THE EFFECTS OF BINAURAL AMPLIFICATION ON THE SPEECH DISCRIMINATION PERFORMANCE OF NORMAL HEARING SUBJECTS

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ABSTRACT

THE EFFECTS OF BINAURAL AMPLIFICATION ON THE SPEECH DISCRIMINATION PERFORMANCE OF NORMAL HEARING SUBJECTS

by Mary Katherine Flucke

The purpose of this study is to analyze the results obtained from normal hearing subjects as they responded to the CID Auditory Test W-22 with and without amplification by a binaural hearing aid in order to determine the effects of amplification on their speech discrimination ability.

The subjects for this study were twelve university students. Testing was conducted in two phases. For Phase 1 the standardized recordings of the CID Auditory Test W-22 (Lists 1A, 2A, 3A, 4A, 1B, 2B, 3B, and 4B), were transcribed onto magnetic tape and presented to the subjects at a level of 70 decibels in a reverberant room. White noise at a level of 52 decibels was employed to control the ambient noise level of the room. Subjects were tested individually (except for one instance when two were tested together), aided and unaided, at distances of 24, 48, and 72 feet from the sound source. Responses were recorded by the subjects on forms designed for that purpose. Phase 2 of the testing was

conducted in a sound-treated room to determine the effects of amplification in a relatively noise-free environment. The CID Auditory Test W-22 recordings were played free-field to each of the subjects, aided and unaided, at a level of 0 decibels without a white noise background.

The results of this study show that in both phases of the testing subjects obtained higher discrimination scores in the unaided listening conditions. In Phase 1 this was true of all three positions. In all but two instances a comparison of aided with aided and unaided with unaided conditions showed higher discrimination scores for positions the greater distance from the source of the sound.

Conclusions drawn from this study suggest that normal hearing subjects perform better on speech discrimination tasks without amplification by a binaural hearing aid in an environment of a reverberant acoustical nature with a background of white noise and in one which is relatively noise-free. Information, speech discrimination appears to be somewhat easier in the latter type of environment as evidenced by relatively higher scores obtained in both aided and unaided listening conditions.

Approved by ____________________
Director

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By

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CHAPTER I

STATEMENT OF THE PROBLEM

Introduction

There is some information available about the distorting effects of hearing loss upon the speech discrimination ability of hearing impaired individuals. There is also something known about the effects of amplification on speech discrimination ability. Some individuals with hearing losses are able to discriminate better with the assistance of a hearing aid; however others, even with the increased intensity provided by an aid, have difficulty in discrimination of speech. Audiologists have come to realize that they may be faced with not one, but two distorting factors in attempting to improve speech discrimination scores of hearing impaired individuals. The first of these is frequently associated with the hearing loss itself; the second, results from the inability of the hearing aid to reproduce speech accurately. Corliss mentions this problem in a discussion of the types of distortion caused by hearing aids. Although a hearing aid's major function is to produce gain, since the gain is not independent of frequency, the structural relationships of transmitted sounds will be altered.[1] Speech sounds represent a complicated combination of frequencies; therefore, Kranz states that to reproduce them with as little distortion as possible, They must have approximately the same relative intensities that they had in the original sound. However, each component of a hearing aid has the tendency to reproduce some frequencies much more efficiently than it will others.[2]

Studies directed toward comparing the efficiency of monaural and binaural hearing aids (to be discussed in Chapter II) have been made in order to learn more about the effect of amplification on the ability to discriminate speech. In most cases subjects for these studies have been individuals with hearing losses. It appears, however, that additional valuable information in this area relative to the effect of hearing aid distortion on speech discrimination

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[1]Edith L. R. Corliss, "Types of Distortion in Hearing Aids." Abstracted in ASHA, 3 (October, 1961), p. 344.

[2]Fred W. Kranz, Hearing Aids, Sonotone Corporation, Elmsford, New York, 1946, p. 29.

might be obtained by providing amplification via a hearing aid to the normal ear, thus eliminating one distorting factor, that of the hearing loss.

Purpose of the Study

The purpose of this study is to analyze and compare the results obtained from normal hearing subjects as they responded to the CID Auditory Test W-22 (lists 1A, 2A, 3A, 4A, 1B, 2B, 3B, and 4B) with and without amplification by a binaural hearing aid. From this analysis it is hoped that it might be determined (1) if the normal hearing adult is able to discriminate better as a result of amplification, or (2) if the distorting effects of a hearing aid are such as to hinder his ability to discriminate. It is also hoped that by obtaining responses to these lists, aided and unaided, at three distances from the source of the sound, the effects of increasing distance upon discrimination of amplified speech might be obtained. As an aid to analysis the following questions have been formulated:

1. Is there a difference in speech discrimination scores as a result of applying a hearing aid to the ears of normal hearing subjects?

2. Does discrimination of speech vary as a function of distance from the sound source?

3. What is the trend in speech discrimination through the conditions unaided and aided?

4. Is there a difference in the aided and unaided speech discrimination scores as subjects were tested in a sound-treated room?

Importance of Study

This study is important for two reasons. In the first place, since the most important function of hearing is to allow an individual to communicate and understand communication,[1] the significance of assessing discrimination ability in the hard of hearing individual becomes apparent. If response norms can be established for normal hearing subjects with hearing aids, it may be possible to determine the degree of distortion imposed by the hearing aid by assessing the distortion caused by the aid when applied to the ear of a normal hearing subject.

Secondly, if it is determined that amplification by means of a hearing aid does, in fact, improve discrimination

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[1]Douglas MacFarlan, "Speech Hearing Testing," Larynogoscope, 55 (February, 1945), p. 71.

in normal hearing people, it may be that individuals with jobs requiring a high degree of accuracy in their ability to discriminate speech will be found better able to perform these jobs through the use of amplification such as that provided by a hearing aid. In this instance also, information concerning the effects of distance on the ability to discriminate with amplification might also prove valuable.

Definition of Terms

For the purpose of this study the terms used are defined in the following manner:

Speech Discrimination or Articulation Test.--A test which allows for evaluation of a patient's ability to differentiate among acoustically similar sounds or among words that contain acoustically similar sounds.

CID Auditory Test W-22.--A discrimination test consisting of four lists of 50 phonetically balanced, one-syllable words adapted by the Central Institute for the Deaf from the Phonetically Balanced Word Lists of the Psycho-Acoustic Laboratory, Harvard University. These words are available in recorded form. They are presented to the subject at a level above his Speech Reception Threshold.[1]

Phonetically Balanced.--Test items in which all, or nearly all, of the fundamental sounds into which speech can be analized are represented. The frequency of occurrence of these fundamental sounds is in proportion to their distribution in normal speech.[2]

Speech Reception Threshold.--The sensation level at which the patient can repeat 50 per cent of the stimulus words correctly.[3]

Amplification.--Increase in intensity--in this case, to be provided by a binaural hearing aid.

Binaural Hearing Aid.--An instrument providing each ear with a separate transmitter having its own receiver.

Normal Hearing Subjects.--Persons who are able to hear pure tone stimuli, 250 through 6000 cycles per second

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[1]Ira J. Hirsh, et. al., "Development of Materials for Speech Audiometry," Journal of Speech and Hearing Disorders. 17 (September, 1952), pp. 322-323.

