# DISCRIMINATION BY NORMALLY HEARING SUBJECTS FOR FILTERED SPEECH UNDER CONDITIONS OF HEARING AID AMPLIFICATION

Thesis for the Degree of M. A.

MICHIGAN STATE UNIVERSITY

Constance Rae Walton

1964

THESIS

LIBRARY
Michigan State
University

ABSTRACT

DISCRIMINATION BY NORMALLY HEARING SUBJECTS FOR FILTERED SPEECH UNDER CONDITIONS OF HEARING AID AMPLIFICATION

by Constance Rae Walton

The purpose of this study was to analyze the results obtained from normally hearing subjects as they responded to filtered PB Word Lists under three conditions of amplification by hearing aids. The CID Auditory Test W-22 List 1A was filtered to represent four different hearing loss patterns.

Twenty-four university students participated as subjects for the study. Subjects were randomly assigned to the four different filter patterns, six subjects to each pattern. Each of three conditions of amplification was assigned to two of the subjects under each filter pattern. A screening test for normal discrimination of speech eliminated all subjects whose ability to discriminate was not within the defined limits of normality. Subjects assigned to Condition One listened without a hearing aid to the filtered PB Word List. Subjects assigned to Condition Two listened with a selected hearing aid to the filtered PB Word List. Subjects in Condition Three listened to the filtered PB Word List by means of a randomly-selected

hearing aid. Subjects utilizing a hearing aid adjusted the volume control to the most comfortable loudness level as determined by a recording of continuous speech. The speech signal was presented at 55 decibels (sensation level) for all conditions. Under each condition the subjects responded to the filtered word list and recorded their responses on forms provided for them.

The results of this study showed that in comparing the discrimination scores of normally hearing subjects, a significant difference existed between the filter patterns employed. No significant differences between the discrimination scores were observed, however, for the three conditions of amplification. A very slight difference in favor of the selected hearing aids was observed, but this was not statistically significant.

The conclusion drawn from this study was that there is a significant difference in the speech discrimination scores of normally hearing subjects as a result of listening to PB Word Lists under conditions of four different filter patterns.

# DISCRIMINATION BY NORMALLY HEARING SUBJECTS FOR FILTERED SPEECH UNDER CONDITIONS OF HEARING AID AMPLIFICATION

By

Constance Rae Walton

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF ARTS

Department of Speech

1964

G29932
9/2/04

# TABLE OF CONTENTS

LIST OF TABLES

## LIST OF FIGURES

## LIST OF APPENDICES

CHAPTER I

# STATEMENT OF THE PROBLEM

## Introduction

Auditory communication is the most important function of hearing for modern man,[1] and the loss of it can produce practical difficulties as well as adverse psychological effects. The difficulties resulting from a loss of hearing appear to be somewhat proportional to the severity of the impairment. Those individuals with hearing impairment generally desire to hear and communicate more effectively. Fortunately for some, a hearing aid adequately suits their need. Unfortunately for others, the degree and nature of the loss are such that amplification does not prove useful.

A review of the literature by this writer has indicated a disparity in the information available regarding the effects of amplification on the ability to discriminate. Amplification appears to improve discrimination in some individuals with hearing loss, whereas with others discrimination is reduced with the increased intensity provided

---

[1] Hallowell Davis, "The Articulation Area and the Social Adequacy Index for Hearing," Laryngoscope, 58 (1948), 761.

by a hearing aid. "The first objective of a hearing aid is to make speech intelligible."[1] If this objective is not attained a hearing aid will provide little benefit to the hearing impaired individual insofar as oral communication is concerned.

The ability to discriminate appears to be an important factor in hearing aid selection.

> Since this is a perceptual rather than a sensory function, it becomes extremely important to evaluate disturbances of auditory perception as a specific symptom that often accompanies loss of hearing. . .[2]

> Tests of the ability to understand the spoken word are generally recognized as the most realistic, valid, and (when properly performed) the most sensitive tests of auditory function.[3]

The instrument that provides maximum intelligibility for the suitable hearing aid candidate is generally considered to be the best instrument for him.

Davis feels that the distinction between hearing loss and discrimination loss is fundamental.

> The shift downward (discrimination loss) is due to a failure of sense organ, nerve, or brain. It cannot be offset by mere increase in loudness; but sometimes

---

[1] Hallowell Davis and S. Richard Silverman, _Hearing and Deafness_ (New York: Holt, Rinehart and Winston, Inc., 1960), p. 265.

