adjustable stand and placed on the output of a beat frequency oscillator in his experiment. The subject had to stand in front of the apparatus and was asked to listen closely if he could hear any sounds coming from the earphone. The preferred ear was noted. The experiment was carried out a few times and Peterson concluded that, "to varying degrees, individuals do prefer the same ear when listening to a localized sound source".²⁴ However, if

²³ Gordon E. Peterson, "Ear Preference", Journal of Speech Disorders, Vol. 7, No. 4, December 1942, p. 319-321.

²⁴ Ibid., p. 321.

his findings are observed more closely, it is noted that of the twenty-four subjects used, only eleven used consistently the same ear. The rest had mixed preferences, even within numbers of the same trial. Although adequate statistical treatment of data is non-existent in this study, the reliability of findings alone appears to be considerably below an acceptable level. The same method has been tried out on a number of subjects and it was also found that the preference for one ear is very inconsistent and influenced by body posture and telephone speaking habits.

In another study by Mounsey and Peterson²⁵ the possible relationship between ear preference and other laterality characteristics was investigated. They used the same technique, already described, to determine ear preference. Each subject was given three trials and one inconsistent choice labelled the subject as inconsistent regarding ear preference. The same procedure was followed in determining handedness. Four tests were given, one where the subject had to unscrew the cap of a fountain pen; another where the subject was asked to write from dictation, numbers with both hands on a blackboard; a third test where the same procedure was followed on paper instead of on the blackboard; and a fourth test where

²⁵ Claudine Mounsey and Gordon E. Peterson, "The Relationship of Ear Preference to Other Laterality Characteristics", Journal of Speech Disorders, Vol. 9, No. 2, June 1944, p. 121-123.

the subject had to copy a pattern with both hands simultaneously, on a piece of paper. The subjects had to show consistent preference on three of the four tests before they were accepted as either right- or left-handed.

Three tests were used to determine eye preference. Subjects had to aim with a pencil at the examiner's nose, then the same procedure was repeated when the subject aimed through a funnel, which necessitated the use of one eye, and lastly, the test of convergence was used where the subject had to focus on an object that was approaching him. The eye that broke away first was considered the non-dominant eye.

To determine foot preference, four tests were used. The subject had to step upon a box and then down, the leading foot being considered the dominant foot. In the second test, the subject had to kick a ball directly into a corner, the foot used was considered the preferred foot. In the third test, the subjects were asked to fall forward and catch themselves by stopping their fall with one leg. The leg used was considered to indicate the preferred foot. In the last test, the subjects were asked to try to get on a table by placing one knee on the table top. The leg used was considered to indicate the preferred foot.

Of the forty-five subjects tested, 37.8 per cent preferred the same ear and the same hand. Only nine consistently

preferred the opposite ear and hand. The relationship between preferred eye and preferred ear was less marked, only 28.9 per cent of the subjects preferred the same eye and ear. Only seven subjects consistently preferred the opposite ear and eye. Ear and foot preferences showed the closest relationship; 42.2 per cent of the subjects preferred the same ear and foot and only four consistently preferred the opposite ear and foot. Mounsey and Peterson therefore concluded:

These data indicate that there is some positive relationship between ear preference and the other laterality characteristics examined in this study, although the data do not indicate that this relationship is particularly close.²⁶

However, the reason for choice of tests, and especially the scoring criteria, remains unclear. Unless an action to be performed requires some degree of dexterity or meaningfulness in terms of approaching a goal, any one of the two organs can be applied equally well. Walking, for example, is an activity that everyone has developed so well that the leading foot in starting the action can hardly be considered as the preferred foot. The same applies for the test where subjects had to unscrew the top of a pen. Which action is actually more important, unscrewing the top or holding the pen? Subjects executing the movement with both hands simultaneously were also labelled as inconsistent. This

²⁶ Mounsey and Peterson, Op. Cit., p. 123.

explains the large number of so-called inconsistent choices in their table²⁷ and casts some doubt on the validity of other findings.

In an attempt to demonstrate relationships between ear preference and hearing acuity, Bilto and Peterson²⁸ used the same technique to determine ear preference and administered audiograms to sixty-nine subjects, using the following frequencies: 128, 256, 512, 1024, 2048, 4096, and 8192. They used a method of taking the difference in decibal between the acuity of the two ears for each of the frequencies. The average of these seven differences was taken as an indication of the degree of right- or left ear superiority. When the right ear was superior, the difference was considered positive and when the left ear was superior, the difference was considered negative. Again, a large number of subjects were inconsistent in their ear preference, for reasons already mentioned. After analyzing their findings, and trying to relate it to ear preference in various ways, they concluded:

Thus, a more general consideration indicates that the difference in hearing acuity between the two ears would not usually be a primary factor in determining ear preference.²⁹

27 Mounsey and Peterson, Op. Cit., p. 122.

28 E.W. Bilto and Gordon E. Peterson, "The Relation Between Ear Preference and Hearing Acuity", Journal of Speech Disorders, Vol. 9, No. 2, June 1944, p. 123-125.

29 Ibid., p. 125.

No further studies in this direction could be located after these apparently unsuccessful attempts to demonstrate the existence of an ear dominance. As was pointed out, these investigations were concerned with ear preference and not with a functional predominance of the one ear over the other. Superiority of acuity scores of one ear over the other does, to some extent, indicate a possible functional predominance, although Bilto and Peterson³⁰ have demonstrated no significant relationship of hearing acuity with ear preference.

Another attempt to demonstrate the existence of auditory dominance with another approach was the study of Elkins.³¹ She tried to demonstrate auditory dominance on the assumption that one ear takes leadership in the monitoring process of speech, already described. She used the same method as Peterson³² to determine ear preference and assumed that when the preferred ear is exposed to delayed auditory feedback, the effects noticeable on speech would be more disrupting than those effects noticeable when the non-preferred ear is exposed to delayed auditory feedback. She used a

³⁰ Bilto and Peterson, Op. Cit., p. 125.

³¹ E.F. Elkins, Effects of Side-tone Delay on Oral Reading Responses under Conditions of Binaural and Mon-Aural Stimulus Presentation, unpublished Master's thesis, University of Maryland, 1936, 37 p.

³² Mounsey and Peterson, Op. Cit., p. 121.

loud white noise to mask the contralateral ear and presented the delayed feedback first to the preferred ear and later to the non-preferred ear. The experiment was also repeated with a binaural presentation of the stimulus. One hundred and twenty-seven subjects were used and had to read very short passages, some only phrases of three words.³³ The over-all reading time was taken with a stop watch to one fifth of a second. No differences could be found in reading between the conditions where the preferred and the non-preferred ear had been exposed to delayed auditory feedback. She concluded:

The results of this study do not support the hypothesis of dominance in the auditory sense. The failure to demonstrate statistical significance of differences in duration of oral reading responses under delayed side-tone suggests the possible effects of factors that were not controlled in this investigation.³⁴

The use of such short reading phrases and the rather awkward timing device could possibly have influenced the results to such an extent that no significant conclusion could really be drawn from this study. In such a short reading period, the reaction time of the experimenter in pushing the stop watch, is probably longer than the difference between the duration of reading passages compared. Also, the fact that the subjects were screened on ear preference principles, which is not a very reliable measure, could have influenced the

³³ Elkins, Op. Cit., p. 15.

³⁴ Ibid., p. 29.

results. No attempt was made to relate ear preference to other laterality characteristics for the final experiment. The approach, however, appeared to be useful in attempts to demonstrate auditory dominance.

Doreen Kimura,³⁵ in a recent study, used subjects with epileptic foci in various areas of the brain and presented digits to the two ears, either simultaneously in pairs, or in rapid succession. The subject was required to repeat all the numbers he had heard after each group of six. It was found that damage to the left temporal lobe impaired over-all performance, regardless of which ear received the stimuli. Post-operative scores also suggested that unilateral temporal lobectomy, on either side, significantly impaired the recognition of material arriving at the ear contralateral to the removal. Frontal lobectomy did not impair the performance in any way. It was therefore concluded that the crossed connections from ear to cortex are stronger or more numerous than the uncrossed or ipsilateral connections. These findings have already been well established in the animal literature³⁶ and it now appears as if a similar organization exists in man. Another finding of this study was that pre-operative scores of

³⁵ Doreen Kimura, "Some Effects of Temporal-Lobe Damage on Auditory Perception", Canadian Journal of Psychology, Vol. 15, No. 3, September 1961, p. 156-165.

³⁶ Ibid., p. 163.

recognition were significantly higher for the right ear than for the left ear, regardless of the site of the lesion. This was interpreted to indicate that in the subjects used, the left temporal lobe was more important (dominant) than the right temporal lobe in recognition of verbal material. This finding is well in agreement with the fact that the left temporal lobe is usually dominant for speech, as already discussed in a previous section.

This conclusion probably led Kimura to follow up the previous study to investigate the hypothesis that, "in subjects with speech represented in the right hemisphere, recognition of verbal material arriving at the left ear should be more efficient".³⁷ In this study she used 120 patients at the Montreal Neurological Institute who had epileptogenic lesions of various parts of the brain. The group was divided into two, 107 who had speech represented in the left hemisphere and 13 who had speech represented in the right hemisphere. The method used in determining lateral dominance for speech was the sodium amytal aphasia test, introduced by Wada (1949) and described by Penfield and Roberts.³⁸ Sodium amytal is injected into the internal carotid artery of one side, whereby the functions of that hemisphere are temporarily

³⁷ Doreen Kimura, "Cerebral Dominance and the Perception of Verbal Stimuli", Op. Cit., p. 186.

³⁸ Penfield and Roberts, Op. Cit., p. 66.

disrupted. Dysphasia usually occurred after the dominant hemisphere had been injected. The test procedure was the same as in the previous study, digits in groups of six were presented to the subject in such a way that half came to the left ear and half to the right ear. She concluded:

These data indicate 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.³⁹

Subsequent analyses were performed to determine if this finding is related to handedness and it was found that handedness was not a factor in producing these results. Again, no criteria are given for any laterality tests that may have been used to determine handedness. These findings are also in agreement with her previous study⁴⁰ where it was stated that the crossed auditory pathways are more efficient than the uncrossed. In a concluding remark, she stated that one of the reasons why the better efficiency of the ear, contralateral to the speech centre has so far gone undetected, may be that in most people both pathways are well developed and that a difference can only be detected when the material has a certain degree of difficulty, or when the two pathways

³⁹ Doreen Kimura, "Cerebral Dominance and the Perception of Verbal Stimuli", Op. Cit., p. 168.

⁴⁰ -----, "Some Effects of Temporal-Lobe Damage on Auditory Perception", Op. Cit., p. 163.

are in direct competition during simultaneous presentation of stimuli.⁴¹

By way of conclusion the most important findings, mentioned in the previous sections, will be summarized and a rationale and general hypothesis stated for the present investigation. This general hypothesis will then be broken down into statistical hypotheses and descriptions of experimental design in the following chapter.

4. Summary, Rationale and General Hypothesis.

A systematic survey of the literature over the past hundred years, by several authors, on the occurrence of left- and right-hemiplegia with aphasia, has led to the conclusion that cerebral language laterality is usually restricted to the left hemisphere. There are cases known where the right hemisphere undoubtedly subserved the speech function, but this seems to be an extremely rare occurrence. Language laterality also appeared to be a function independent of handedness. These findings were later confirmed by methods used in electrically stimulating or interfering with certain parts of the cortex. However, laterality tests, used in determining handedness of the patients, were not mentioned and it appears that the findings should be interpreted only

⁴¹ Doreen Kimura, "Cerebral Dominance and the Perception of Verbal Stimuli", Op. Cit., p. 169.

in terms of handedness in the strict sense of the word, and not in terms of laterality or sidedness. Also, without exception, these findings have been derived from the observations made on brain damaged subjects where either speech functions or certain laterality aspects could have been transferred to the opposite hemisphere. Since, in most cases, the onset of the damage is not known, the possibility of such a confusion could not be ignored and findings should be very cautiously applied to fit the general non-hospitalized population.

In a following section it has been pointed out to what an extent the ears perform a monitoring function of the subject's vocal output. A model, using a closed cycle control system, was discussed to point out how a phenomenon like delayed auditory feedback can seriously disrupt speech. Since this model assumed identical functions played by the two ears in feeding back information to the control unit, a further investigation was necessitated to evaluate statements which claimed the presence of dominance in the auditory sense.

It was found that an auditory dominance does appear to exist, using ear preference as a measure. However, ear preference does not seem to be a reliable measure since it is influenced by some external factors that cannot be controlled. Further attempts to relate ear preference to

other laterality characteristics and to auditory acuity were rather inconclusive, although the possibility of some relationships were indicated. A better controlled study, using brain damaged subjects, found that the crossed auditory pathways are more efficient than the uncrossed and that information arriving at the ear, contralateral to the hemisphere that is dominant for speech, is better recognized than information arriving at the ipsilateral ear. This in itself is a clear demonstration of the existence of auditory dominance. These findings were not related to handedness but appeared to be only a function of cerebral language laterality.