[2]James P. Egan, "Articulation Testing Methods," Laryngoscope, 58 (September, 1948), p. 957.

[3]Hayes A. Newby, Audiology, (New York: Appleton-Century-Crofts, Inc., 1958), p. 111.

at a level of 15 decibels.

Organization of the Thesis

Chapter I has contained the statement of the problem that led to this study. It has included an introduction to the topic and an outline of the purpose of the study. It has put forth the questions to be considered in this study, discussed the importance of the study, and defined the terms which will be used.

Chapter II contains a review of the literature pertinent to this topic.

Chapter III consists of a discussion of the subjects, equipment, materials, and testing procedures utilized in the study.

Chapter IV consists of a discussion of the results of the study.

Chapter V contains a summary and the conclusions of the study and implications for further research.

CHAPTER II

REVIEW OF THE LITERATURE

Speech-Hearing Tests

For many years the field of audiometry was limited in scope to the evaluation of hearing by means of pure-tone testing. With the realization that speech is the most important thing with which hearing is concerned came a growing interest in the evaluation of how well people hear speech. There seemed to be, however, no way of predicting a person's ability to hear speech from a pure-tone audiogram.[1] Thus, emphasis came to be placed on the development of appropriate means of measuring speech-hearing ability.

In this process of development it became evident that two measures of a person's ability to hear speech are desirable. The first of these, a quantitative measure, indicates the level at which a person is able to understand 50 per cent of what is said to him. This level is evaluated

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[1]Hallowell Davis, "The Articulation Area and the SAI for Hearing," Larynogscope, 58 (1948), p. 761.

by means of Speech Reception Threshold Tests. The second measure is qualitative in nature in that it yields a picture of a person's ability to discriminate fine differences in speech sounds when these sounds are given at a level easily audible to the listener. This ability is evaluated by means of phonetically balanced word lists. Since both tests are similar to common auditory experiences, they add validity to pure-tone audiometry as well as being valuable for diagnostic and prognostic purposes.[1] Of these two measures discrimination testing has been particularly useful with individuals having difficulty in communication because they confuse speech sounds even though they are able to hear the speaker.

Davis, in his attempt to fill a need for a quantitative measure of the social adequacy of hearing, used these two kinds of speech-hearing tests to develop the Social Adequacy Index, a single number that indicates how well a person hears speech under everyday conditions. The Social Adequacy Index is derived from the relation of a patient's discrimination score to the level at which he hears speech.[2]

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[1]Hirsh, op. cit., p. 321.

[2]Davis, op. cit., pp. 776-777.

With this index it is possible to estimate numerically the handicap of a person's hearing loss. The value of this index in facilitating the planning of rehabilitation programs for patients and in evaluating the results of fenestration operations and hearing aids has placed an even greater importance upon speech-hearing testing, and in particular, discrimination testing.

A great deal of research and experimentation with a variety of speech-hearing tests preceded the development of speech-hearing tests as we know them today. Early research in connection with the telephone, phonograph and radio industries yielded information which aided the development of these tests. From this research it was learned that because words, parts of words, and individual vowels and consonants vary greatly in their acoustic characteristics, some words are more easily heard and understood than others. Vowel sounds are heard twice as easily as consonant sounds; thus, most mistakes in interpretation can be attributed to the mishearing of consonant sounds. Familiarity, mental acuity, word memory, and word association were all found to be factors important to good hearing. On the other hand, noises, interruptions, distractions, and cross-talk were found to interfere with good hearing.[1]

This information proved to be valuable in the construction of test materials as did such criteria as familiarity, phonetic dissimilarity, normal sampling of English speech sounds, and homogeneity in terms of basic audibility.[2] More specific criteria have been adopted for materials designed to test speech discrimination. These criteria, as specified by Egan, are: (1) monosyllabic structure, (2) equal average difficulty, (3) equal range of difficulty, (4) equal phonetic composition, (5) composition representative of the English language, and (6) words in common usage.[3]

One of the first speech-hearing tests developed was that used by the Bell Telephone Laboratories in a study of the efficiency of telephone circuits. This test, designated as the "Standard Articulation Lists," consisted of a large series of unintelligible sounds--combinations of consonant-vowel-consonant, consonant-vowel, and vowel-consonant.[4] An

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[1]MacFarlan, op. cit., p. 77.

[2]Hudgins, et. al., "Development of Recorded Auditory Tests for Measuring Hearing Loss for Speech," Laryngoscope, 57 (1947), p. 58.

[3]Egan, op. cit., p. 958.

[4]MacFarlan, op. cit., p. 77.

attempt was made to make these lists as much like speech as possible but difficulty remained in the reporting of meaningless sounds heard and in the recording or writing of what was reported.[1]

A more widely used speech-hearing test developed by the Bell Telephone Laboratories used digits spoken in groups of three for its items. It was one of the first recorded tests and was used with the Western Electric 4A Audiometer. The intensity of the recorded speech decreased in steps of 3 decibels. Although this was a much used test, it was found to be ineffective in differentiating between uniform and high-frequency hearing losses.[2]

One of the earlier tests of speech discrimination developed was the Wengel Audioselective Hearing Test. The test, consisting of three groups of words, was designed to measure the perception of and discrimination between voiced and voiceless consonants, vowel resonances, and high-frequency consonants.[3]

In 1938 Robert West developed a speech-hearing test helpful in discovering the frequency area of a hearing loss.

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[1] *Ibid*., p. 78.

[2] Hudgins, *op. cit.*, p. 60.

[3] MacFarlan, *op. cit.*, p. 90.

The test, one of so-called selective amplification, measures hearing acuity for groups of words listed in various frequency zones.[1]

In 1940 L. A. Watson and Vern Knudsen constructed a test designed to measure both the level of speech-hearing acuity and speech discrimination. The test, composed of 69 words--20 vowels and 49 consonants, is first given to determine threshold. Tests are then conducted at various levels above threshold to find a percentage score of syllable articulation.[2]

Another test of speech discrimination was developed in 1941 by Alfred R. Thea. This "Word Hearing Test" is comprised of blocks of three words which sound alike. After listening to each group of words, the person being tested indicates the word he believes he heard.[3]

In the 1940's the Psycho-Acoustic Laboratory (PAL) at Harvard University conducted a program of audiometric test development with three main objectives in mind. The first of these was to explore further some of the problems associated with the construction of audiometric tests for the direct

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[1] Ibid., pp. 90-91.

[2] Ibid., pp. 93-95.