[2] Otto J. Menzel, "Auditory Discrimination," _Eye, Ear, Nose and Throat Monthly_, 41 (October, 1962), 827.

[3] Hallowell Davis, _et al._, "The Selection of Hearing Aids," _Laryngoscope_, 56 (1946), 144.

> it can be off-set wholly or in part, by psychological factors such as auditory training."[1]

Portmann and Portmann in a discussion on discrimination ability state that,

> It appears theoretically difficult that a hearing aid should be able to procure better discrimination than the ear itself, especially as one interposes an amplification which can deform words. However, very often testing proves that the hearing aid is capable of improving the selective power of the different phonetic elements.[2]

Studies directed toward the selection of hearing aids (to be discussed in Chapter II) have been made in an attempt to determine those frequency response characteristics that are best suited for the hearing impaired individual. Generally the subjects for those studies have been persons with hearing losses. It appears that additional information on ability to discriminate might be obtained by providing amplification via a hearing aid to a normal ear. By presenting phonetically balanced word lists which have been filtered to approximate the frequency distortion typical of several hearing loss patterns, an objective evaluation could be made of the effects of amplification with regard to frequency distortion. Other factors of distortion present in the pathological ear, therefore, would not be influential.

---

[1]Davis, op. cit., 768.

[2]Michael Portmann and Claudine Portmann, Clinical Audiometry (Springfield, Illinois: Charles C. Thomas, 1961), p. 294.

## Purpose of the Study

The purpose of this study was to analyze and compare the results obtained from normally hearing subjects as they responded to the CID Auditory Test W-22 List 1A under the conditions of amplification as follows: (a) no hearing aid, (b) a selected hearing aid, (c) a randomly-selected hearing aid. The test lists were filtered to approximate the frequency distortion typical of several hearing loss patterns. From this analysis it was hoped that it might be determined whether the speech discrimination performance of normally hearing subjects for filtered word lists could be improved with amplification by a hearing aid and, if so, to what degree. The following null hypotheses were formulated:

1. There is no difference in discrimination scores among normally hearing subjects due to filter patterns (see Appendix A).
2. There is no difference in discrimination scores among normally hearing subjects due to the following different conditions of amplification:
    (a) no hearing aid--listening to filtered Phonetically Balanced (PB) Word Lists.
    (b) a selected hearing aid--listening to filtered PB Word Lists with a selected hearing aid (see Appendix B).

(c) a randomly-selected hearing aid--listening to filtered PB Word Lists with a randomly-selected hearing aid (see Appendix C).

3. There is no difference in the discrimination scores of normally hearing subjects due to interaction of filter patterns by conditions of amplification.

## Importance of the Study

This study is considered to be important in that it may yield information that will be helpful to those who conduct hearing aid evaluations and counsel the hearing aid wearer.

Since auditory communication is the primary function of hearing in man,[1] the significance of assessing the ability to discriminate in the hard of hearing individual becomes apparent. If it is determined that certain means of amplification prove more useful to the ability to discriminate than others, then it follows that these means should be utilized by the hard of hearing individual to improve his discrimination performance.

By assessing the ability of normally hearing subjects for discrimination of filtered word lists, other distortion factors present in the pathological ear are eliminated permitting an objective evaluation of the performance of

[1]Davis, op. cit.

several conditions of amplification. Any observed differences in the subjects' ability to discriminate should be the result of the effects of amplification of a selected band of frequencies by the hearing aid and not the function of distortion factors present in the hearing impaired ear.

## Definition of Terms

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

Amplification.--To increase the intensity of sound, in this case by means of a hearing aid.

Normally hearing subjects.--Persons who are able to attain a discrimination score of 94% or better monaurally. The CID Auditory Test W-22, Lists 3A and 3B were presented as the speech signal at 55 decibels sensation level, sound field, and with 55 decibels effective masking (saw tooth noise) in the contralateral ear.

CID Auditory Test W-22.--A discrimination test consisting of four lists of 50 phonetically balanced one-syllable words. These words are usually presented to the patient at a level above his speech reception threshold and are available in recorded form.[1]

Speech discrimination test.--A test which allows for evaluation of a patient's ability to differentiate among

---

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

acoustically similar sounds or among words that contain acoustically similar sounds. The experimenter uses the terms "discrimination" and "intelligibility" interchangeably for the purpose of this study.