The main intention of the present study is to demonstrate the existence of auditory dominance with a normal population where there is no history of brain damage. In the previous study that demonstrated a difference between the ears contralateral and ipsilateral to the speech centre, there was knowledge regarding the localization of speech functions. Since such a drastic measure as the sodium amytal aphasia test cannot possibly be used in a normal population to locate the speech centre, cerebral language laterality is going to be assumed on grounds of laterality tests. Two samples will be taken of high school students who demonstrate complete right- and left-sidedness. Instead of ear preference, a measure of auditory dominance in terms of acuity scores will

be taken. Those subjects that demonstrate adequately the presence of right-handedness, -eyedness, -footedness, and -earedness will be called completely right-sided. The same measures will be taken to secure a left-sided group. It will be inferred that the right-sided group has left cerebral language laterality and that the left-sided group has right cerebral language laterality. The ear contralateral to the assumed speech centre will be called the dominant ear, and the ear ipsilateral to the assumed speech centre will be called the non-dominant ear.

Since it has been demonstrated that the difference between the ears is only detected when the material reaches a certain level of difficulty or when the two pathways are in competition, the dominant and non-dominant ear will be exposed simultaneously, the one to a direct feedback and the other to a delayed feedback of the subject's voice. Since it is known that delayed auditory feedback impairs speech, it is assumed that the subject's speech will be more impaired when the dominant ear is exposed to delayed feedback than when the non-dominant ear is exposed to delayed feedback. The same tendency is hypothesized for the right-sided, as well as the left-sided group.

The following chapter will be concerned with an elaboration of the general hypothesis into more specific statistical hypotheses and with a description of the experimental design.

CHAPTER II

DESIGN OF THE STUDY

The present chapter will attempt to give a precise description of the methods employed in screening the subjects, in setting up equipment and calibrating it, of testing procedure and analysis of speech samples into raw scores and, finally, of the statistical design and hypotheses to be tested. The description will be done in such a way that the present study can be duplicated by other investigators, if so desired.

1. The Sample.

The sample consisted of two groups of high school students, twenty of whom demonstrated complete right-sidedness and ten who were completely left-sided. The procedure in securing the subjects was as follows:

a) Administration of Laterality Tests.- The full co-operation of one of the local high schools and its staff members was obtained and the project was explained to the principal. It was found that there were approximately fifty students in the school who demonstrated preference for the left hand. Of these, ten were eliminated because they were in higher grades and testing would have interfered with school work and class routine. Of the remaining forty, two

were eliminated because of known brain damage, one subject who had had polio at an early stage was also eliminated and five more who demonstrated, to some extent, speech disorders of a very mild nature. One subject did not speak English as a first language and another had had damage of the right eardrum. Both these cases were also eliminated. The remaining thirty were then administered the following laterality tests:

The subject was handed a piece of paper and a pen and asked to write his name. Then he was also asked to write his name with the non-preferred hand. He was also asked whether he considered himself to be a left-hander and whether he performs any other actions with his right hand. Only when the subject replied that he considered himself to be a left-hander and that he constantly preferred his left hand, was testing continued. He then was given a piece of paper that was rolled in the form of a ball and he was asked to stand back a few yards and throw it as hard as he could.

The subject was then given a piece of cardboard, approximately four inches by six inches with a small hole punched in the center, and was asked to stand back a few yards, keep it in both hands at arm's length, and to look through the hole at the examiner's nose. He was then handed a V-scope and asked to keep it in both hands and to look at the examiner. Finally, the subject was given a kaleidoscope

and asked to hold it against the light and to look inside. If at any stage the subject demonstrated a preference for the right eye, the test was discontinued.

The test for footedness consisted of handing the subject a sheet of paper that was rolled in the form of a ball, and he was asked to kick it as hard as he could so that he could hit the ceiling of the room. This was repeated a few times to note consistency in the choice of foot. Only when the subject clearly demonstrated a preference for the left hand, left eye and left foot, was the test continued to determine earedness.

The test for earedness consisted of the administration of audiograms to the remaining subjects. A quiet room was chosen for this purpose and a Maico MA-2B portable audiometer was used. The subject was properly informed about the test and given explanations when he asked questions. He was then given the instructions to the test and asked to indicate with his finger as soon as he heard a sound on one of the two earphones. He should keep out his finger as long as he heard the sound and should only pull back his finger when the sound was no longer audible. Before the test started, the subject was given an indication of the nature of the sounds and also told at which ear to expect the sound. The subject was then placed in such a way that he could not see the examiner, the earphones were placed

on his ears and the test started at a frequency of one thousand cycles per second. The test was started at a level of approximately ten decibels and was gradually decreased until the subject could no longer hear the pure tone. The same procedure was then repeated, approaching the threshold from a level of -10 decibels. A common point was determined in this way to indicate the threshold of the subject at that particular frequency. The same procedure was subsequently repeated for the following frequencies in this order: 1,500, 2,000, 3,000, 4,000, 6,000, 8,000, 750, 500, 250, and 125. After a rest period of a few minutes the same procedure was repeated for the other ear. Only air-conducted pure tones were used in the audiometric testing.

b) Analysis of Audiograms.- The obtained audiograms were then analyzed to determine if any significant hearing impairment for either of the two ears was present. The method employed was that prepared by the Subcommittee on Noise and approved by the Council of the American Academy of Ophthalmology and Otolaryngology.¹ Only audiograms which indicated zero per cent hearing loss for either ear were considered for further analysis. The audiograms were then

¹ Dean M. Lierle, Chairman, "Guide for the Evaluation of Hearing Impairment - A Report of the Committee on Conservation of Hearing", Transactions American Academy of Ophthalmology and Otolaryngology, March-April, 1959, p. 236-238.

transformed into units on a ten-point scale to compare the relative efficiency of the two ears. The values have been chosen arbitrarily so that a threshold of -10 db. for any frequency would correspond with a value of 10 on the ten-point scale; a threshold of -5 db. would indicate a value of 9; 0 db. would correspond to 8; +5 db. with 7, and so on. A threshold of +40 db. for any frequency would therefore correspond to a value of 0. In this way a value has been obtained for each of the eleven frequencies tested. An average of these eleven values for the left ear was then used to indicate the mean acuity score for the left ear. In a similar way, the mean acuity score for the right ear has been obtained. Only those audiograms were retained for the left-sided group which showed a higher mean acuity score for the left ear. Using this procedure, ten subjects were retained for the final left-sided group. An average has also been obtained of the ten values for each of the eleven frequencies. Figure 3 shows the distribution of mean acuity scores of the ten left-sided subjects on each of the eleven frequencies. On the vertical axis the transformed values are indicated and in parentheses are the original values from the audiogram that indicate hearing loss in decibels. It can be seen from the figure that the dominant ear (left ear) has better acuity than the non-dominant ear (right ear). They basically follow the same pattern but do not overlap at any

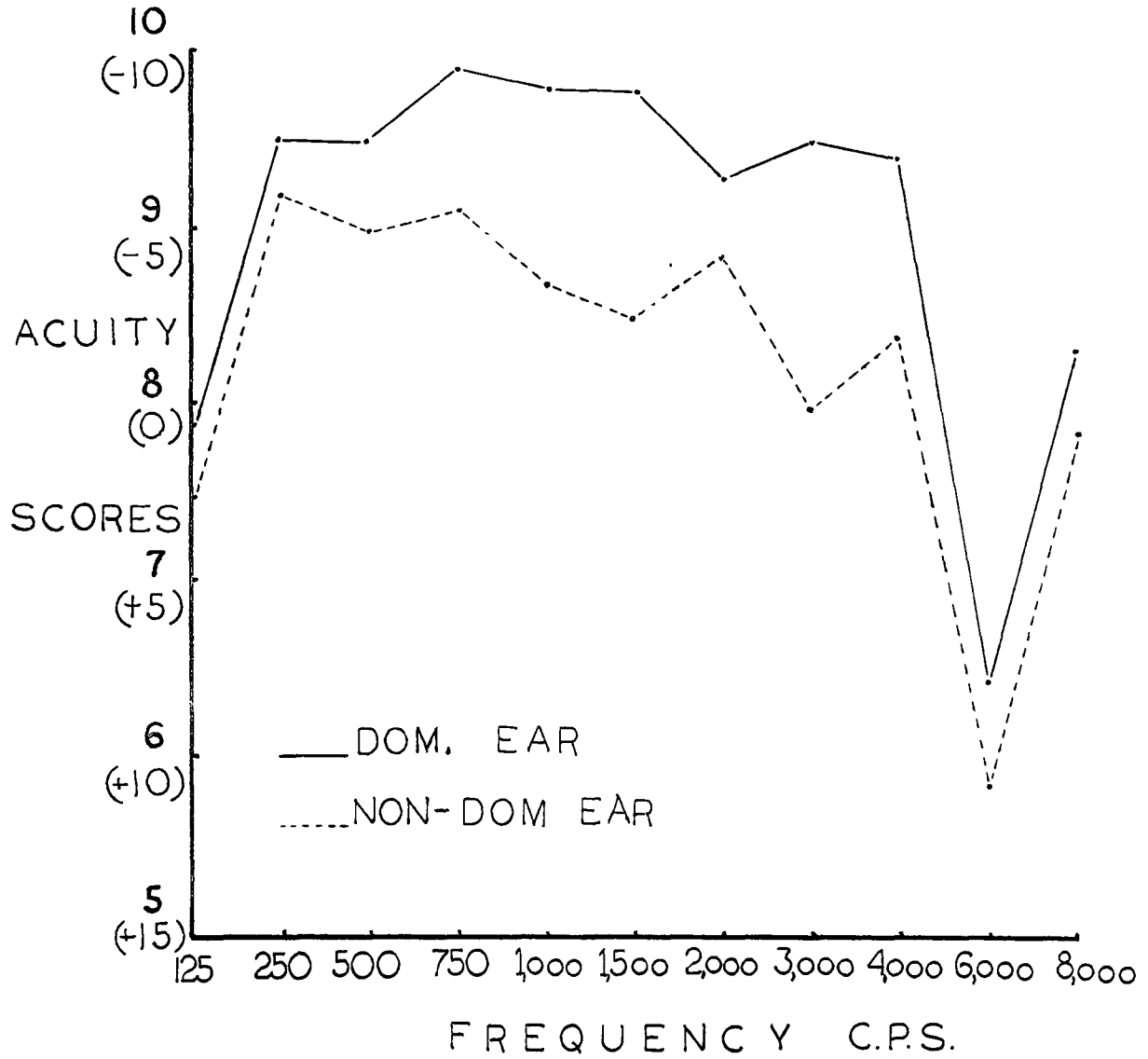


Figure 3. Mean acuity scores for ten left-handed subjects.

frequency. A t test has been performed to determine whether the mean acuity scores for the dominant ear are significantly higher than those of the non-dominant ear. A t value of 1.95 has been obtained which is not significant at the .05 level of probability.

After the ten subjects for the left-sided group have been obtained, exactly the same procedures were followed to secure a right-sided group. Relatively few subjects had to be eliminated and a group of twenty right-sided subjects was obtained. Figure 4 shows the distribution of mean acuity scores of the twenty right-sided subjects on each of the eleven frequencies. It can be seen that the difference between dominant- and non-dominant ear is more marked than for the left-sided subjects. A t test yielded a value of 13.2, which indicates a significant difference between the mean acuity scores of the dominant and non-dominant ear, at the .001 level of probability. Figure 4 also indicates the possibility of a difference in variance between the acuity scores of dominant and non-dominant ears on the eleven frequencies. The variance was obtained for dominant and non-dominant ears and a test of significance indicated that the variance for the non-dominant ear is significantly greater than for the dominant ear. This was significant at the .001 level of probability.