[3] Ibid., p. 99.

measurement of hearing loss for speech. Much of the earlier work with speech-hearing tests carried out by the Bell Telephone Laboratories helped in accomplishing this objective. The second purpose of the study was to produce a test appropriate for exact laboratory measurements of all degrees of hearing loss. Two tests, Auditory Test No. 9, Threshold of Hearing for Words, and Auditory Test No. 12, Threshold of Hearing for Sentences, were constructed to meet this objective. These allowed for a rapid and dependable measurement of the threshold of intelligibility and its related clinical measurement, hearing loss for speech. A high frequency test was developed to meet a third objective, that of finding a means of differentiating between uniform and high-frequency hearing losses. However, this test was found to offer no real advantage over pure-tone adiometry as a diagnostic approach, so work was then concentrated on the development of speech-hearing tests, leaving the differentiation of various kinds of hearing loss to pure-tone audiometry.[1]

During the course of this articulation testing program the Psycho-Acoustic Laboratory also constructed several sets of word lists. From these lists of monosyllabic

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[1]Hudgins, op. cit., pp. 62-64.

words, 24 lists of 50 words each were constructed. Words were selected on the basis of the phonetic composition of the first part of the word. These were called the RM (revised monosyllabic) lists. Though somewhat satisfactory, Egan felt the need for more phonetically balanced lists and thus constructed the PB word lists. The PB series consists of 20 lists each made up of 50 monosyllables.[1]

With a growth in general acceptance and use of speech audiometry came the need for newer tests satisfying more clinical needs. As a result, the Central Institute for the Deaf refined the PAL tests in an attempt to correct some of the deficiencies that had been noted in them. For example, it was discovered that some of the recordings of the Auditory Test No. 9 yielded different thresholds than others. The vocabularly on the PB lists was found to be too long and unfamiliar, and the recordings were not in standardized form. The revisions made by the Central Institute for the Deaf are in the form of three tests, presently widely accepted for speech-hearing testing.[2]

<u>CID Auditory Test W-1</u>.--This test, measuring the

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[1]Egan, <u>op. cit.</u>, pp. 962-963.

[2]Hirsh, <u>op. cit.</u>, p. 322.

threshold of intelligibility for speech, is made up of 36 spondaic words (two-syllable words in which both syllables are equally stressed) chosen on the basis of ratings of familiarity from the 84 spondaic words on the PAL Auditory Test No. 9. The words are recorded at a constant level 10 decibels below the carrier phrase, "Say the word." Six scramblings of the original list are available.[1]

CID Auditory Test W-2.--The same words and six word orders comprising the CID Auditory Test W-1 are used in this test. The intensity of the words is attenuated within each list at the rate of 3 decibels for every three words, thus allowing for a rapid estimate of the threshold of intelligibility for speech.[2]

CID Auditory Test W-22.--This test, a modification of the PAL PB-50 Lists, is designed to determine a patient's discrimination loss for speech. This loss is designated as the difference between 100 per cent and the per cent of the words presented that a listener repeats correctly at a level that is sufficiently high so that further increase in intensity is not accompanied by further increase in the number of

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[1]Ibid., p. 323.

[2]Ibid., p. 326.

words repeated correctly. Two hundred monosyllabic, phonetically balanced words make up four lists of words, each of which has six scramblings. Each word is preceded by the carrier phrase, "You will say." The words were selected to meet a criteria of familiarity and phonetic composition similar to that of the English language.[1]

The Use of Binaural Hearing Aids

The recent development of binaural hearing aids has stimulated a new interest in binaural hearing and the possible benefits of binaural amplification for hard of hearing individuals. Research in the area of binaural hearing, however, is not new. Much information exists concerning the advantages of two-eared hearing. Listed among these advantages are better localization, discriminative selection, speech sound discrimination, more ease of listening, better sound identification, and improved sound fidelity.[2]

From such research it might well be assumed that similar benefits can be derived from binaural hearing aids. However, much of the information gathered thus far on the

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[1] Ibid., pp. 328-329.

[2] LeRoy D. Hedgecock, and Boyd V. Sheets, "A Comparison of Monaural and Binaural Hearing Aids for Listening to Speech," A.M.A. Archives of Otolaryngology, 68 (1958), p. 624.

properties of binaural hearing has been obtained from normal hearing subjects. There is considerable empirical evidence indicating that hard of hearing individuals often do not respond to sound amplification in the same manner as normal ears. Also, not all hard of hearing persons benefit from a hearing aid even of the monaural type.[1] Considerations such as these and the fact that clinicians must be aware of the advantages and limitations of binaural systems in order to have well defined criteria for the hard of hearing patient have pointed to a need for careful study of binaural hearing aids.

It is the belief of Haskins and Hardy that the benefits of a binaural hearing aid cannot always be assessed by formal clinical testing. They have found that often this can be determined only by the patient's own listening experience under conditions in which he needs amplification.[2]

Similarly, Kodman discovered certain advantages which he felt could not be determined by clincial techniques. From a sample of 50 successful binaural eyeglass hearing aid users he found that 42 per cent had no criticisms of their aids as

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[1] Ibid., p. 625.

[2] Harriet Haskins and William G. Hardy, "Clinical Studies in Stereophonic Hearing," Laryngoscope, 70 (1960), p. 1433.

compared with 30 per cent reported by monaural hearing aid users in a previous study. As a result of his study he suggests that binaural hearing promotes an intra-aural effect that manifests itself in better sound balance and ease of perception. The latter may not be shown in the discrimination score.[1]

Carhart, on the other hand, advocates more rigid clinical procedures for the study of binaural hearing aids. He streses a need for refining and standardizing methods for appropriately testing the efficiency of binaural aids. In order to approximate the difficult listening situations of everyday life he suggests that these methods must embody a certain rigor and acoustic complexity. Three such procedures are discussed: (1) Measurement of discrimination for phonetically balanced words when these are presented in noise, (2) Measurement of an individual's ability to attend to one of two competing trains of test items, and (3) Measurement of the ability to discriminate test material that competes with itself, as occurs in everyday situations when reverberation and reflection of sound are severe.[2]

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[1]Frank Kodman, "Successful Binaural Hearing Aid Users," Archives of Otolaryngology, 74, (1961), pp. 302-304.

[2]Raymond Carhart, "The Usefulness of the Binaural Hearing Aid," Transactions of the American Academy of Ophthamology and Otolaryngology, 62 (1958), pp. 125-126.

During the past six years a number of procedures similar to these, as well as other techniques, have been devised and tested to compare binaural and monaural hearing aids with respect to their ability to improve hearing for speech. The results of some of these studies shall be considered at this time.

One of the earlier studies of this nature was conducted by Markle and Aber at the Hearing and Speech Center of the New York University-Bellevue Medical Center. Ten subjects with clincial otosclerosis, considered to be ideal hearing aid candidates, were tested, first while wearing a "conventional" hearing aid in a "conventional" manner, and then with two "conventional" hearing aids, one mounted on each side of the head. Auditory Tests W-1 and W-22 were administered at signal/noise ratios of +10, 0, and -10. No significant difference in speech reception thresholds was found between the two listening conditions. At signal/noise levels of +10 decibels there was a slight difference in discrimination with the binaural hearing aid being favored. Significant differences in discrimination were found at the signal/noise levels of 0 and -10.[1]

Hedgecock and Sheets in testing 30 hearing impaired subjects with monaural and binaural amplification at the Mayo Clinic obtained differential results which were not statistically significant, but which revealed a trend favoring the binaural over the monaural hearing aid fitting in respect to speech discrimination. Unlike the Markle and Aber study, testing was conducted in quiet surroundings. In addition, they found that when relative severity of hearing was considered, subjects falling into the category of moderate hearing losses, for the most part, derived greater benefit from the binaural aid than those with milder or severer hearing losses.[2]

In a later study by Belzile and Markle the efficiency of monaural and binaural hearing aids was again compared in a noisy environment. In this investigation only individuals with conductive or perceptual hearing losses were studied. Those with bilateral conductive losses achieved higher discrimination scores with the binaural aid than with the

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[1]Donald M. Markle and William C. Aber, "A Clinical Evaluation of Monaural and Binaural Hearing Aids," Archives of Otolaryngology, 67 (1958), pp. 606-608.