Filter.--An electrical network composed of reactive elements used for attenuating or removing a given band or audio frequencies.[1]

Filter pattern.--The characteristic response of the output signal from the filter-attenuator system.

Frequency response.--"Frequency response is the relative acoustic gain of the hearing aid expressed as a function of the frequency."[2]

Randomly-selected hearing aids.--Hearing aids with different frequency response characteristics selected randomly from the clinic stock without regard to specific response characteristics, acoustic gain, maximum output, etc.

Selected hearing aids.--Hearing aids selected by the experimenter. An effort was made to compensate for the frequency distortion of the subject's filter pattern by choosing the instrument that selectively amplified those frequencies for which the intensity was most distorted by filtering.

---

[1] "Filter," Audio Cyclopedia (Indianapolis 6, Indiana: Howard W. Sams and Co., Inc., 1959).

[2] "Methods for Measurement of Electroacoustical Characteristics of Hearing Aids," American Standards Association Bulletin, S3.3 (1960), 7-15.

## Organization of the Study

Chapter I contained the statement of the problem that led to this study. An introduction to the topic and an outline of the purpose of the study were included. Hypotheses were stated that were to be considered in this study, the importance of the study was discussed, and terms to be used were defined.

Chapter II contains a review of the literature pertinent to this topic, and Chapter III consists of a discussion of the subjects. Equipment, materials, and testing procedures utilized in this study are also within Chapter III. Chapter IV discusses the results of the study, and Chapter V contains the summary and conclusions. Implications for further research are also discussed in the final chapter.

# CHAPTER II

## REVIEW OF THE LITERATURE

Clinical hearing aid evaluations are performed to guide the hard of hearing in the selection of an aid. Differences exist in the way such evaluations are conducted. Generally, however, differences among aids are sought with respect to speech discrimination, gain, tolerance, and noise thresholds.[1]

In 1949 Carhart suggested that more time than is necessary is being spent in the testing of several aids on each individual seen for a hearing aid evaluation. ". . . the time should come when otology is exerting positive guidance by referring problem cases to hearing clinics and other cases directly to reputable dealers."[2]

Shore, Bilger, and Hirsh reported that:

> . . .most of the adults seen at the hearing clinic at Central Institute for the Deaf appear not to require the extensive evaluation they receive, and we find that a good many of our hearing-aid recommendations are made on the basis of non-auditory factors like price, size and availability of service.[3]

---

[1]Irvin Shore, Robert C. Bilger, and Ira J. Hirsh, "Hearing Aid Evaluation: Reliability of Repeated Measurements," Journal of Speech and Hearing Disorders, 25 (1960), 152.

[2]Raymond Carhart, "Hearing Aid Selection by University Clinics," Journal of Speech and Hearing Disorders, 15 (1950), 112.

[3]Shore, Bilger, and Hirsh, *op. cit.*

An investigation of procedures in other hearing clinics might well indicate similar practices.

Several studies have been reported in the literature concerning hearing aid selection. The studies reported in this chapter include only those where monaural aids were under consideration.

At the Tenth Anniversary Meeting of the Acoustical Society of America in 1939, Knudsen alluded to results of tests performed in the hearing laboratory at University of California. These, he stated, showed not only the value of high quality amplification but also the advantage of selective amplification in certain cases.[1]

In 1940 Watson and Knudsen tested listening intelligibility of hearing impaired individuals using both uniform and selective amplification. Conclusions of their study were that, ". . .the superiority of properly prescribed selective amplification over uniform is greater for ears with perceptive impairment than for those with conductive impairment."[2] They also suggested tentative criteria to determine whether or not to prescribe selective amplification as well as how to prescribe it. These criteria were:

---

[1] Vern O. Knudsen, "An Ear to the Future," The Journal of the Acoustical Society of America, 11 (July, 1939), 30.

[2] N. A. Watson and V. O. Knudsen, "Selective Amplification in Hearing Aids," The Journal of the Acoustical Society of America, 11 (April, 1940), 418.