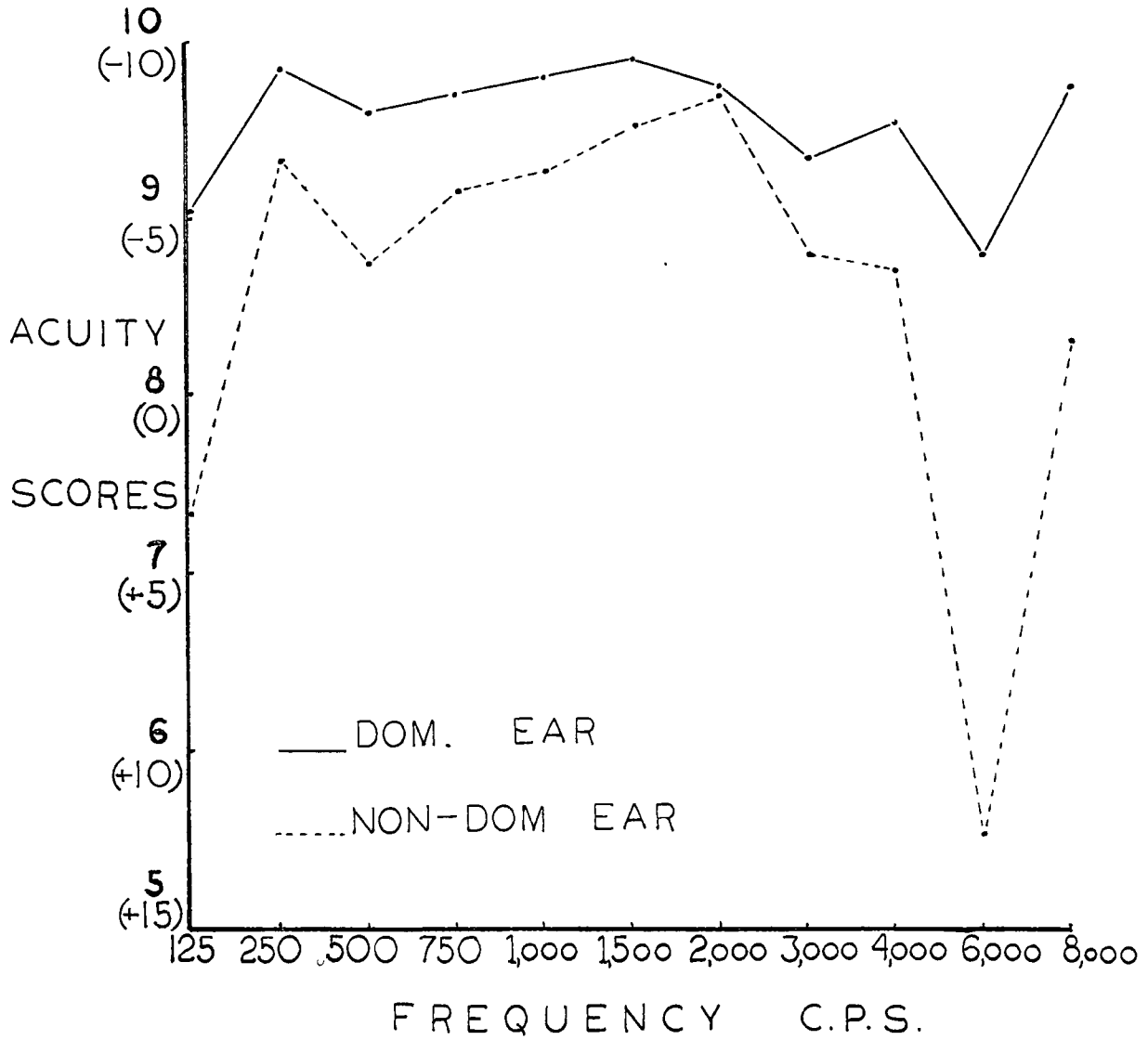


Figure 4. Mean acuity scores for twenty right-handed subjects.

The thirty subjects obtained for the experiment did not demonstrate any obvious speech or reading disabilities; there was no history of any brain damage; hearing acuity was essentially normal and intelligence was average or above average. The left-sided group consisted of four girls and six boys with a mean age of fifteen years and three months and a range of thirteen years and two months to seventeen years and one month. The right-sided group consisted of ten girls and ten boys with a mean age of fourteen years and eight months, and a range of thirteen years and three months to sixteen years and nine months.

2. Instrumentation.

The instruments used for the experiment consisted of a Harman Kardon Stereo amplifier, type A 500; an Apex tape recorder, type 960; two Shure ceramic microphones, type 275S; one pair of Phillips liquid insulated stereo earphones; a Malco MA-2B audiometer; a constructed metal switch box; and two Shurite VU-meters, rectifier type. Figure 5 contains a diagram of the circuit.

It can be seen that the switch allowed one of three different conditions to the earphones. The first condition simply relayed the subject's voice from the microphone through the amplifier to the earphones. With the switch in this position the subject will hear himself directly on

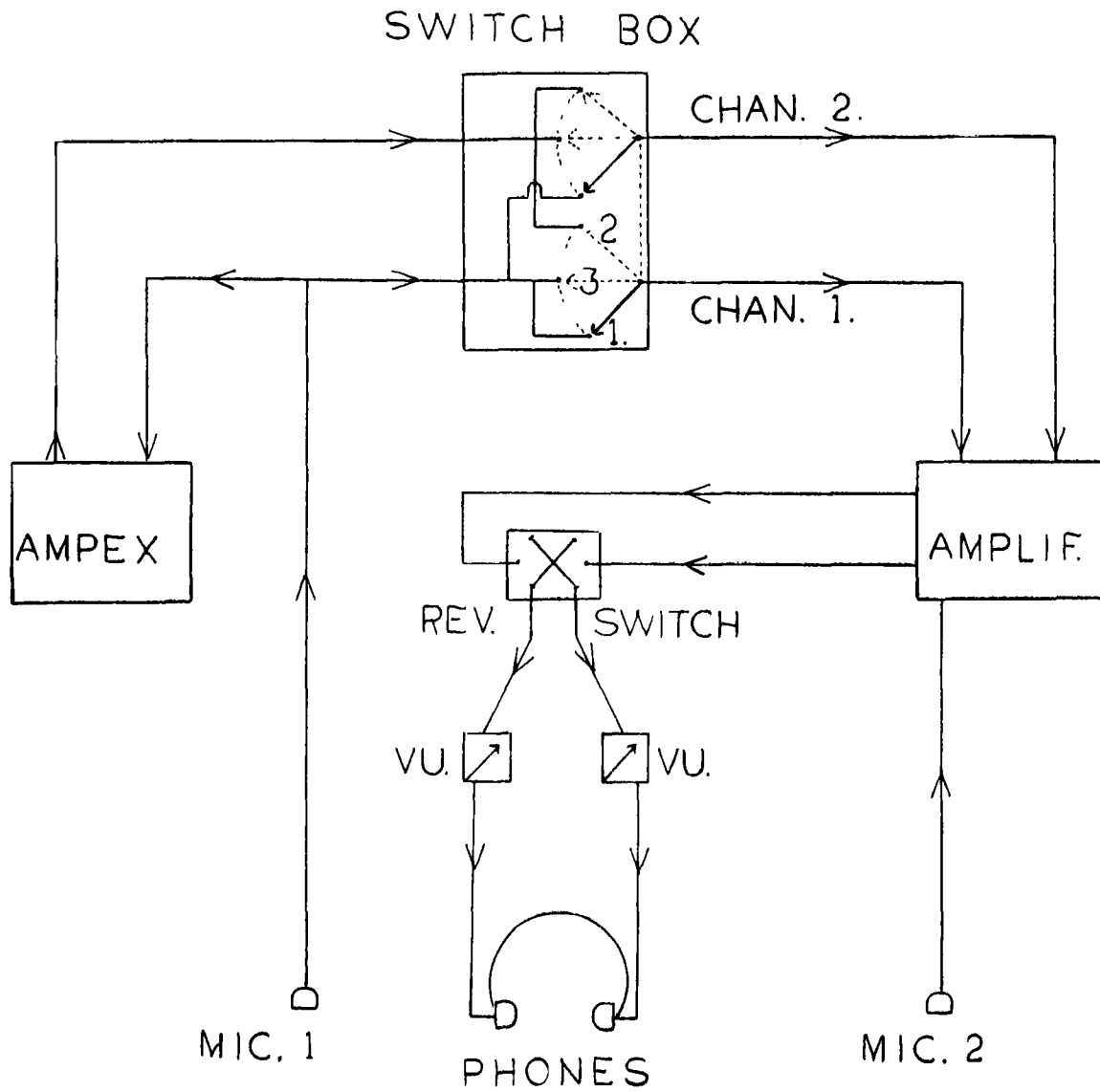


Figure 5. Diagram of circuit.

both ears of the earphones. This condition will be called condition (a). A connection to the Ampex allows the subject's voice to be recorded while he speaks.

With the switch in position 2, the subject's voice is first relayed to the Ampex and recorded. A second playback head, mounted a little distance away from the recording head, picked up the recorded voice a fraction of a second later, relayed it through the amplifier to both earphones directly. With the switch in this position the subject heard his own voice after a short delay in the feedback process. This condition will be called condition (b). The distance between the recording and playback heads was measured accurately and with a tape speed of 7.5 inches per second, which was used throughout the experiment, the delay induced into the feedback was estimated at .158 second.

With the switch in position 3, the impulse is divided into two separate channels. The one goes directly to the amplifier and from there, through one of the two channels of the amplifier, to one of the earphones. The other circuit is first relayed through the Ampex where it is recorded and delayed in a manner already described. From there it is fed through the other channel of the amplifier to the other earphone. With the switch in this position the subject hears his own voice directly on the one ear and delayed on the other ear. This condition will be called condition (c) when

the delayed signal was on the non-dominant ear and the direct signal on the dominant ear.

An extra reverse switch, mounted on the output terminals of the amplifier, allowed the signals to be reversed so that the delayed signal is on the dominant ear and the direct signal on the non-dominant ear. This condition will be called condition (d).

Since, in the main experiment, conditions (c) and (d) will be compared, it is of the utmost importance to assure that the two signals arriving at the two ears, are identical, except for the delay in the one. The first important consideration is that of frequency response of the equipment. The Harmann Kardon amplifier is capable of delivering a flat, undistorted signal between 25 and 15,000 c.p.s. The Aspek tape recorder, when a tape speed of 7.5 inches per second is used, also responds with a flat curve up to approximately 15,000 c.p.s. The Phillips stereo earphones have a flat frequency response between 25 and 12,000 c.p.s. and the microphone is said to be free from any undesirable peaks up to 12,000 c.p.s. It is therefore assumed that the signals, whether they are direct or delayed, are undistorted, at least within the range of normal hearing.

A next consideration was that of phasing. It appears to be important that the two earphones be in phase.

This was accomplished by a switch on the amplifier that enables this adjustment.

A last consideration was that of intensity on the earphones. The following procedure was followed to calibrate the equipment for equal intensity on both channels: two Shurite VU-meters were connected to the output terminals of the two channels. The meters were adjusted to have a common zero and then the microphone socket on the switch box was used as an input for the audiometer. The audiometer was set for a frequency of 500 c.p.s. and an intensity of 60 decibels. When the audiometer and the amplifier were switched on, the pure tone was heard on the earphones and the VU-meters indicated a reading. The amplifier was then adjusted to give maximum channel separation on the stereo-mono control and the balance control was gradually adjusted until both meters gave the same reading. The volume control was then adjusted until the VU-meters showed a deflection of 100% or 0 VU-units. The reverse switch was then put in to reverse the signals, and the controls were again adjusted until both meters showed the same reading. When the calibration has been completed both meters indicated the same reading of 0 VU-units, which stayed constant regardless of the condition used. It was therefore assumed that the intensity on both ears was exactly the same.

The controls were then locked and not touched until the experiment was completed. Nevertheless, at the

beginning of each session with a subject, the pure tone was applied for ten seconds and was recorded. This served a dual function, to determine whether the controls remained untouched and to serve as a calibrating signal for the analysis of the tapes, which will be described later. All speech samples were recorded on Ampex recording tape, .6 mil. aylar.

3. Testing Procedure.

The reading passage used in the experiment consisted of a 127-syllable paragraph (see appendix) that was adopted from Hull.² The passage was typed in spaced capitals on a piece of paper and mounted on a cardboard. The experiment was conducted in a sound insulated room and when the subject entered the room he was seated comfortably at the table in front of the microphone. He was then given an explanation of the procedure and was asked to read the passage for himself to get acquainted with it. Any words that he did not know, or which he mispronounced, were corrected so that the subject was fairly familiar with the passage at the beginning of the experiment.

It was then explained to him that it is the aim of the study to investigate reading habits of left- and right-handed people and that it is only required of him to read

² Forest Melvin Hull, An Experimental Investigation of Speech Disturbance as a Function of the Frequency Distortion of Delayed Auditory Feedback, unpublished Ph.D. dissertation, University of Illinois, 1952, p. 5.

the passage in a normal way. In order to get used to the experimental condition, where the subject was wearing earphones and heard himself through the earphones, the subject was allowed a few minutes of spontaneous speech while wearing the phones. He was also asked to read the passage aloud. When he finished, he was instructed that it was very good, and that that is all that was required of him. He was asked to read in a normal way without hesitations. Should he make any errors, he was asked to ignore them and continue. The subject was also asked to maintain the distance of approximately five inches between his mouth and the microphone at all times. When everything was clear, the tape recorder was started and a tap on his shoulder was the indication for the subject to start.

Another microphone, microphone 2, enabled the experimenter to communicate with the subject. After completion of condition (a), where the subject was exposed to a direct feedback of his own voice, he was then instructed through the microphone that the same procedure will be repeated for three more conditions. He is again asked to read the passage as normal as he can, however, in the following conditions he will probably experience some difficulty in reading. He was asked not to laugh or stop, but to continue and to read as normally as he could. Conditions (b), (c), and (d) were then completed in the same way while a

recording was made of the subject's speech. When all four conditions were completed the earphones were removed and the subject was given a rest period of ten minutes. The whole procedure was then repeated for a second time. In this way speech samples were obtained of four different conditions over two occasions. When the testing was completed the subject was asked not to communicate with the other subjects.

For all the subjects, the experiment started with condition (a), i.e., a direct feedback of their voice. However, the remaining three conditions were rotated from subject to subject and also for every subject between the two occasions. This way it was assured that no practice effects could accumulate on one condition because of its place in the presentation of conditions. The reason why condition (a) was not rotated but kept at the beginning of the experiment was to obtain as reliable a measure of normal speech as was possible. Presumably the (a) condition was not influenced so much by the other conditions in this way. This measure of normal speech was necessary to determine, for future analysis, what the amount of disturbance is for each of the other three conditions.