[2]Hedgecock, op. cit., pp. 624-629.

monaural in all listening conditions tested (+20 through -10 signal/noise levels). Subjects with bilateral perceptual losses received higher scores with the binaural aid only in the listening conditions representing signal/noise ratios between +10 and 0. For both groups the improvement was most significant at the 0 signal/noise ratio; however, it was discovered that for both groups 50 per cent discrimination can be achieved in the presence of 10 decibels more noise while wearing a binaural hearing aid than while wearing a monaural aid.[1]

Jerger and Dirks later replicated this study with the exception that for the monaural listening condition they mounted the hearing aid on the subject's head rather than on the body as did the previous investigators. Jerger and Dirks' results failed to confirm the binaural superiority found in the Belzile and Markle study.[2] Hirsh believes that this discrepancy in results might well be due to the slight difference in procedure, since in the Jerger study the single

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[1]Marcel Belzile and Donald M. Markle, "A Clinical Comparison of Monaural and Binaural Hearing Aids Worn by Patients with Conductive or Perceptual Deafness," Laryngoscope, 69 (1959), pp. 1317-1323.

[2]James Jerger and Donald Dirks, "Binaural Hearing Aids. An Enigma," Journal of the Acoustical Society of America, 33 (1961), p. 537.

aid derived benefits from head movement in the monaural condition.[1] Nevertheless, it is felt by the investigators that head mounting of the single aid provides a more exact procedure for comparing monaural and binaural hearing aids with respect to discrimination in noise.[2]

To explore the comparative values of binaural, pseudo-binaural, and monaural listening, DiCarlo used 60 subjects with conductive, mixed, or sensory-neural losses as an experimental group and 20 normal hearing adults as a control group. The three types of amplification were used to determine speech reception thresholds, discrimination scores, speech-noise ratios, and localization. The results of this study showed that binaural listening provided some lowering of the speech reception threshold as compared with the pseudo-binaural and better monaural thresholds; however, discrimination scores were not significant for any of the listening conditions. Amplification by means of the binaural hearing aid proved to be better for localizing a noise source than either the pseudo-binaural or the monaural

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[1] Ibid.

[2] Ibid., p. 358.

aid. In general monaural listening was subjectively preferred to binaural listening for the required tasks by the hearing impaired subjects.[1]

Two types of measurement using competing speech signals were used by Jerger, Carhart, and Dirks in one of the most recent studies to determine the possible advantages of binaural hearing aid use for increasing speech intelligibility. Their 48 subjects, all having sensori-neural hearing losses, were tested with monaural-body, monaural-head, and binaural-head hearing aids. The binaural listening condition was not found to be markedly superior, although on the Northwestern University (NU) Test #2 there was a slight (roughly 10 per cent) improvement in PB discrimination against a background of competing sentences. NU Test #3 yielded results showing no improvement in sentence intelligibility with a background of continuous discourse with the binaural hearing aid.[2]

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[1] Louis DiCarlo and William J. Brown, "Effectiveness of Binaural Hearing Aids for Adults with Hearing Impairments," Journal of Auditory Research, 1 (1960), pp. 35-76.

[2] James Jerger, Raymond Carhart, and Donald Dirks, "Binaural Hearing Aids and Speech Intelligibility," Journal of Speech and Hearing Research, 4 (1961), pp. 137-148.

CHAPTER III

SUBJECTS, EQUIPMENT, MATERIALS, AND TESTING PROCEDURES

In order to carry out this study a procedure was decided upon that called for testing of university students. A minimal amount of materials and equipment was required. Subjects employed, as well as the materials, equipment, and testing procedures used are described below.

Subjects

Twelve university students, eleven females and one male, were the subjects for this study. It was determined audiometrically that each subject had normal hearing. They all were administered a pure tone sweep check test at 15 decibels at frequencies 250 through 6000 cycles per second. They ranged in age from 20 to 26 years and in education, from three to five years of college. Although no effort was made to select subjects on the basis of a particular educational background, six subjects were majors in speech and hearing science.

Equipment

Pure-tone portable audiometer (Beltone, Model 10-A, see Appendix A, page 44)

Two tape recorders (Wollensack, Model T1500)

Clinical audiometer (Allison, Model 21)

Binaural hearing aid (Beltone eyeglasses-"Bolero Red Dot")

Batteries (RM 675)

Individual plastic ear inserts of general sizes

Sound pressure level meter (M.S.A. Soundscope)

Materials

CID Auditory test W-22 (Lists 1A, 2A, 3A, 4A, 1B, 2B, 3B, and 4B, see Appendix B, page 45)

Tape recorded white noise

Forms for the recording of responses to each list by the subjects. (See Appendix C, page 49)

Procedure

Preliminary procedures.--The CID Auditory Test W-22 recordings were transcribed onto magnetic tape at the studios of the Michigan State University radio station WKAR. Two tapes, one of lists 1A, 2A, 3A, and 4A and the other of lists 1B, 2B, 3B, and 4B were made. In order that the speech stimulus could be presented at the same level to all subjects, a 1000 cycle per second calibration tone was recorded at the beginning of each tape. A third tape of white noise was made to be presented simultaneously with the CID lists in order to provide a constant ambient noise level in the room used for the first part of the testing. Forms for the recording of responses to each list by the subjects were devised by the examiner.

Each subject was given a pure-tone sweep check hearing test monaurally in each ear at 250, 500, 1000, 2000, 4000, and 6000 cycles per second at a level of 15 decibels. This screening took place in the children's hearing testing room of the Michigan State University Speech and Hearing Clinic. No subject was included in this study who failed the screening test at any one of the frequencies.

Testing--Phase one.--In order to determine whether subjects' discrimination differed as they were provided amplification by a binaural hearing aid, CID Auditory Test W-22 discrimination testing was conducted. This testing was carried out in a room the dimensions of which are 73.5' x 61' x 9'. The walls and ceiling are plastered; the floor is cement. The room appeared to be somewhat reverberant. The background noise of the room without additional white noise was tested by the sound pressure level meter using the C scale and was found to be 48 decibels.

The calibration tone of the tapes of the CID lists as each was presented was set at 70 decibels, 18 decibels above the level of the white noise which was set at 52 decibels. These measurements were taken from position one, a distance of 24' from the source of the sound. The two tape recorders were centrally located along the front wall of the room. As each subject was tested, he was seated in direct line with the tape recorders at distances of 24', 48', and 72'. The third position was located at the back wall of the room. The CID lists were presented to each of the subjects, aided and unaided, at each of the three positions. Thus, six different listening conditions were involved for which six different phonetically balanced lists of words were used for each subject. Responses were recorded by the subjects for each list as the words were presented. The order of the conditions was randomized for all persons according to Edwards' Table of Random Numbers in an attempt to lessen the possibility of practice effects.[1] The subjects were tested individually except for once instance when two were tested together. Prior

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[1]Allen L. Edwards, Statistical Methods for the Behavioral Sciences, (New York: Holt, Rinehart and Winston, 1961), pp. 250-251.

to the testing with the hearing aid each subject was carefully fitted with individual ear inserts of general sizes ranging from small to large. Because the hearing of the subjects was normal, the volume control of the hearing aid was arbitrarily set by the investigator, while wearing the aid, at a level just below that at which feedback was present. This setting was held constant for each subject.