> 1. Determine the air and bone conduction threshold curves and the air conduction hearing loss for speech at threshold.
>
> 2. Determine the most comfortable level above threshold for listening to speech; take several articulation lists at this level, and from these calculate the corresponding percentage syllable articulation; find the hearing loss for speech (in decibels) at this most comfortable level by comparison with the normal curve. . . .
>
> 3. If the hearing loss for speech at the most comfortable level is approximately equal to the hearing loss for speech at threshold, prescribe uniform amplification. . . .
>
> 4. If the hearing loss for speech at the most comfortable level is less than the hearing loss for speech at threshold, prescribe selective amplification by means of the criterion based on the "most comfortable equal loudness curve" . . . .
>
> 5. If the hearing loss for speech at the most comfortable level is appreciably greater than the hearing loss for speech at threshold, prescribe selective amplification by means of the criterion based on the "most comfortable equal loudness curve" . . . .[1]

Perhaps one of the most revolutionary studies involving the transmission of speech by hearing aids was that of the Psychoacoustic Laboratory at Harvard University. Known as the "Harvard Report," this study was concerned with the ". . .theoretical analysis of the general problem of 'fitting' a hearing aid, and a critique of several present and proposed 'fitting' procedures."[2]

---

[1]Ibid.

[2]Davis et al., op. cit., p. 86.

The relative value of several widely different patterns of frequency response characteristics was obtained for 25 hard of hearing ears by means of a Master Hearing Aid.

> The patterns which yielded the best results were found to bear very little relation either to the subject's audiogram or to an equal-loudness contour. Even if the audiogram was used only as a general guide to determine whether or not additional amplification should be provided for high frequency, it proved actually misleading in several instances. On the other hand, a particular set of frequency-response patterns proved uniformly successful for all ears tested. These results, definitely contrary to the original expectations of the experimenters, seem to show that it is possible to specify the desirable frequency characteristics of a hearing aid more successfully by a simple general rule than by an interpretation of the patient's audiogram.
> . . . . . . . . . . . . . . . . . . . . . . . . . .
> Experimental evidence seems to show that the principle of 'selective amplification' to compensate for impairment of hearing is fallacious.[1]

The authors concluded that,

> The appropriate frequency characteristic for a hearing aid is not correctly indicated by current principles of 'audiogram fitting' or 'selective amplification.' A uniform frequency characteristic that can be varied by a tone control between 'flat' and a moderate accentuation of high tones will provide the most satisfactory performance for all or nearly all cases of hearing loss.[2]

Davis and others studied appropriate design objectives for the construction of hearing aids. Using a Master Hearing Aid on 18 hard of hearing subjects, the relative value of the various frequency patterns for each of these selected ears was determined.

---

[1] _Ibid._, p. 102-103.

[2] _Ibid._, p. 87.

> The consistent superiority of moderate high-tone emphasis in making speech intelligible to hard-of-hearing ears disproves the popular theory that the best frequency pattern for a hearing aid is one which compensates for a patient's individual hearing loss by 'mirroring' his audiogram. . . . As a practical matter, the best choice for all ears lies only between a flat pattern and moderate high-tone emphasis.[1]

In 1948 Hudgins _et al_. studied the problem of design objectives in a portable hearing aid. The experimental hearing aid incorporated most of the desirable features emphasized from previous studies. Its performance on a group of six hard-of-hearing persons was compared with the performance of a Master Hearing Aid and two representative commercial hearing aids. Test materials consisted of phonetically balanced word lists which were presented with static noise in a signal to noise ratio of +15 to +20. Articulation curves for the subjects were derived for all instruments.

Results of this study confirmed the findings of the previous experimental study in that all types of hard-of-hearing subjects performed better with an instrument that provided adequate gain and a relatively broad, flat, high-fidelity frequency response.[2]

---

[1]Hallowell Davis _et al_., _Hearing Aids: An Experi-Study of Design Objectives_ (Cambridge, Massachusetts: Harvard University Press, 1947), p. 6.

[2]C. V. Hudgins _et al_., "The Comparative Performance of an Experimental Hearing Aid and Two Commercial Instruments," _The Journal of the Acoustical Society of America_, 20 (May, 1948), 241-254.

A study by Shore, Bilger, and Hirsh concerned possible significant differences in using different hearing aids, different tone settings, and different testing days on 15 hard-of-hearing patients. The subjects all had mild to moderate hearing losses in three diagnostic categories: conductive, mixed, and sensory-neural.