4. Analysis of Speech Samples.

After the experiment had been completed all the speech samples under the four different conditions were taped. These tape recordings had to be transcribed into quantitative measures or speech variables for purposes of analysis. Since it has already been indicated that the differences are often difficult to detect, the idea of using a panel of judges to judge the speech samples, had been abandoned. Instead, it was decided to transcribe the tape recordings by means of a high speed graphic level recorder. This would enable a more objective interpretation of the various samples. Spilka,³ in investigating the possible relationships between personality makeup and the effects of delayed speech feedback, used six different voice variables. They were: per cent phonation time, mean syllable duration, mean vocal intensity, degree of change in vocal intensity variance, degree of increasing change in vocal intensity variance and degree of decreasing change in vocal intensity variance. It was found that only those variables, dealing with vocal intensity variance, correlated with personality characteristics. The first three variables mentioned did

³ Bernard Spilka, "Relationships Between Certain Aspects of Personality and Some Vocal Effects of Delayed Speech Feedback", Journal of Speech and Hearing Disorders, Vol. 19, 1954, p. 491-503.

not correlate with personality aspects. Since this study is not concerned with personality aspects - as a matter of fact, the possible influence of this variable should be eliminated - it was decided to take the first three variables.

The voice variables for this study are therefore:

1. per cent phonation time;
2. mean syllable duration;
3. mean intensity (above an arbitrary reference point).

In order to transcribe the tape recordings on paper, the following procedure was used: the tape recording with speech samples was placed on an Ampex tape recorder, model 620. Since this model delivers a constant output and it is not possible to adjust any volume control, the calibration procedure was extremely simple. It was noted that the pure tone, which was applied and recorded before each session, registered at a level of 38 decibels above the arbitrary reference point. Every time the pure tone was heard, it was transcribed on exactly the same level, indicating that the speech samples from subject to subject could be compared.

The Ampex was then connected to a Brüel & Kjaer spectrometer, type 2109, and the function selector was adjusted to the "Linear A" position to filter out some low frequency disturbance on the tape in the form of ambient noise. The spectrometer then fed a Brüel & Kjaer Level Recorder,

type 2505. It was found that a writing speed of one hundred millimeters per second for the pen, was sufficient to react to quick changes in the speech output. It also permitted a clear transcription that could be analyzed easily. The paper speed was adjusted for ten millimeters per second. The tape recordings were then transcribed on paper while the experimenter monitored the output on a separate set of earphones. The beginning and end of each condition was indicated with a pencil mark to facilitate analysis. However, the condition was not indicated on the paper until the final analysis for all three variables had been completed. The order of presentation of conditions was recorded during the actual experiment and after final analysis the conditions were then marked on the paper. This was done to eliminate possible bias in the scoring and analysis of the speech transcriptions.

In this way the speech samples of all thirty subjects, each with eight different conditions (four conditions over two occasions), were transcribed on paper. The three individual voice variables were then calculated from the paper in the following manner:

a) Per cent phonation time -

Since the paper speed was known to be ten millimeters per second, every millimeter indicated one tenth of a second. The overall reading time was obtained by measuring

the distance on the horizontal axis from the point where the pen left the zero mark, up to a perpendicular that was dropped from the peak of the last curve. This method compensated for possible pen lag. The actual phonation time was then measured by subtracting from the overall reading time all the periods that did not contain any speech. These periods were measured out in the same way, by dropping a perpendicular from the peak of the curve, just before it returned to the zero mark (no speech), and measuring the distance between this perpendicular and the point where the pen left the zero mark. All the silent periods in the speech were obtained in this way, added, and finally subtracted from the overall reading time.

In this way, overall reading time and phonation time was obtained for all the speech samples of the thirty subjects. From these measures per cent phonation time was calculated as follows:

$$\frac{\text{phonation time}}{\text{overall time}} \times \frac{100}{1}$$

This variable will be called variable 1 in subsequent discussions. (See appendix for measures obtained on variable 1.)

b) Mean syllable duration -

To obtain the mean syllable duration for each of the subjects on each of the conditions, the phonation time measure was taken and divided by the number of syllables in the

reading passage, i.e., 127. To simplify programming for the analysis this measure was expressed in milliseconds. The obtained syllable duration in seconds was therefore multiplied by one thousand. This variable will be called variable 8 in subsequent discussions. (See appendix for measures obtained on variable 2.)

c) Mean intensity above an arbitrary reference -

The range of the potentiometer used on the level recorder was fifty decibels, thus allowing a maximum of fifty decibels above the zero point. None of the speech samples approached this level. Since any level indicated on the paper is not an absolute measure in decibels, but rather a relative measure in terms of the zero point, any obtained value from the samples should not be interpreted as decibel. This is the reason why the variable is expressed in decibel above an arbitrary reference (the zero mark on the paper). Since the absolute value of this reference point is not known, the obtained values cannot be transformed into absolute values.

To determine a mean point for the curve above the horizontal axis, the conventional method of peak counting was considered. However, it was found that in some speech samples the variation in intensity was large and a measure based on peak samples was not considered to be too reliable.

It was therefore decided to use a compensating polar planimeter to determine the whole area under the curve.

Since there are some objections against the use of planimeters, the following tests were first made: a planimeter in the metric system was used to trace an irregular area of one hundred square centimeters. It was found that the error was less than one per cent. This test was repeated a few times and the difference between obtained measures was also less than one per cent. This accuracy was ascribed to a very smooth surface on which the planimeter was used and a very slow movement of the instrument in tracing the curve.

Using this technique the curve for all the conditions was traced and the area under the curve determined in square centimeters. This was divided by the length of the horizontal axis to give the mean height above the zero mark. Finally, this level was expressed in terms of decibels above an arbitrary reference. This variable will be called variable 3 in subsequent discussions. (See appendix for measures obtained on variable 3.)

5. Statistical Design and Hypotheses.

The general statistical approach used in this study is that of a triple classification factorial design,

employing analysis of variance. The three variables used were individuals, occasions, and conditions.

A mixed model, type $a_1A_1A_1$ was used in this study.⁴ Since it is assumed that there will be significant individual differences, no test is performed for the main effect on individuals. Similarly, no test of double interactions of individuals by occasions and individuals by conditions is performed. Also, the triple interaction is not tested for significance. The error term for the two remaining main effects will be as follows:

1. individual x occasion interaction for the occasions;
2. individual x condition interaction for the conditions.

The one remaining double interaction, occasion x condition, will be tested against the triple interaction.

Since the three voice variables are not expressed in the same units of measurement, separate analyses will be performed for each of the three variables. Also, since the performance of left- and right-sided individuals will be compared eventually, these two groups are treated separately. Six separate analyses will therefore be performed; three on the three voice variables of the ten left-sided subjects,

⁴ Quinn McNemar, Psychological Statistics, New York, Wiley, third edition, 1962, p. 333.

and three on the twenty right-sided subjects. In both groups there are two occasions and eight conditions. When any significant differences for conditions are found, a t technique, which will be described in the following chapter, will be used to probe for the location of the significant differences.

Since the main interest of this study is to compare the voice variables under the different conditions, and especially the (c) and (d) conditions, the null hypothesis is stated as follows: there are no significant differences in speech between the different conditions, for each of the three voice variables.

The second occasion is mainly used to determine reliability coefficients and no null hypothesis is stated for differences between occasions. Also, the occasion by conditions interaction is of no particular interest in this study and no specific null hypothesis is stated.

If, in the main analysis, there are indications that the left-sided and right-sided subjects behaved differently from condition to condition, an analysis will be performed to compare the amount of speech disturbance between the two groups. The procedure will be described in the following chapter.

In the following chapter, a presentation will be given of the analyses and results.

CHAPTER III

THE RESULTS OF THE EXPERIMENT

The results of the experiment will mainly be considered in terms of the hypothesis formulated at the end of the previous chapter. Since there are only two occasions which were used to determine reliability, occasions will not be considered in the main effects. If a significant difference is found for occasions, visual inspection will determine which of the two occasions had higher scores. Only significant differences for conditions will be inspected more closely and followed up by subsequent t tests.

1. Reliability.

Since the two groups were exposed to exactly the same treatment, it was decided to group them together in determining reliability coefficients. This also provided an N of thirty which gives a more stable coefficient.

In determining the coefficients the raw scores on each of the three voice variables were correlated between first and second occasion. Therefore, condition (a) first occasion was correlated with condition (a) second occasion, and so on. In this way, twelve correlation coefficients were obtained, four for each variable. Table 1 contains the obtained coefficients where (a), (b), (c), and (d) refer

Table I.-
Reliability Coefficients.

Variable	Conditions			
	(a) ₁	(b) ₁	(c) ₁	(d) ₁
1.	(a) ₂	.855		
	(b) ₂		.894	
	(c) ₂			.835
	(d) ₂			.901
2.	(a) ₂	.812		
	(b) ₂		.942	
	(c) ₂			.922
	(d) ₂			.954
3.	(a) ₂	.953		
	(b) ₂		.936	
	(c) ₂			.931
	(d) ₂			.937

to the four conditions; 1, 2, and 3 refer to the variables; and the subscripts refer to the first or second occasion.

2. Analysis of Data for Main Effect: Conditions.

A. For Left-Sided Subjects:

a) Per Cent Phonation Time: Variable 1.- The obtained F-ratio for conditions, as seen in table II, is significant beyond the .001 level of probability. This indicates that the scores obtained on the four different conditions differ significantly. The null hypothesis is therefore rejected.

In order to probe for the exact location of the significant differences between the means of the different conditions, t tests were used. The formula applied was:

$$\text{Significant Difference} \geq t (p = .05) \times \sigma_{\text{Diff.}}$$

The formula used for the $\sigma_{\text{Diff.}}$ was:

$$\sigma_D = \sqrt{\frac{2 \sigma^2}{nS}}$$

The variance of the I x C interaction was used as the error term for the σ^2 of the above formula. The value of t (p = .05) was read from the t table for a number of degrees of freedom corresponding to that of the error term used, i.e., twenty-seven. This way a minimum difference is obtained that would be significant between the means of the

Table II.-

Analysis of Variance Table: Left-Sided Subjects, Variable 1.

Source of Variation	Sum of Squares	df.	Est. of Variance	F	F.05	F.01
I (Individuals)	2096.6666	(9)	232.963			
O (Occasions)	.0246	(1)	.0246	.002	5.12	10.56
C (Conditions)	1173.4546	(3)	391.152	26.661	2.965	4.615
I x O	91.5384	(9)	10.171			
I x C	392.8834	(27)	14.551			
O x C	41.3554	(3)	13.785	3.199	2.965	4.615
I x O x C	116.5516	(27)	4.309			
Total	3912.2746	(79)				

conditions at the .05 level of probability. The same procedure was followed, using the value of t ($p = .01$) in the above formula to obtain a minimum difference that would be significant at the .01 level of probability. Table III summarizes the results of this analysis.

It is found that any of the three conditions where delayed feedback was employed, differed significantly from condition (a) where there was no delay. These differences are all significant beyond the .01 level of probability. However, the two conditions that are most important in this study, condition (c) and condition (d), did not differ significantly. It can be observed, however, that in the above formula no correction factor was introduced to account for correlations between conditions. If a correlation coefficient is used as a correction factor, it should be a multiple correlation coefficient, based upon all eight conditions. This is a tedious procedure and it was decided to perform a separate analysis of variance on the level of conditions (c) and (d) alone. This way it could be determined whether true differences between these conditions were masked by larger differences between the other conditions. The model employed was exactly the same as the previous, using only conditions (c) and (d) and adjusting the formulae to fit the smaller matrix.

Table IV indicates that no significant differences exist between conditions (c) and (d), and the null hypothesis is therefore accepted.

Table III.-

Evaluation of the Difference of Means Between Conditions for Left-Handers, Variable 1.

Conditions Used	Mean Values Compared	Difference	Significant Difference
$a_1 - b_1$	73.116-85.335	12.219	Yes, .01
$a_1 - c_1$	73.116-82.157	9.041	Yes, .01
$a_1 - d_1$	73.116-81.778	8.662	Yes, .01
$b_1 - c_1$	85.335-82.157	3.178	No
$b_1 - d_1$	85.335-81.778	3.557	Yes, .05
$c_1 - d_1$	82.157-81.778	.379	No
$a_2 - b_2$	75.552-84.115	8.563	Yes, .01
$a_2 - c_2$	75.552-81.250	5.648	Yes, .01
$a_2 - d_2$	75.552-81.596	6.044	Yes, .01
$b_2 - c_2$	84.115-81.250	2.865	No
$b_2 - d_2$	84.115-81.596	2.519	No
$c_2 - d_2$	81.250-81.596	.346	No

Table IV.-

Analysis of Variance Table; Evaluation of the Difference of Means Between Conditions (c) and (d) for Left-Handers, Variable 1.

Source of Variation	Sum of Squares	df.	Est. of Variance	F
I	1017.446	(9)	113.05	
O	2.959	(1)	2.959	.684
C	.002	(1)	.002	.0006
I x O	38.945	(9)	4.327	
I x C	28.269	(9)	3.141	
O x C	1.311	(1)	1.311	.517
I x O x C	22.827	(9)	2.536	
Total	1111.759	(39)		

b) Mean Syllable Duration: Variable 2.- Table V indicates that the obtained F-ratio of 12.212 for conditions is significant beyond the .001 level of probability. Subsequent t tests, by the method already described, indicate significant differences between all conditions compared, except conditions (c) and (d). (See table VI.) These differences are all significant at the .01 level.