Testing-Phase two.--In order to have a standard of comparison for the tests made in the reverberant room, the effects of amplification upon discrimination in a relatively noise-free environment were measured by testing the subjects in the sound-treated testing rooms of the Michigan State University Speech and Hearing Clinic. For this testing a speech audiometer and the standardized CID Auditory Test W-22 recordings were employed. These were presented free-field to each subject, aided and unaided, in randomized order. The subjects, tested individually, were seated at a distance of 10 feet from the speaker. In order to make the listening task sufficiently difficult the words were transmitted at a level of 0 decibels. White noise was not used in this testing. As in Phase one, the subjects wrote down their response to the CID Auditory Test W-22 test lists on forms provided them.

CHAPTER IV

RESULTS AND DISCUSSION

Results

The test results were tabulated and subjected to statistical treatment. Since it was the desire of the investigator to predict the significance of the difference between the mean scores of the six listening conditions, a t test was carried out (the quantity t is the distance from the means expressed in terms of standard error of the mean).[1] The formula $t = \frac{\bar{X}_1 + \bar{X}_2}{\frac{S_1}{\sqrt{n}} - \frac{S_2}{\sqrt{n}}}$ was used.[2] There were 12 subjects in the study; thus the degrees of freedom were (N-1) or 11. With 11 degrees of freedom a t of 2.201 is needed for significance at the .05 level of confidence. A t of 3.106 is needed for significance at the .01 level of confidence. The results of the tests for t are presented in Table I and Table II.

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[1] Henry E. Garrett, Statistics in Psychology and Education, (New York: Longmans, Green, and Company, 1947), p. 191.

[2] Edwards, op.cit., pp. 253-254.

TABLE I

t SCORES FOR PHASE 1 OF TESTING
(REVERBERANT ROOM)

Listening Condition	Mean Per cent Scores	*t*	Level of Confidence
1 - U 1 - A	32.66 6.83	4.98	Significant at 1 per cent
2 - U 2 - A	27.50 6.83	5.77	Significant at 1 per cent
3 - U 3 - A	33.33 12.50	4.98	Significant at 1 per cent
1 - A 2 - A	6.83 6.83	0	Nonsignificant at 5 per cent
1 - A 3 - A	6.83 12.50	-2.00	Nonsignificant at 5 per cent
2 - A 3 - A	6.83 12.50	-2.42	Significant at 5 per cent
1 - U 2 - U	32.66 27.50	- .77	Nonsignificant at 5 per cent
1 - U 3 - U	32.66 33.33	- .10	Nonsignificant at 5 per cent
2 - U 3 - U	27.50 33.33	-1.08	Nonsignificant at 5 per cent

1 - Position 1 (24')
2 - Position 2 (48')
3 - Position 3 (72')
U - Unaided
A - Aided

TABLE II

t SCORE FOR PHASE 2 OF TESTING
(SOUND-TREATED ROOM)

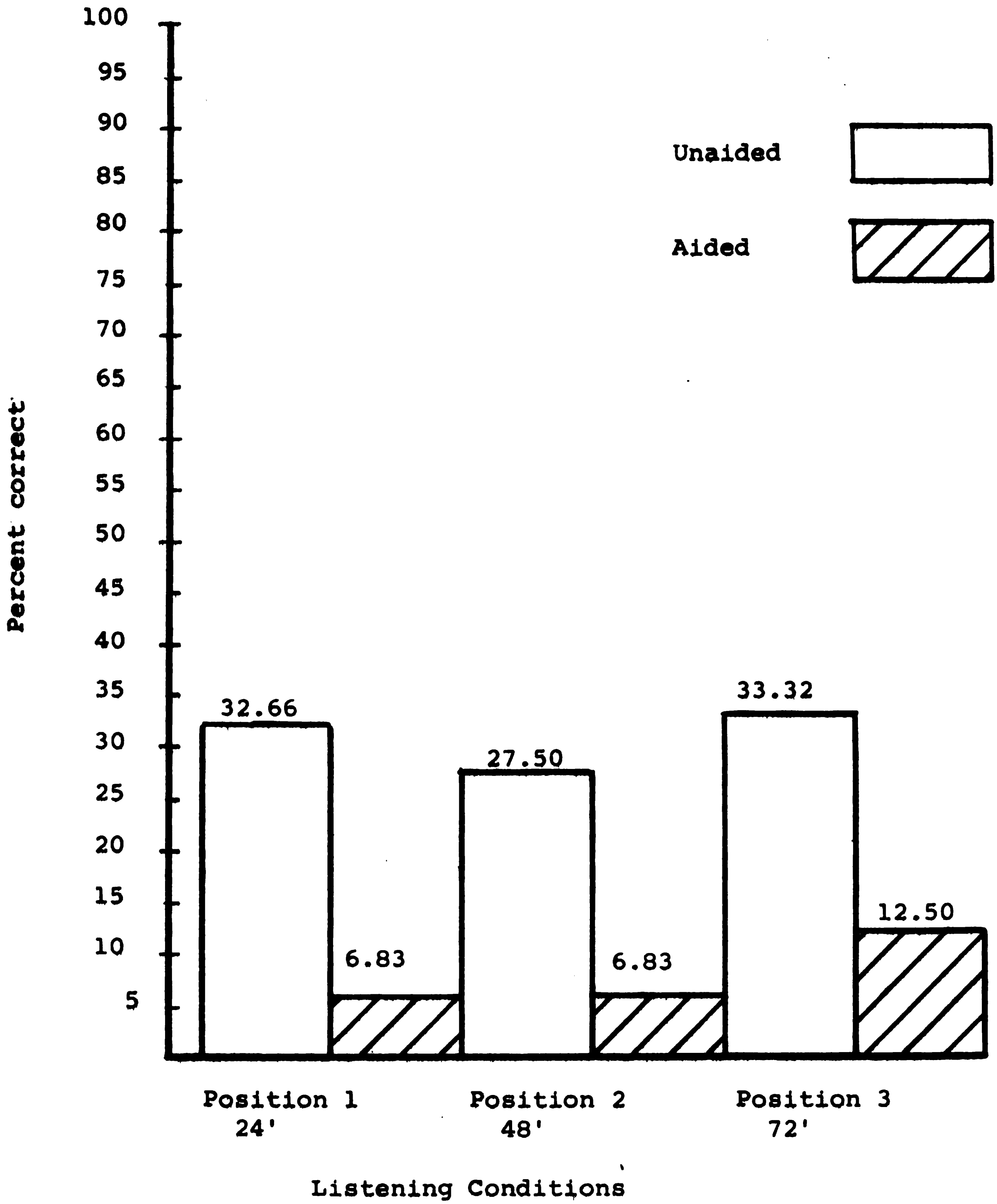
Listening Condition	Mean Per cent Scores	*t*	Level of Confidence
Unaided	56.33	1.71	Nonsignificant
Aided	45.17		at 5 per cent

Discussion

The *t* scores for positions 1, 2, and 3 are significant at the 1 per cent level of confidence, indicating that amplification does make a difference in speech discrimination of normal hearing subjects when tested in a background of noise. In each case discrimination was better in the unaided listening condition.