In this analysis there is reason to suspect that the very large differences between conditions (a) and (b) may mask true significant differences between conditions (c) and (d). A separate analysis of variance is therefore again performed on the level of these two conditions alone. Table VII indicates that the difference between conditions (c) and (d) is significant at the .01 level of probability. The null hypothesis is therefore rejected and it is concluded that the mean syllable duration was significantly longer under condition (d) than under condition (c).

Table V.-

Analysis of Variance Table: Left-Sided Subjects, Variable 2.

Source of Variation	Sum of Squares	df.	Est. of Variance	F	F.05	F.01
I	280939.888	(9)	31215.543			
O	1565.638	(1)	1565.638	3.928	5.12	10.56
C	212371.038	(3)	70790.346	12.212	2.965	4.615
I x O	3588.162	(9)	398.684			
I x C	156508.062	(27)	5796.594			
O x C	407.762	(3)	135.920	.852	2.965	4.615
I x O x C	4309.688	(27)	159.618			
Total	689690.438	(79)				

Table VI.-

Evaluation of the Difference of Means Between Conditions for Left-Handers, Variable 2.

Conditions Used	Mean Values Compared	Difference	Significant Difference
$a_1 - b_1$	164.251-314.960	150.709	Yes, .01
$a_1 - c_1$	164.251-222.952	58.701	Yes, .01
$a_1 - d_1$	164.251-230.078	65.827	Yes, .01
$b_1 - c_1$	314.960-222.952	92.008	Yes, .01
$b_1 - d_1$	314.960-230.078	84.882	Yes, .01
$c_1 - d_1$	222.952-230.078	7.126	No
$a_2 - b_2$	162.007-299.960	137.953	Yes, .01
$a_2 - c_2$	162.007-213.858	51.850	Yes, .01
$a_2 - d_2$	162.007-221.023	59.016	Yes, .01
$b_2 - c_2$	299.960-213.858	86.102	Yes, .01
$b_2 - d_2$	299.960-221.023	78.937	Yes, .01
$c_2 - d_2$	213.858-221.023	7.165	No

Table VII.-

Analysis of Variance Table; Evaluation of the Difference of Means Between Conditions (c) and (d) For Left-Handers, Variable 2.

Source of Variation	Sum of Squares	df.	Est. of Variance	F	F.05	F.01
I	105477.240	(9)	11719.693			
O	823.442	(1)	823.442	4.267	5.12	10.56
G	510.527	(1)	510.527	14.435	5.12	10.56
I x O	1736.898	(9)	192.988			
I x G	318.303	(9)	35.367			
O x G	.081	(1)	.081	.002	5.12	10.56
I x O x G	296.786	(9)	32.976			
Total	109163.270	(39)				

e) Mean Intensity above an Arbitrary Reference:

Variable S.- Table VIII indicates a significant difference between conditions beyond the .001 level of probability. The null hypothesis is therefore rejected and subsequent t tests indicate the location of significant differences between the conditions, table IX. Again, all conditions compared differ significantly except conditions (c) and (d). Since the differences between these conditions are not very big and the differences between the other conditions are clustered around one point, no further analysis is performed on conditions (c) and (d). The null hypothesis is therefore accepted for differences between these two conditions.

Table VIII.-

Analysis of Variance Table: Left-Sided Subjects, Variable 3.

Source of Variation	Sum of Squares	df.	Est. of Variance	F	F.05	F.01
I	844.4698	(9)	93.829			
O	7.5392	(1)	7.539	4.362	5.12	10.56
C	1874.2903	(3)	624.763	123.072	2.965	4.615
I x O	15.5369	(9)	1.726			
I x C	137.0142	(27)	5.074			
O x C	7.2877	(3)	2.429	2.283	2.965	4.615
I x O x C	31.0641	(27)	1.150			
Total	2917.8028	(79)				

Table IX.-

Evaluation of the Difference of Means Between Conditions for Left-Handers, Variable 3.

Conditions Used	Mean Values Compared	Difference	Significant Difference
$a_1 - b_1$	9.67-23.72	14.05	Yes, .01
$a_1 - c_1$	9.67-17.67	8.00	Yes, .01
$a_1 - d_1$	9.67-18.42	8.75	Yes, .01
$b_1 - c_1$	23.72-17.67	6.05	Yes, .01
$b_1 - d_1$	23.72-18.42	5.30	Yes, .01
$c_1 - d_1$	17.67-18.42	.75	No
$a_2 - b_2$	10.03-23.20	13.17	Yes, .01
$a_2 - c_2$	10.03-16.36	6.33	Yes, .01
$a_2 - d_2$	10.03-17.44	7.41	Yes, .01
$b_2 - c_2$	23.20-16.36	6.84	Yes, .01
$b_2 - d_2$	23.20-17.44	5.76	Yes, .01
$c_2 - d_2$	16.36-17.44	1.08	No

B. For Right-Sided Subjects:

a) Per Cent Phonation Time: Variable 1.- The obtained *F*-ratios in table X are all significant at the .01 level of probability. It is observed that occasion 2 had significantly higher scores than occasion 1 and that the first order interaction, $O \times O$, is also significant at the .01 level. This difference will be observed closer in a subsequent section.

Since the conditions differ significantly, the null hypothesis is rejected and the exact location of significant differences between conditions is indicated in table XI. The same technique has been used that was described in analyzing data of left-sided subjects.

The main emphasis falls on the difference between conditions (c) and (d) and it is found that they differ significantly at the .05 level for the first occasion but not for the second occasion. It should be remembered that no correction factor was used in probing for differences and the possibility exists that true differences may be masked by large differences when the data is treated together. A separate analysis of variance is therefore performed on the level of conditions (c) and (d) only. The same model is again used, adjusting the formulae where necessary.

Table XII indicates that the differences between conditions (c) and (d) are significant at the .001 level of probability. The null hypothesis is therefore rejected and it is concluded that the per cent phonation time was significantly higher under condition (d) than under condition (c).

Table X.-

Analysis of Variance Table: Right-Sided Subjects, Variable 1.

Source of Variation	Sum of Squares	df.	Est. of Variance	F	F.05	F.01
I	4891.46	(19)	257.44			
O	93.78	(1)	93.78	35.05	4.41	8.30
C	4788.52	(3)	1596.17	66.00	2.76	4.12
I x O	50.83	(19)	2.67			
I x C	1378.49	(57)	24.18			
O x C	187.82	(3)	52.60	9.06	2.76	4.12
I x O x C	330.87	(57)	5.60			
Total	11691.77	(159)				

Table XI.-

Evaluation of the Difference of Means Between Conditions for Right-Handers, Variable 1.

Conditions Used	Mean Values Compared	Difference	Significant Difference
$a_1 - b_1$	70.752-87.009	16.257	Yes, .01
$a_1 - c_1$	70.752-82.408	11.636	Yes, .01
$a_1 - d_1$	70.752-85.543	14.791	Yes, .01
$b_1 - c_1$	87.009-82.408	4.601	Yes, .01
$b_1 - d_1$	87.009-85.543	1.466	No
$c_1 - d_1$	82.408-85.543	3.135	Yes, .05
$a_2 - b_2$	75.660-87.958	12.298	Yes, .01
$a_2 - c_2$	75.660-82.804	7.144	Yes, .01
$a_2 - d_2$	75.660-85.412	9.752	Yes, .01
$b_2 - c_2$	87.958-82.804	5.154	Yes, .01
$b_2 - d_2$	87.958-85.412	2.546	No
$c_2 - d_2$	82.804-85.412	2.608	No

Table XII.-

Analysis of Variance Table; Evaluation of the Difference of Means Between Conditions (c) and (d) for Right-Handers, Variable 1.

Source of Variation	Sum of Squares	df.	Est. of Variance	F	F.01	F.001
I	2362.802	(19)	124.358			
O	.368	(1)	.368	.005		
C	164.847	(1)	164.847	15.992	8.18	15.08
I x O	126.628	(19)	6.665			
I x C	195.858	(19)	10.308			
O x C	1.373	(1)	1.373	.343		
I x O x C	75.966	(19)	3.998			
Total	2927.842	(79)				

b) Mean Syllable Duration: Variable 2.- Table XIII indicates that a significant difference exists between the conditions and the null hypothesis should therefore be rejected. Probing for the location of significant differences, table XIV, reveals that all conditions, except (c) and (d), differ significantly from each other. These differences are significant at the .01 level.

Table XV contains the results of a separate analysis performed on conditions (c) and (d) alone. It is observed that they differ significantly, the difference being significant at the .05 level and approaching the .01 level. The null hypothesis is therefore rejected and it is concluded that the mean syllable duration was significantly longer under condition (d) than under condition (c).

Table XIII.-

Analysis of Variance Table: Right-Sided Subjects, Variable 2.

Source of Variation	Sum of Squares	df.	Est. of Variance	F	F.05	F.01
I	193323.91	(19)	10174.942			
O	443.14	(1)	443.14	1.316	4.41	8.30
C	371723.74	(3)	123907.913	85.548	2.76	4.12
I x O	6599.99	(19)	336.841			
I x C	82558.39	(57)	1448.392			
O x C	1174.16	(3)	391.386	2.498	2.76	4.12
I x O x C	8929.81	(57)	156.663			
Total	664553.14	(159)				

Table XIV.-

Evaluation of the Difference of Means Between Conditions for Right-Handers, Variable E.

Conditions Used	Mean Values Compared	Difference	Significant Difference
$a_1 - b_1$	156.967-299.587	142.620	Yes, .01
$a_1 - c_1$	156.967-228.445	71.478	Yes, .01
$a_1 - d_1$	156.967-239.646	82.679	Yes, .01
$b_1 - c_1$	299.587-228.445	71.142	Yes, .01
$b_1 - d_1$	299.587-239.646	59.941	Yes, .01
$c_1 - d_1$	228.445-239.646	11.201	No
$a_2 - b_2$	162.717-291.909	129.192	Yes, .01
$a_2 - c_2$	162.717-224.331	61.614	Yes, .01
$a_2 - d_2$	162.717-232.382	69.665	Yes, .01
$b_2 - c_2$	291.909-224.331	67.578	Yes, .01
$b_2 - d_2$	291.909-232.382	59.527	Yes, .01
$c_2 - d_2$	224.331-232.382	8.051	No

Table XV.-

Analysis of Variance Table; Evaluation of the Difference of Means Between Conditions (c) and (d) for Right-Handers, Variable 2.

Source of Variation	Sum of Squares	df.	Est. of Variance	F	F.05	F.01
I	110351.384	(19)	5807.968			
O	647.599	(1)	647.599	3.757	4.38	8.18
C	1853.502	(1)	1853.502	7.406	4.38	8.18
I x O	3275.503	(19)	172.384			
I x C	4755.400	(19)	250.284			
O x C	49.290	(1)	49.290	.425		
I x O x C	2203.332	(19)	115.965			
Total	123135.810	(79)				

c) Mean Intensity Above an Arbitrary Reference:

Variable 3.- The results of analysis of this variable is contained in table XVI. It is observed that the two occasions differ significantly, occasion 2 being higher than occasion 1. The conditions are also significantly different at the .01 level and the null hypothesis is rejected.

Table XVII contains the result of probing for the location of differences between conditions. It is found that all the conditions, except conditions (c) and (d), differ significantly at the .01 level of probability. Since these differences all cluster around one point and since the differences between conditions (c) and (d) are very small compared to the others, no further analysis is performed on these two conditions. The null hypothesis is therefore accepted on the level of conditions (c) and (d).

Table XVI.-

Analysis of Variance Table: Right-Sided Subjects, Variable 3.

Source of Variation	Sum of Squares	df.	Est. of Variance	F	F.05	F.01
I	3869.5143	(19)	203.658			
O	54.7023	(1)	54.702	33.55	4.41	8.30
C	3492.6923	(3)	1164.230	149.90	2.76	4.12
I x O	30.9727	(19)	1.630			
I x C	442.6767	(57)	7.766			
O x C	5.7317	(3)	1.910	1.759	2.76	4.12
I x O x C	61.9003	(57)	1.085			
Total	7958.1903	(159)				

Table XVII.-

Evaluation of the Difference of Means Between Conditions for Right-Handers, Variable 3.

Conditions Used	Mean Values Compared	Difference	Significant Difference
$a_1 - b_1$	8.312-21.379	13.067	Yes, .01
$a_1 - c_1$	8.312-16.226	7.914	Yes, .01
$a_1 - d_1$	8.312-16.636	8.324	Yes, .01
$b_1 - c_1$	21.379-16.226	5.153	Yes, .01
$b_1 - d_1$	21.379-16.636	4.743	Yes, .01
$c_1 - d_1$	16.226-16.636	.410	No
$a_2 - b_2$	9.827-22.957	13.130	Yes, .01
$a_2 - c_2$	9.827-17.042	7.215	Yes, .01
$a_2 - d_2$	9.827-17.405	7.578	Yes, .01
$b_2 - c_2$	22.957-17.042	5.915	Yes, .01
$b_2 - d_2$	22.957-17.405	5.552	Yes, .01
$c_2 - d_2$	17.042-17.405	.363	No

3. Analysis of Data for First Order Interaction: Occasion x Condition.

Although no specific null hypothesis was stated for the first order interaction, it is observed in tables II and X that the obtained F-ratios are significant at the .05 and the .01 level respectively. This occurred only on variable 1. The same probing technique was used, however, using the error term of the triple classification for the σ^2 in the formula. It was found that for both left-sided and right-sided individuals, occasion 2 was significantly higher on condition (a). For the left-sided subjects, this difference was significant at the .05 level, and for the right-sided subjects, at the .01 level of probability. No other significant first order interactions were noted elsewhere.

4. Analysis of Data for Comparison of Groups.

At the end of the previous chapter, it was stated that the two groups will be compared if there are indications that they performed differently on the three voice variables. Previous analysis revealed that between conditions (c) and (d) there were significant differences for both groups on variable 2, mean syllable duration, and no significant differences for either group on variable 3, mean intensity. However, on variable 1, per cent phonation time, the (c) and (d) conditions differed very significantly for the right-sided

group but not for the left-sided group. This suggests the possibility of a significant difference between the groups which will not be investigated.

Figures 6, 7, and 8 compare the means of the two groups on the different conditions for each of the three voice variables. Figure 6 suggests that the greatest difference between the two groups is on variable 1. Figures 7 and 8 show a close resemblance in the performance of the two groups. The problem under investigation is to determine whether the means of the left-sided group on conditions (b), (c), and (d) differ significantly from the means of the right-sided group on the same conditions. The amount of speech disturbance caused by various amounts of delayed feedback will therefore be compared between the two groups.

However, since there is a strong suspicion that the two groups were not the same to start with, as can be inferred from their performance on condition (a), this will have to be considered in the comparison of conditions (b), (c), and (d). It is therefore decided to work with difference scores, where condition (a) will be subtracted from the remaining three conditions. These differences will then be compared between the two groups. McNemar¹

¹ Quinn McNemar, Psychological Statistics, New York, Wiley, third edition, 1962, p. 105.

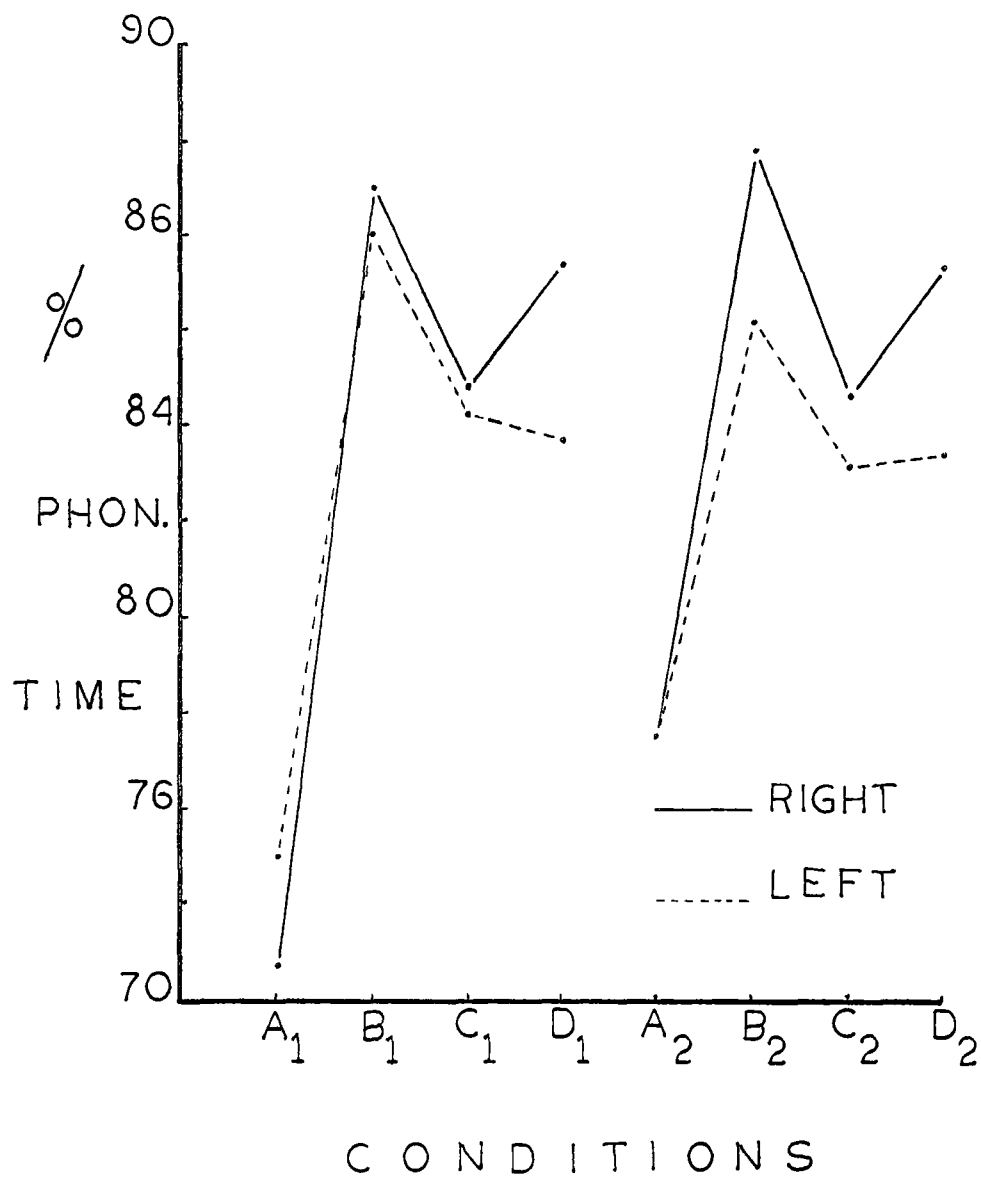


Figure 6. Mean scores for left- and right-sided subjects on Variable 1.

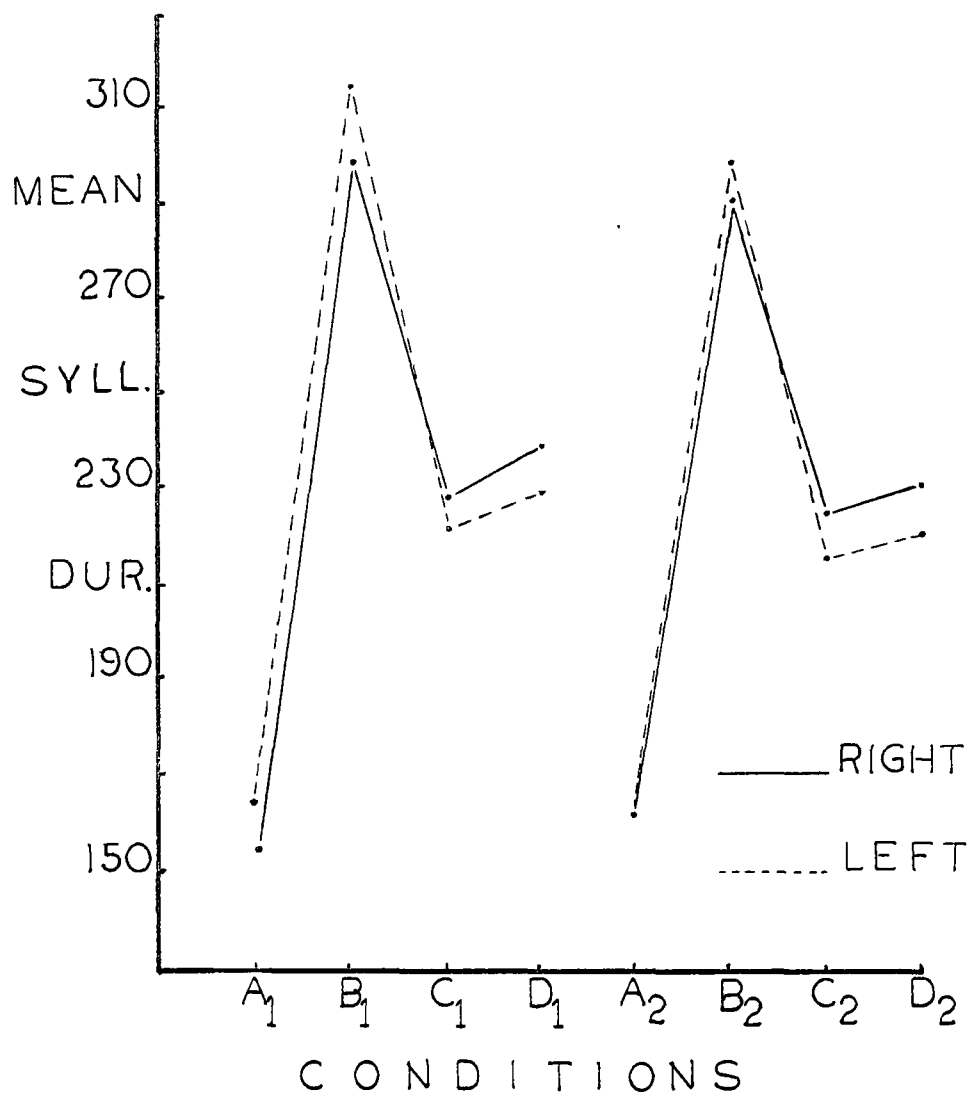


Figure 7. Mean scores for left- and right-sided subjects on Variable 2.

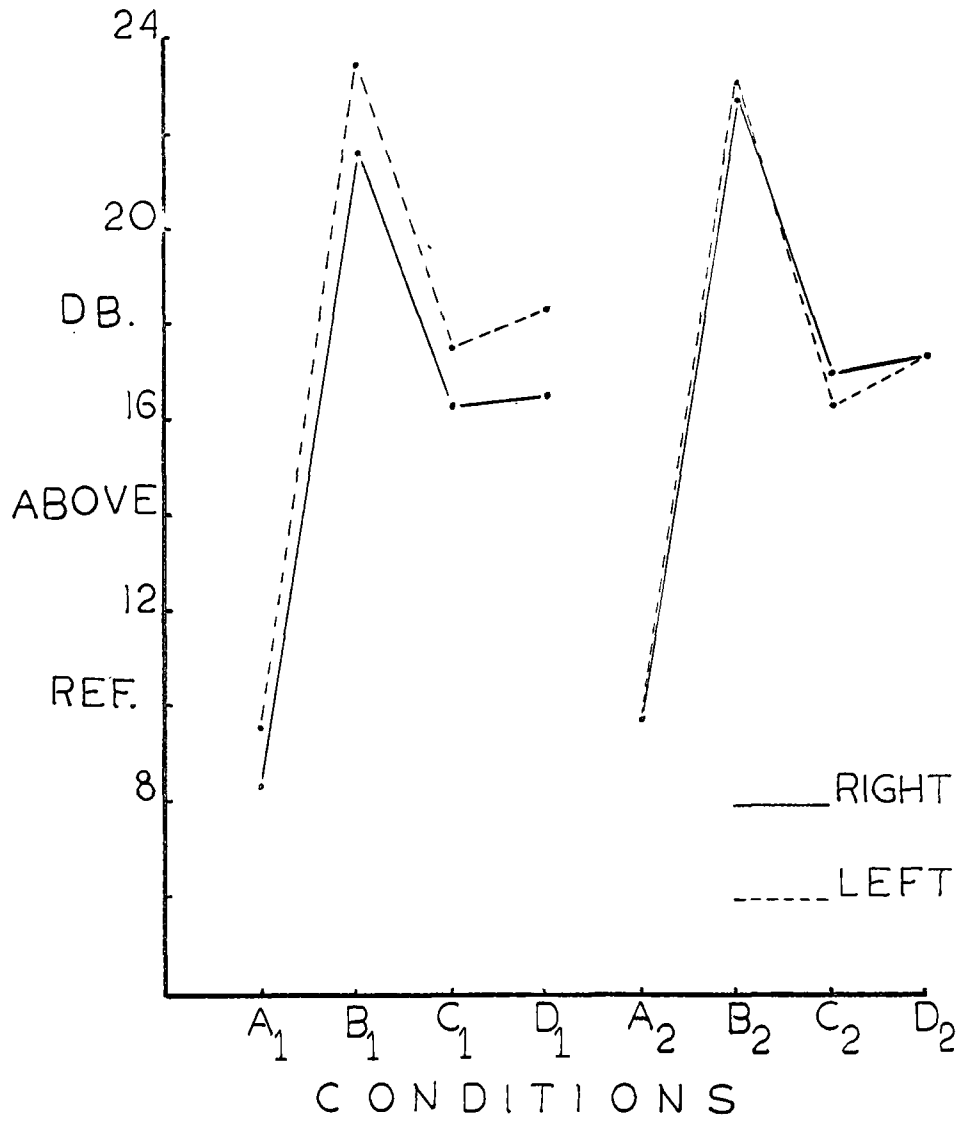


Figure 8. Mean scores for left- and right-sided subjects on Variable 3.

suggests that when changes like these are compared, the procedure is exactly the same as that for testing the difference between two independent means, X is only replaced by D , a difference score. A simple t test will be employed, using the formula for uncorrelated and unequal groups.

The null hypothesis is stated as follows: There are no significant differences in changes from the (a) condition to conditions (b), (c), and (d) between the left-sided and right-sided subjects for any of the voice variables.

Table XVIII summarizes the findings of this analysis. It is observed that only one significant difference in changes was found: the change between condition (a) and condition (d) was significantly smaller on variable 1, occasion 1, for the left-sided subjects than for the right-sided subjects. This difference was significant at the .02 level of probability and the null hypothesis is therefore rejected in this case. In all the other tests performed, the null hypothesis is accepted since no significant differences were found.