In answering the question of whether discrimination of speech varies as a function of distance from the source of the sound, it was necessary to consider mean scores of both the aided and unaided listening conditions. These are presented in Figure 1. There was no difference between the aided scores at positions 1 and 2. A slight difference exists between the aided scores of positions 1 and 3, however, this difference is not statistically significant at the 5 per cent level of confidence. A difference, significant at the

Figure 1. Mean Percent Scores for Phase 1 of Testing



5 per cent level of confidence, was found between the aided scores of positions 2 and 3. In both instances scores were highest in the third position, the greatest distance from the source of the sound.

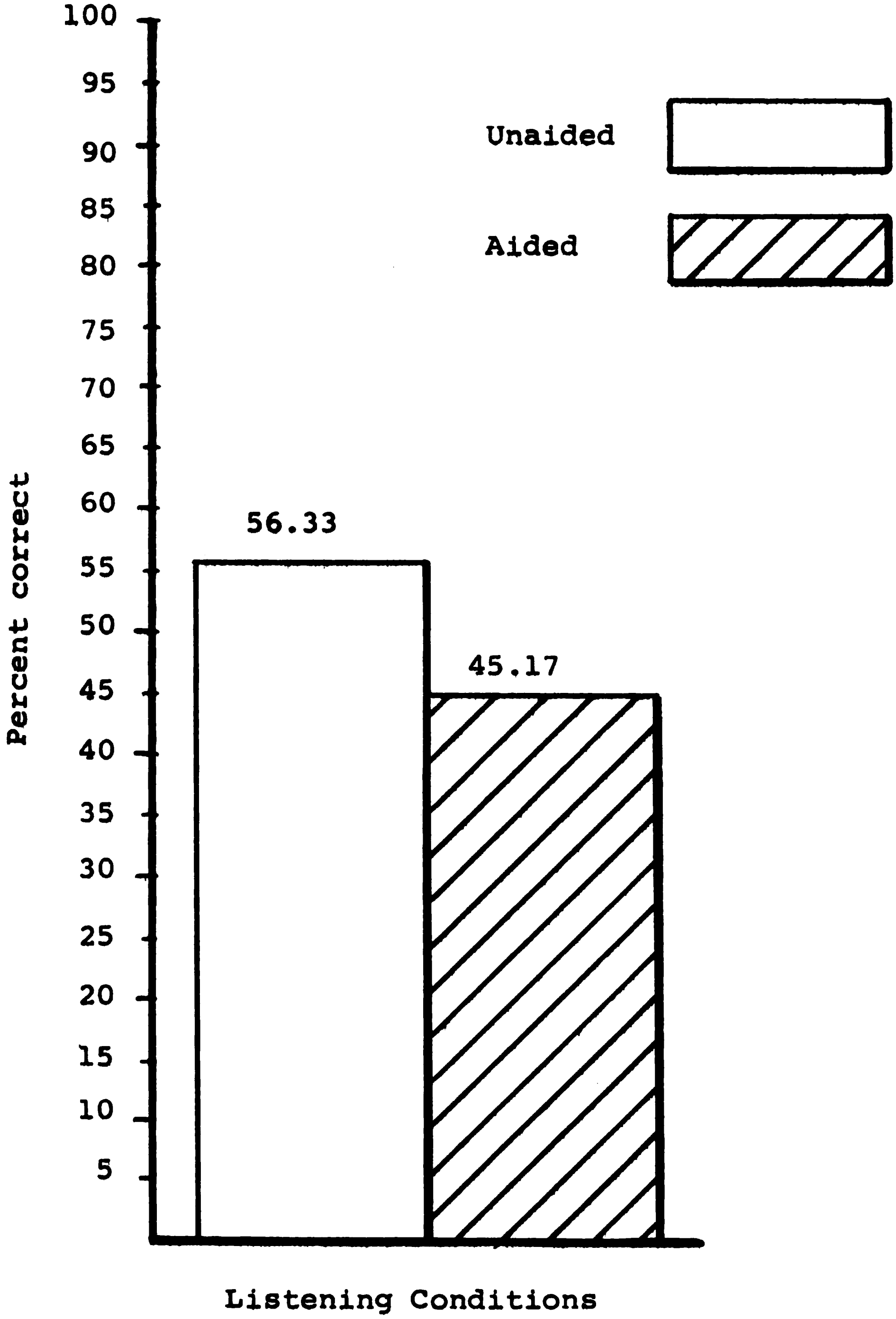
The *t* scores for the unaided listening conditions indicate a tendency similar to that shown by the *t* scores for the aided conditions. Unlike the aided conditions, however, a slight, though statistically nonsignificant, difference was found between the mean scores of positions 1 and 2 in the direction of the position closest to the source of the sound. Differences also existed between positions 1 and 3 and between positions 2 and 3, but neither was significant at the 5 per cent level of confidence. In both cases discrimination was better at the distance farthest from the source of the sound.

Judging from these results, in which in every instance but one there was a difference between positions, one might conclude that distance is a factor in the ability to discriminate speech. It is to be noted that all but one of these differences (although statistically significant in only one case) were better at the greater distance from the source of the sound, a somewhat surprising result. It appears very likely that the reverberant nature of the listening environment in which this experiment took place was a real factor, however, the possibility of another variable should also be considered. Although the six listening condidtions were randomized for each subject, it is to be noted that a greater number of them were tested last in the third position than in the first or second positions. Thus, in spite of an attempt to minimize practice effects, it is possible that they did occur and were manifested in higher discrimination scores at the greatest distance from the source of the sound.

In the sound-treated room there was a small difference between the aided and unaided listening conditions, better discrimination being found in the unaided condition. This is shown in Figure 2. This difference was not significant at the 5 per cent level of confidence. Thus, it appears that, although the subjects performed better on discrimination tasks without the amplification of the binaural hearing aid, the difference between the aided and unaided conditions was not as great in the sound-treated room as it was in the room used for Phase 1 of the testing.

In the latter room discrimination scores in both aided and unaided listening conditions were generally lower than those obtained in the sound-treated room. This

Figure 2. Mean Percent Scores for Phase 2 of Testing



might well be accounted for by the reverberance of the room. The fact that discrimination was more adversely affected in the aided listening condition, however, leads the investigator to suspect that the lower scores might well have been a function of the increased distortion produced by the hearing aid in Phase 1 of the testing.

CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

The problem of achieving greater social adequacy of hearing for the hard of hearing person by means of amplification with a hearing aid has been studied for many years. It has been recognized that one of the greatest difficulties in dealing with this problem is that expected improvements in the ability to discriminate speech as a result of amplification with hearing aids are not always found due to two distorting factors. These are the hearing loss itself, and the manner in which sound is reproduced with the hearing aid. Therefore, the question of what effects amplification have on speech discrimination of normal hearing people has been raised. A review of the literature reveals a paucity of information pertaining to this questions. Thus, the purpose of this study has been to determine if amplification with a binaural hearing aid improves or hinders the speech discrimination ability of normal hearing people.