Table XVIII.-

Comparison of Differences in Changes Between Left-Sided and Right-Sided Subjects.

Vari- able	Conditions Used	Diff. Between Means for Left-Sided S.	Diff. Between Means for Right-Sided S.	Diff. between Diff.	Signi- ficant
1.	$a_1 - b_1$	12.219	16.257	4.038	No
	$a_1 - c_1$	9.041	11.656	2.615	No
	$a_1 - d_1$	8.662	14.791	6.129	Yes
	$a_2 - b_2$	8.563	12.298	3.735	No
	$a_2 - c_2$	5.648	7.144	1.496	No
	$a_2 - d_2$	6.044	9.752	3.708	No
2.	$a_1 - b_1$	150.709	142.620	8.089	No
	$a_1 - c_1$	58.701	71.478	12.777	No
	$a_1 - d_1$	65.827	82.679	16.852	No
	$a_2 - b_2$	no test			
3.	no test				

In the following chapter, the results of the analyses will be discussed in the light of theoretical assumptions stated in the first chapter. The order of discussion will be the same as the order of the presentation of the results.

CHAPTER IV

DISCUSSION OF THE DATA

In this chapter a discussion will be made of more important findings presented in the previous chapter. Since the main concern of the study is the comparison of speech samples under four different conditions, the discussion of findings will emphasize this aspect. The left-sided and right-sided groups will be discussed separately and the conclusions will be integrated in a final section.

1. Discussion of the Main Effect: Conditions.

A. Left-Sided Subjects:

It was shown in the previous chapter that on variable 1, per cent phonation time, speech under any of the experimental conditions (b), (c), and (d), differed significantly from normal speech, condition (a). This was also true for the second occasion. All these differences were significant beyond the .01 level of probability. This indicates the amount of speech disturbance that can take place by interfering with the monitor on a temporal level. This difference has occurred constantly throughout the experiment, also with the right-sided group. No future reference will be made to these differences since they are interpreted to demonstrate

that various degrees of delayed auditory feedback do interfere with speech on the variables investigated.

Throughout the experiment condition (b) - binaural delayed feedback - has caused the greatest amount of speech disturbance. The absence of any clue to continue normal monitoring of voice output is probably responsible for this. This phenomenon can be explained by the closed loop control system for speech, discussed in the first chapter. The error signal fed to the mixer remains unaltered and does not return to zero. The most immediate result is a slowing down in the tempo of speech output to compensate for the disturbance on the temporal level. This is noticed in a longer phonation time primarily, but also in observable hesitations, repetitions and pauses.

However, the main concern of the study is a comparison of the two conditions of monaural delayed auditory feedback, conditions (c) and (d). These two conditions affected speech less seriously than did the condition of binaural delayed feedback. This is explained in terms of the direct feedback on the opposite ear that permitted a clue for continuation of normal speech monitoring.

A comparison of the amount of speech disturbance under these two conditions do not indicate a significant difference in the per cent phonation time. Since per cent phonation time is actually a ratio of the phonation time

to the overall reading time, this finding cannot be properly evaluated without taking into consideration phonation time. It is observed that the phonation time, as expressed in mean syllable duration, is significantly longer for the (d) condition than for the (c) condition. The per cent phonation time therefore did not change significantly between the two conditions because the ratio of phonation time to overall time remained relatively unchanged.

This finding is interpreted to indicate that the dominant ear disrupted speech significantly more when exposed to delayed feedback, than did the non-dominant ear. This disruption was noticeable in a longer mean syllable duration, but not in a longer phonation time ratio. It was hypothesized in the first chapter that speech would be more seriously disrupted under a condition of monaural delayed feedback to the assumed dominant ear, than to the assumed non-dominant ear. Since it has been proved before that the ear contralateral to the speech centre (dominant ear) is more efficient in conveying messages, it stands to reason that this ear is also more efficient in monitoring speech output. The observed disruption of speech could therefore only occur when the speech centre is located in the hemisphere contralateral to the ear that received the delayed feedback. This ear is called the dominant ear and for the

left-sided group it is the left ear. Therefore, in view of these findings, the left-sided group has right cerebral language laterality.

On variable 3, mean intensity, no significant differences between the two conditions of monaural delayed feedback were found. It has been pointed out before that differences between the efficiency of the two ears are difficult to demonstrate. It is therefore assumed that an interference on the temporal level of the two separate ears does not significantly interfere with speech on the intensity level. Temporal auditory interference of separate ears only produces significant temporal disturbance in speech, though this is not the case when the temporal interference is produced binaurally.

B. Right-Sided Subjects:

For the right-sided subjects it is also observed that the mean syllable duration is significantly longer when the dominant ear is exposed to delayed feedback than when the non-dominant ear is exposed to delayed feedback. Again, this can only occur when speech is represented contralaterally to the ear that received the delayed signal. For the right-sided group the dominant ear is the right ear and it is therefore concluded that this group has left cerebral language laterality.

It is also observed that another variable, per cent phonation time, was sensitive in picking up the difference between these two conditions for the right-sided subjects. The condition of delayed feedback to the dominant ear produced a significantly higher per cent phonation time than for a delayed feedback to the non-dominant ear. This difference was significant at the .001 level of probability. Since the ratio of phonation time to overall time is significantly longer for the (d) condition than for the (e) condition, it is concluded that the (d) condition had comparatively shorter rest or silent periods. This is also interpreted as an indication of speech disturbance produced by a delayed feedback to the dominant ear. This significant result was not found for the left-sided group.

The results of variable 3, mean intensity, correspond very closely to those of the left-sided group. The same explanation offered for the left-sided group applies here. On the level of monaural temporal interference with auditory intake, the result is only observed in temporal speech disturbance.

2. Discussion of the First Order Interaction: Occasion x Condition.

A significant interaction between occasions and conditions occurred only on variable 1, per cent phonation time,

for both left- and right-sided groups. Probing for the specific condition that interacted significantly with the occasions, revealed that for both groups, the (a) condition (normal speech) had a higher per cent phonation time on the second occasion. The difference was significant at the .05 level for the left-sided group and at the .01 level for the right-sided group.

A possible explanation for this finding is that this variable is probably sensitive to psychological factors. In the re-testing the subjects knew what to expect and were taking measures to resist the effect of the delayed feedback. Since condition (a) was always the first condition during re-testing, this was reflected in their normal speech. A higher per cent phonation time indicates shorter stops and rest periods and it seems reasonable that emotional factors can produce this.

3. Discussion of the Comparison of Groups.

It was noted in the analysis of data, and in the discussion, that the left- and right-sided groups differed only on variable 1, per cent phonation time. An analysis of the difference in changes between the two groups revealed only one significant difference. This occurred in the amount of change from normal speech to condition (d). The right-sided subjects showed a significantly greater increase in

per cent phonation time from normal speech to delayed feedback on the dominant ear, than did the left-sided group. This difference was significant at the .02 level.

Since this is the only difference between the two groups that could be found and since the possibility exists that this variable is sensitive to psychological factors, any explanation should be made cautiously. It may be said that this difference was caused by a difference in test taking attitude between the groups, but this does not explain why it could not be found in the comparison of other changes. It is felt, therefore, that in the light of the large difference in numbers between the two groups, and the lack of consistent evidence, the apparent difference between the two groups should be ascribed to unknown or chance factors.

Attention will now be turned to the summary and conclusions where the most important findings will be presented briefly.

SUMMARY AND CONCLUSIONS

A survey of the literature has indicated that right hemiplegia with aphasia is a much more frequent occurrence than is left hemiplegia with aphasia. Methods of electrically stimulating certain areas of the exposed cortex also suggested that speech is usually represented in the left hemisphere, even for left-handers. Right cerebral language laterality is regarded as an extremely rare occurrence and independent of handedness. These observations have been made on patients with epileptogenic lesions and cerebral damage of the speech areas.

It was the main concern of the present study to investigate auditory dominance and cerebral language laterality with two groups of normal left-sided and right-sided subjects. These subjects were screened on laterality tests and only those subjects that showed a consistent left or right preference for hands, eyes, and feet were used. A measure of auditory dominance was also introduced and left-sided subjects had to demonstrate superior acuity scores on the left ear and right-sided subjects on the right ear.

It was hypothesized that the left-sided group has right cerebral language laterality and that the right-sided group has left cerebral language laterality. It was indicated in the review of the literature that the crossed auditory pathways are more numerous than the uncrossed, and

that the ear contralateral to the speech centre is more efficient in conveying messages than is the ear ipsilateral to the speech centre. It was therefore assumed that the ear contralateral to the speech centre (dominant ear) will be more efficient in monitoring the speech output than will the non-dominant ear.

A method of monaural delayed auditory feedback was used to interfere with speech and the results were analyzed on three variables. It was found that both left- and right-sided groups had a longer mean syllable duration when the delayed feedback was presented to the dominant ear than when it was presented to the non-dominant ear. This difference was significant at the .01 level for the left-sided group and at the .05 level for the right-sided group, approaching the .01 level. The right-sided group also showed a significant increase in per cent phonation time when the dominant ear received the delayed feedback as compared to a stimulus presentation on the non-dominant ear. The left-sided group did not demonstrate this difference. The apparent difference between the two groups on this point was ascribed to unknown or chance factors due to a lack of insufficient evidence to explain it. The variable on mean intensity was not sufficiently sensitive to demonstrate the difference between ears when interference was presented on the temporal level.

It is therefore concluded that the observed speech disturbances could only occur in this particular relationship if the hypothesis of cerebral language laterality is accepted. The following implications of this finding are suggested:

1. The presence of auditory dominance on the level of speech monitoring appears to be an acceptable finding.
2. The possibility of dominant ear impairment in some forms of speech disabilities should be seriously considered.
3. A servosystem theory of the speech mechanism should be revised, allowing for different sensors of the two ears and their connections to the speech centre.
4. The existence of right cerebral language laterality has been demonstrated with normal subjects. It appears to be a less uncommon phenomenon than was previously suggested. It may even be the prevalent form of speech representation with natural left-sided people. However, it is still agreed that this is a less common occurrence than is left-handedness.
5. The present study was not designed to determine the possible relationships between auditory dominance and cerebral language laterality. Lateral preferences were controlled in this study and no causal relationships between cerebral language laterality and other

laterality characteristics can be postulated. It is strongly suspected that auditory dominance plays a role and a study should be performed where laterality characteristics are manipulated instead of being controlled.

6. Finally, in normal right-sided subjects left-cerebral language laterality is evident and in normal left-sided subjects right cerebral language laterality is evident. This was found for a group of subjects between thirteen and eighteen years of age. A study should be performed where this phenomenon is investigated at various age levels to determine when cerebral language laterality is established.

BIBLIOGRAPHY

Bauer, Robert W., and Joseph M. Wepman, "Lateralization of Cerebral Functions", Journal of Speech and Hearing Disorders, Vol. 20, 1955, p. 171-177.

They investigated possible relationships between handedness and cerebral dominance for speech. References to various other investigations were made and they concluded that no right-hemisphere dominance exists but rather that cerebral dominance is unique to the left-hemisphere. Left-handed people are therefore individuals in whom lateralization has not fully developed.

Bilto, E.W., and Gordon E. Peterson, "The Relation Between Ear Preference and Hearing Acuity", Journal of Speech Disorders, Vol. 9, No. 2, 1944, p. 123-125.

Pure tone audiograms of sixty-nine subjects were made on seven frequencies and were transcribed into acuity scores. Ear preference of these subjects was also determined and it was found that the difference in hearing acuity between the two ears would not usually be a primary factor in determining ear preference. Large percentage of inconsistent preferences makes findings doubtful, however.

Elkins, E.F., "Effects of Side-Tone Delay on Oral Reading Responses Under Conditions of Binaural and Non-Aural Stimulus Presentation", unpublished Master's thesis, University of Maryland, 1956, 37 p.

She attempted to demonstrate the existence of auditory dominance on the level of speech monitoring. Monaural delayed auditory feedback was presented to the preferred and non-preferred ears with white noise masking on the opposite ear. No significant differences were demonstrated between the two ears, probably because of isolated ear preference measures and crude measuring devices. This study has, to some extent, inspired the present investigation.

Ettlinger, George, G.V. Jackson, and O.L. Zangwill, "Cerebral Dominance in Sinistrals", Brain, Vol. 79, 1956, p. 569-588.

They reviewed the problem of cerebral dominance in left-handed people and discussed ten of their cases who had predominantly unilateral brain disease. They concluded that the most prevalent form of cerebral organization in left-handers is left-brainedness. Right-brainedness is a distinctly unusual condition.

Fairbanks, Grant, "Systematic Research in Experimental Phonetics: 1. A Theory of the Speech Mechanism as a Servo-system", Journal of Speech and Hearing Disorders, Vol. 19, 1954, p. 133-139.

A review of some models in communication systems is given and a model of the speech mechanism, based on cybernetical principals of feedback, is presented. The ears act as a channel for the sensory feedback of voice to regulate the vocal output. However, the two ears are assumed to play identical roles.

Goodglass, Harold, and F.A. Quadfasel, "Language Laterality in Left-handed Aphasics", Brain, Vol. 77, 1954, p. 521-548.