Twelve university students participated as subjects for the study. A pure-tone screening test at 15 decibels eliminated as subjects all whose hearing was not within the defined normal limits. For Phase 1 of the testing procedure the standardized recordings of the CID Auditory Test W-22 (Lists 1A, 2A, 3A, 4A, 1B, 2B, 3B, and 4B) were transcribed onto magnetic tape and played to the subjects at a level of 70 decibels. In order to control the ambient noise level of the room white noise at a level of 52 decibels was employed. The subjects were tested individually (in all cases but one when two were tested together) in a reverberant room at distances of 24, 48, and 72 feet from the source of the sound. At each distance the subjects responded to words with and without amplification and recorded their responses on forms provided them.

In Phase 2 of the testing the CID Auditory Test W-22 was again administered individually to the subjects, aided and unaided, in a sound-treated room to determine the effects of amplification in a relatively noise-free environment. The words were presented free-field without white noise at a level of 0 decibels.

The results of the study show that in comparing the aided and unaided listening conditions in all positions of Phase 1 of the testing, subjects obtained higher scores without amplification, the differences being statistically significant at the 1 per cent level of confidence. In Phase 2 of the testing the subjects also performed better in the unaided listening condition, however, the difference was not statistically significant.

In comparing aided with aided scores and unaided with unaided scores for all three positions, differences were found which, in all but two instances showed better discrimination for positions that were farthest from the source of the sound. There was no difference between the mean per cent scores for the aided listening conditions at positions 1 and 2. A comparison of the unaided scores at these positions showed better discrimination at the position closest to the source of the sound.

Conclusions

Within the limits of this study the following conclusions are offered:

1. There is a lowering of speech discrimination scores as a result of applying a hearing aid to the ears of normal hearing subjects in a reverberant room with a background of white noise.

2. Speech discrimination does not decrease as a function of distance from the sound source.

3. There is no definite trend in speech discrimination through the conditions aided and unaided.

4. Speech discrimination becomes more difficult as a result of amplification in a relatively noise-free environment.

5. Lower speech discrimination scores are obtained with amplification by a binaural hearing aid as compared to those obtained without amplification in a relatively noise-free environment.

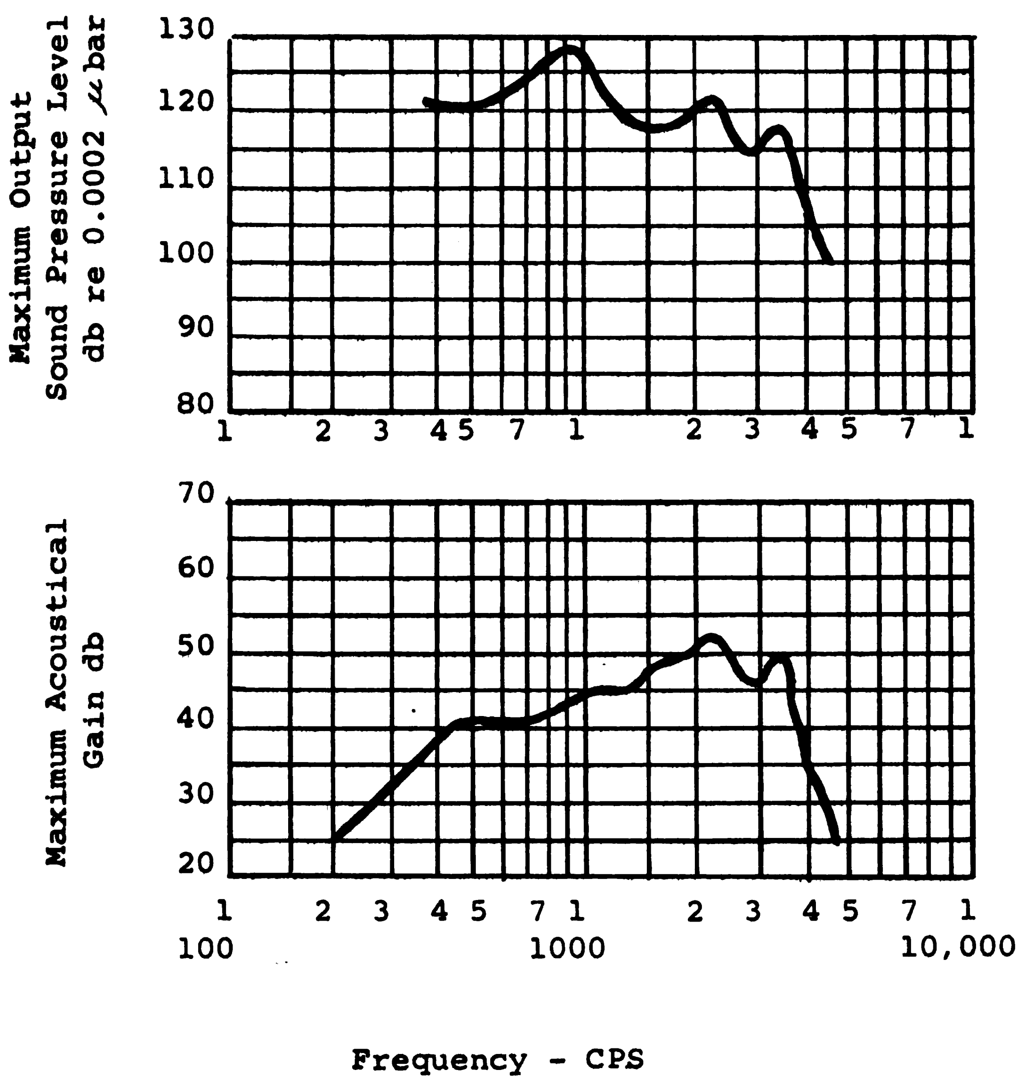
6. Whether the subject is wearing a hearing aid or not, speech discrimination is generally more difficult in a reverberant room with a background of white noise than in a sound-treated room without white noise.

Implications for Future Research

This study has shown several tendencies relating to the effects of amplification on the speech discrimination performance of normal hearing subjects when tested under certain conditions with the CID Auditory Test W-22. It is known that various other environmental conditions affect the hearing of normal hearing people without amplification. However, further research will be needed in order to determine the effects of such conditions when amplification is applied to the normal ear. Information relative to this problem might well be gained from a study similar to the one reported here but carried out in an open field and at greater varying distances from the sound source. It might also incorporate the use of individual ear inserts made for each subject and amplification applied at the Most Comfortable Loudness level for each subject. With information gained from such a study it is felt that more answers might be obtained to the question of how speech discrimination of normal hearing subjects is affected by amplification and, ultimately, how the needs of hard of hearing individuals might best be met as regards amplification and discrimination.

APPENDIX A

Acoustical Characteristics of the Binaural Hearing Aid[1]



[1] Beltone Consultant's Manual, 1961, Section IV, I-5, Page 4. "Bolero Red Dot."

APPENDIX B

C.I.D. AUDITORY TEST W-22 (PB WORD LISTS)

List 1A

1. an
2. yard
3. carve
4. us
5. day
6. toe
7. felt
8. stove
9. hunt
10. ran
11. knees
12. not (knot)
13. mew
14. low
15. owl
16. it
17. she
18. high
19. there (their)
20. earn (urn)
21. twins
22. could
23. what
24. bathe
25. ace
26. you (ewe)
27. as
28. wet
29. chew
30. see (sea)
31. deaf
32. them
33. give
34. true
35. isle (aisle)
36. or (oar)
37. law
38. me
39. none (nun)
40. jam
41. poor
42. him
43. skin
44. east
45. thing
46. dad
47. up
48. bells
49. wire
50. ache

List 2A

1. yore (your)
2. bin (been)
3. way (weigh)
4. chest
5. then
6. ease
7. smart
8. gave
9. pew
10. ice
11. odd
12. knee
13. move
14. new
15. jaw
16. one (won)
17. hit
18. send
19. else
20. tare (tear)
21. does
22. too (two, to)
23. cap
24. with
25. air (heir)
26. and
27. young
28. cars
29. tree
30. dumb
31. that
32. die (dye)
33. show
34. hurt
35. own
36. key
37. oak
38. new (knew)
39. live (verb)
40. off
41. ill
42. rooms
43. ham
44. star
45. eat
46. thin
47. flat
48. will
49. by (buy)
50. ail (ale)

APPENDIX B (Continued)

C.I.D. AUDITORY TEST W-22 (PB WORD LISTS)

List 3A		List 4A	
1. bill	26. aim	1. all (awl)	26. darn
2. add (ad)	27. when	2. wood (would)	27. art
3. west	28. book	3. at	28. will
4. cute	29. tie	4. where	29. dust
5. start	30. do	5. chin	30. toy
6. ears	31. hand	6. they	31. aid
7. tan	32. end	7. dolls	32. than
8. nest	33. shove	8. so (sew)	33. eyes (ayes)
9. say	34. have	9. nuts	34. shoe
10. is	35. owes	10. ought (aught)	35. his
11. out	36. jar	11. in (inn)	36. our (hour)
12. lie (lye)	37. no (know)	12. net	37. men
13. three	38. may	13. my	38. near
14. oil	39. knit	14. leave	39. few
15. king	40. on	15. of	40. jump
16. pie	41. if	16. hang	41. pale (pail)
17. he	42. raw	17. save	42. go
18. smooth	43. glove	18. ear	43. stiff
19. farm	44. ten	19. tea (tee)	44. can
20. this	45. dull	20. cook	45. through (thru)
21. done (dun)	46. though	21. tin	46. clothes
22. use (yews)	47. chair	22. bread (bred)	47. who
23. camp	48. we	23. why	48. bee (be)
24. wool	49. ate (eight)	24. arm	49. yes
25. are	50. year	25. yet	50. am

APPENDIX B (Continued)

C.I.D. AUDITORY TEST W-22 (PB WORD LISTS)

List 1B

1. carve	26. dad
2. wire	27. stove
3. felt	28. ache
4. thing	29. us
5. knees	30. him
6. poor	31. not (knot)
7. owl	32. me
8. law	33. it
9. there (their)	34. see (sea)
10. give	35. earn (urn)
11. what	36. true
12. chew	37. bathe
13. as	38. you (ewe)
14. twins	39. wet
15. isle (aisle)	40. could
16. ace	41. them
17. deaf	42. high
18. she	43. or (oar)
19. none (nun)	44. low
20. new	45. jam
21. skin	46. ran
22. hunt	47. east
23. up	48. toe
24. day	49. bells
25. an	50. yard

List 2B

1. way (weigh)	26. ail (ale)
2. by (buy)	27. chest
3. smart	28. thin
4. eat	29. gave
5. odd	30. rooms
6. ill	31. knee
7. jaw	32. send
8. oak	33. one (won)
9. else	34. hurt
10. show	35. tare (tear)
11. can	36. dumb
12. tree	37. with
13. young	38. and
14. air (heir)	39. cars
15. that	40. too (two, to)
16. does	41. flat
17. own	42. new (knew)
18. hit	43. key
19. live (verb)	44. now
20. more	45. off
21. ham	46. ice
22. pew	47. star
23. die (dye)	48. ease
24. then	49. well
25. yore (your)	50. bin (been)

APPENDIX B (Continued)

C.I.D. AUDITORY TEST W-22 (PB WORD LISTS)

List 3B

1. year	26. west
2. cute	27. ate (eight)
3. though	28. tan
4. hand	29. dull
5. raw	30. out
6. lie (lye)	31. if
7. may	32. king
8. pie	33. no (know)
9. have	34. farm
10. this	35. shove
11. do	36. camp
12. wool	37. tie
13. aim	38. when
14. book	39. are
15. use (yews)	40. ten
16. end	41. done (dun)
17. smooth	42. owes
18. jar	43. he
19. oil	44. knit
20. is	45. nest
21. start	46. glove
22. on	47. say
23. ears	48. chair
24. we	49. bill
25. add (ad)	50. three

List 4B

1. chin	26. wood (would)
2. all (awl)	27. bee (be)
3. who	28. they
4. few	29. dust
5. stiff	30. ought (aught)
6. my	31. jump
7. nuts	32. leave
8. save	33. in (inn)
9. his	34. ear
10. tin	35. than
11. aid	36. bread (bred)
12. yet	37. will
13. art	38. eyes (ayes)
14. so (sew)	39. arm
15. why	40. toy
16. darn	41. cook
17. tea (tee)	42. shoe
18. men	43. hang
19. of	44. near
20. pale (pail)	45. go
21. our (hour)	46. can
22. through(thru)	47. net
23. dolls	48. clothes
24. yes	49. where
25. at	50. am

APPENDIX C

ANSWER SHEET

Name______________Subj. No.______Condition No.______List No. ___

1. ________	21. ________	41. ________
2. ________	22. ________	42. ________
3. ________	23. ________	43. ________
4. ________	24. ________	44. ________
5. ________	25. ________	45. ________
6. ________	26. ________	46. ________
7. ________	27. ________	47. ________
8. ________	28. ________	48. ________
9. ________	29. ________	49. ________
10. ________	30. ________	50. ________
11. ________	31. ________	
12. ________	32. ________	
13. ________	33. ________	
14. ________	34. ________	
15. ________	35. ________	
16. ________	36. ________	
17. ________	37. ________	
18. ________	38. ________	
19. ________	39. ________	
20. ________	40. ________	

APPENDIX D

RAW SCORES PER CENT CORRECT FOR PHASE 1 OF TESTING (REVERBERANT ROOM)

Subject #	Position					
	1		2		3	
	Aided	Unaided	Aided	Unaided	Aided	Unaided
1	6	10	10	24	12	36
2	4	40	8	34	10	40
3	2	18	4	6	16	18
4	10	24	10	26	8	36
5	10	50	2	24	22	26
6	8	28	6	30	8	36
7	16	60	6	46	8	50
8	0	28	10	30	14	30
9	8	38	6	36	10	54
10	2	28	4	20	14	14
11	10	34	10	28	22	34
12	6	34	6	26	6	26

APPENDIX D (Continued)

RAW SCORES PER CENT CORRECT FOR PHASE 2 OF TESTING
(SOUND-TREATED ROOM)

Subject #	Aided	Unaided
1	48	48
2	48	78
3	44	66
4	48	40
5	34	52
6	48	42
7	24	72
8	46	54
9	46	68
10	46	40
11	60	70
12	50	46

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