A very comprehensive survey of the literature on cases of left-handers with unilateral lesions of the language area. They presented 110 cases from the literature and added thirteen of their own to conclude that cerebral language laterality and handedness are not directly linked. Right cerebral language laterality is much less prevalent than left-handedness. A very useful source of information.

Kiara, Doreen, "Cerebral Dominance and the Perception of Verbal Stimuli", Canadian Journal of Psychology, Vol. 15, No. 3, September 1961, p. 166-171.

In this study 120 patients at the Montreal Neurological Institute were used who had epileptogenic foci in various parts of the brain. They were given an auditory test in which different verbal material was presented to the two ears. The sodium amytal aphasia test was used to divide the group in two, one who had left cerebral language laterality and one who had right cerebral language laterality (thirteen). She found that the ear contralateral to the speech centre was significantly more efficient in conveying and interpreting the message than was the ear ipsilateral to the speech centre. This phenomenon was independent of handedness. An important contribution towards the present study.

-----, "Some Effects of Temporal-lobe Damage on Auditory Perception", Canadian Journal of Psychology, Vol. 15, No. 3, September 1961, p. 156-165.

Seventy-one patients with the presence of epileptogenic foci were used. Digits were presented in simultaneous pairs to the two ears and the subject was asked to repeat them after a pair of six had been presented. She found that unilateral temporal lobectomy impaired the recognition of digits arriving at the ear contralateral to the removal and that left temporal lobectomy impaired the overall efficiency more than did right temporal lobectomy. It was interpreted to mean that the crossed auditory pathways in man are stronger

than the uncrossed and that the left hemisphere played a more important role in recognition of verbal material than the right hemisphere.

Mounsey, Claudine, and Gordon E. Peterson, "The Relationship of Ear Preference to Other Laterality Characteristics", Journal of Speech Disorders, Vol. 9, No. 2, June, 1944, p. 121-123.

Forty-five subjects were administered a test of ear preference where they had to listen to a single sound source. Other tests were performed to determine hand, eye, and foot preference. They concluded that there is some positive relationship between ear preference and other laterality characteristics, although it is not a particularly close relationship. The findings are of doubtful significance.

Penfield, Wilder, and Lamar Roberts, Speech and Brain Mechanisms, Princeton, New Jersey, Princeton University Press, 1959, xiii-286 p.

A monumental work summarizing their work with patients at the Montreal Neurological Institute. Cortical mapping of the speech area by means of electrical stimulation and interference is described in great detail. The section of importance for the present study is discussions of handedness and cerebral dominance and review of the literature on the incidence of hemiplegia with aphasia. Their conclusion is that speech is represented in the left hemisphere regardless of handedness.

Peterson, Gordon E., "Ear Preference", Journal of Speech Disorders, Vol. 7, No. 4, December, 1942, p. 319-321.

This study is an attempt to discover whether individuals consistently choose the same ear in listening to a single sound source. It is concluded that an ear preference does appear to exist, however, no adequate analysis of differences between the frequency of consistent and inconsistent choices was made.

Spilka, Bernard, "Relationship Between Certain Aspects of Personality and Some Vocal Effects of Delayed Speech Feedback", Journal of Speech and Hearing Disorders, Vol. 19, 1954, p. 491-503.

The voice variables used in the present investigation was taken from this study. Spilka found that only measures of change or variance in the degree of vocal intensity correlated significantly with personality characteristics. None of the rate-duration measures and mean vocal intensity revealed any consistent relationship with personality scores. These variables were adopted for the present investigation.

APPENDIX 1

READING PASSAGE USED IN THE EXPERIMENT

APPENDIX 1

READING PASSAGE USED IN THE EXPERIMENT¹

When the sunlight strikes raindrops in the air, they act like a prism and form a rainbow. The rainbow is a division of white light into many beautiful colours. These take the shape of a long round arch, with its path high above, and its two ends apparently beyond the horizon. There is, according to legend, a boiling pot of gold at one end. People look, but no one ever finds it. When a man looks for something beyond his reach, his friends say he is looking for the pot of gold at the end of the rainbow.

¹ Forest Melvin Hull, An Experimental Investigation of Speech Disturbance as a Function of the Frequency Distortion of Delayed Auditory Feedback, unpublished Ph.D. dissertation, University of Illinois, 1952, p. 5.

APPENDIX 2

**RAW SCORES FOR
VARIABLE 1, PER CENT PHONATION TIME**

Table XIX.-
Raw Scores for Variable 1, Per Cent Phenation Time.

Subj. No.	Occasion 1				Occasion 2			
	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)
Left								
1	77.29941	92.65217	88.70968	87.40158	83.11966	93.96709	84.83607	86.26364
2	69.42910	76.95716	78.01418	77.50865	76.29068	77.53304	78.18499	78.96552
3	67.06282	80.00000	78.28571	79.59914	74.55880	80.04751	77.54173	78.49779
4	75.79909	78.71592	74.93606	76.92308	74.28571	77.16469	77.00535	77.07254
5	79.44251	84.62733	84.81244	81.55259	76.61037	79.47417	83.96584	86.25363
6	85.39095	95.77465	91.34438	89.59108	86.22755	97.01493	91.22807	89.57265
7	64.41718	86.03286	74.27785	76.79558	65.34810	78.06236	71.22208	71.65150
8	76.39405	88.77551	80.84034	83.68000	75.30364	82.15712	80.75658	81.62602
9	73.36601	88.13906	89.49580	86.93931	73.84045	89.80815	83.65817	87.25213
10	62.56591	81.49820	80.85714	77.99443	69.94329	85.92965	84.11054	78.70968
Right								
11	75.31381	81.74342	80.59216	79.42308	80.30303	83.76623	78.54331	79.92565
12	71.05719	85.19213	85.03836	88.36317	72.57525	87.83019	84.99353	84.25000
13	70.79038	88.59649	81.10092	86.43333	80.63764	90.10695	80.86124	90.23256
14	66.37782	88.75000	82.50000	88.03089	68.15920	92.68559	82.18527	86.81592
15	75.08532	82.75862	81.38462	78.86905	79.27273	84.12256	79.62963	80.38348
16	83.33333	96.17414	90.10989	94.08194	90.32882	94.60494	92.01331	94.75410
17	61.96013	90.89958	88.75339	88.02228	73.66548	89.94413	83.71429	83.53333
18	77.20588	88.93130	88.16425	91.48681	81.12523	93.67589	90.20045	87.79577
19	68.89251	91.76245	85.02203	91.87328	72.65714	94.26752	80.25078	93.31551
20	61.14082	90.85511	74.08537	86.70695	66.78636	89.83287	83.17757	85.45176
21	65.10417	87.63736	82.67394	78.61111	69.74790	83.52166	78.63696	78.82690
22	77.10438	87.72936	83.98204	88.01090	83.61382	84.48485	86.62614	86.54434
23	73.69338	85.80097	82.59896	83.87097	78.35571	87.18274	83.42391	83.20210
24	68.69565	93.57143	85.87156	90.98940	61.53646	93.48442	82.27612	87.95181
25	76.84211	92.19653	91.71461	92.19858	79.15254	93.37979	89.18919	92.53333
26	71.01727	74.36306	74.78559	76.38191	73.52941	76.23090	74.82143	75.26132
27	54.46735	69.86301	70.36496	74.41177	63.52531	72.62950	71.98142	72.98938
28	75.20161	93.32478	85.73446	90.23111	76.57480	95.30121	90.69401	90.81325
29	58.91608	80.35714	68.69221	75.53594	57.16753	82.21709	74.11464	81.52778
30	82.53582	89.67298	85.39458	87.29604	84.28763	88.05970	88.75596	92.32473

APPENDIX 3

**RAW SCORES FOR
VARIABLE 2, MEAN SYLLABLE DURATION IN MILLISECONDS**

APPENDIX 4

RAW SCORES FOR
VARIABLE 3, MEAN INTENSITY ABOVE AN ARBITRARY REFERENCE

APPENDIX 4

Table XXI.-

Raw Scores for
Variable 3, Mean Intensity Above an Arbitrary Reference.

Subj. No.	Occasion 1				Occasion 2			
	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)
Left								
1	11.60	22.30	17.50	18.50	12.40	21.80	15.80	16.40
2	8.00	22.50	15.70	13.90	9.80	22.40	14.50	13.30
3	10.40	22.40	18.50	17.90	11.30	20.50	15.50	17.50
4	10.10	24.10	16.70	17.70	9.50	23.50	15.80	14.40
5	11.90	28.90	23.80	23.90	12.40	27.40	21.20	25.50
6	8.70	21.90	17.10	16.60	9.60	23.50	17.70	16.70
7	7.70	20.50	13.60	14.90	7.99	19.00	13.80	13.50
8	14.50	30.20	21.90	27.60	13.70	28.80	22.50	24.90
9	8.70	29.40	19.20	21.00	8.10	25.70	14.80	21.10
10	4.90	15.00	12.70	12.25	5.50	19.40	12.00	11.10
Right								
11	8.47	15.72	12.96	12.98	9.98	16.57	12.98	13.23
12	7.53	22.03	18.93	19.08	10.63	23.26	18.27	17.46
13	7.30	18.80	16.10	19.50	10.20	23.70	16.80	21.60
14	5.88	15.56	10.27	11.49	6.92	16.93	12.93	11.55
15	10.91	18.62	13.99	14.27	10.56	21.32	15.32	15.88
16	10.20	26.30	21.52	20.18	11.63	27.65	20.72	20.74
17	5.14	24.06	16.75	16.57	7.80	26.99	17.54	16.24
18	8.70	24.50	21.50	22.00	10.10	26.00	23.80	18.50
19	6.99	26.45	17.02	19.12	9.94	27.16	14.92	20.42
20	4.35	16.09	8.04	9.46	5.02	17.60	10.46	10.82
21	6.10	22.60	18.20	18.10	8.20	25.80	17.50	19.20
22	9.41	26.34	21.04	20.43	12.03	27.00	24.58	20.97
23	11.20	25.90	18.20	20.10	13.30	26.60	18.97	24.46
24	6.63	18.21	13.28	14.11	7.17	20.56	12.75	12.92
25	13.38	27.93	23.36	24.56	14.86	26.53	21.72	22.73
26	7.16	14.86	12.11	11.51	7.86	15.40	14.42	13.15
27	4.87	9.50	8.20	8.70	6.23	12.62	9.41	10.24
28	5.87	22.64	12.68	12.38	5.58	22.51	16.30	12.24
29	3.49	16.01	8.36	8.76	3.28	18.16	8.35	11.75
30	20.66	33.45	31.61	29.40	25.25	34.15	33.29	32.00

APPENDIX 5

ABSTRACT OF

An Experimental Study of Auditory Dominance and
Cerebral Language Laterality

APPENDIX 5

ABSTRACT OF

An Experimental Study of Auditory Dominance and Cerebral Language Laterality¹

The main concern of this study was to investigate auditory dominance and cerebral language laterality with a group of ten left-sided subjects and a group of twenty right-sided subjects. A measure of auditory dominance was introduced, consisting of acuity scores, and the left-sided group demonstrated superior left ear dominance and the right-sided group superior right ear dominance.

The subjects had to read a simple 127 syllable passage under four different conditions which consisted of a direct feedback of their voice through earphones, a binaural delayed auditory feedback and two conditions of monaural delayed auditory feedback with direct feedback on the opposite ear. It was assumed that the left-sided group had right cerebral language laterality and that the right-sided group had left cerebral language laterality. The ear contralateral to the assumed speech centre was called the dominant ear. It was hypothesized that speech will be more seriously

¹ Christiaan D. Roode, doctoral thesis presented to the School of Psychology and Education of the University of Ottawa, Ontario, 1963, viii-109 p.

disrupted with a delayed feedback to the dominant ear than with a delayed feedback to the non-dominant ear. The speech samples were recorded on an Ampex tape recorder and analyzed on three different voice variables; per cent phonation time, mean syllable duration, and mean intensity above an arbitrary reference. Testing procedure was repeated to determine reliability coefficients which varied between .81 and .95 for the different conditions.

Analysis and interpretation of results revealed that both left- and right-sided groups showed a significantly longer mean syllable duration with delayed auditory feedback to the dominant ear than with a delayed auditory feedback to the non-dominant ear. Per cent phonation time was also significantly higher for the right-sided group under a condition of delayed feedback to the dominant ear as compared to a condition of delayed feedback to the non-dominant ear. This difference did not occur with the left-sided group. The variable on mean intensity above an arbitrary reference did not show any significant difference between the two conditions of monaural delayed auditory feedback.

It was therefore concluded that the observed speech disturbances could only occur in that particular relationship if the assumption of cerebral language laterality was accepted. The following conclusions and suggestions for future research were offered: the presence of auditory

dominance on the level of speech monitoring appeared to be an acceptable finding; the possibility of dominant ear impairment in some forms of speech disabilities should be seriously considered; a servosystem theory of the speech mechanism should be revised, allowing for different sensors of the ears and their connections to the speech centre.

Finally, the existence of right cerebral language laterality appears to be a less uncommon phenomenon than was previously suggested. The possible relationships between auditory dominance and cerebral language laterality should be investigated by manipulating laterality characteristics instead of controlling for them, and groups of various age levels can be used to determine when cerebral language laterality becomes established.