Eight specific combinations of four body-type hearing aids with two tone settings were tested on each subject on each of four testing days. The auditory measures of gain, or residual hearing level for speech, speech discrimination in quiet, and speech discrimination in noise were analyzed statistically for each patient.

Results indicated that,

> . . .differences attributable to different hearing aids occur most often for gain. . .less often for discrimination in quiet. . .and not at all for discrimination in noise. . . .It is concluded that the reliability of these measures is not good enough to warrant the investment of a large amount of clinical time with them in selecting hearing aids.[1]

Jeffers investigated quality judgments as a criterion in hearing aid selection. Five hearing aids arranged in pairs were tested on 32 subjects with conductive type hearing losses. Subjects listened to one-minute speech recordings and were asked to list the preferred hearing aid which transmitted the best quality for him.

---

[1] Shore, Bilger, and Hirsh, op. cit., p. 167.

Results of her study showed that, ". . .(1) the 'typical' acoustic differences in the hearing aids were sufficient to result in real differences in the quality of the reproduced speech and (2) that the subjects were excellent judges of these differences."[1]

Jerger, Carhart, and Dirks tested the speech intelligibility of 48 subjects with bilateral sensorineural hearing loss. The following conditions of amplification were employed: (a) binaural, (b) monaural-head, and (c) monaural-body. Two listening conditions were imposed. In the first condition, the subject heard 50 PB words through one loudspeaker while, simultaneously, 50 sentences from the Bell Telephone Intelligibility Lists were heard through another loudspeaker. The subject was asked to repeat back each of the 50 words to the experimenter. In the second listening condition, 30 questions and commands were heard from one loud speaker and continuous discourse from the other. The primary signal shifted in an unpredictable fashion from one loudspeaker to another to create a relatively unstable listening condition.

Subjects were tested individually and the order of the successive amplification conditions was counterbalanced from one subject to the next. In general, the results

---

[1]Janet Jeffers, "Quality Judgment in Hearing Aid Selection," Journal of Speech and Hearing Disorders, 25 (1960), 266.

failed to demonstrate any appreciable advantage of binaural hearing-aid amplification over monaural amplification for these specific listening conditions.[1]

One of the more recent studies in hearing aid selection is that carried out by Zerlin. Zerlin's study involved the recording of hearing-aid outputs onto dual-channel magnetic tape. By using the method of paired comparisons, the listener was able to compare two aids at a time.

Running speech in the presence of cafeteria noise was fed into six different hearing aids as well as half-lists of the CID W-22 recordings of PB Word Lists. Hard-of-hearing subjects listened to each set of two aids and made a paired-comparisons choice. This ultimately generated a rank-ordered preference series for all six aids. "It was noted that while the intelligibility score results did not differentiate among the aids, preference scores based on the paired comparisons yielded clear-cut discriminations among five of the six."[2]

One of the most recent studies reported is that of Shore and Kramer. They devised a new testing procedure

---

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

[2]Stanley Zerlin, "New Approach to Hearing Aid Selection," Journal of Speech and Hearing Research, 5 (1962) 375-376.

consisting mainly of audiometric testing and counseling without the recommendation of a specific aid. Questionnaires were mailed to two groups of people, those for whom a specific hearing aid had been recommended and those for whom such a recommendation had not been made. Replies were statistically analyzed to note any significant differences between the two groups.

> The two groups were statistically different on only a few items of the questionnaire. . . .The authors conclude that evidence from this study as well as the experience with the new testing procedure suggest the recommendation of this procedure."[1]

## Frequency Distortion and Intelligibility

A great deal of research has been reported in the literature with regard to the effects of distortion upon the intelligibility of speech. Steinberg reports that,

> The waves of speech sounds are characterized by three quantities, amplitude, frequency and phase, all three of which are essential to the correct recognition of the sounds by an auditor. In general, the term distortion refers to relative changes in one or more of these quantities, in the process of transmitting the sound waves from speaker to auditor.[2]

---

[1] Irvin Shore and Joan C. Kramer, "A Comparison of Two Procedures for Hearing Aid Selection," Journal of Speech and Hearing Disorders, 28 (May, 1963) 165.

[2] John C. Steinberg, "Effects of Distortion Upon the Recognition of Speech Sounds," The Journal of the Acoustical Society of America, 1 (1929) 121.

It follows that if speech is distorted in any one or more of the three quantities mentioned by Steinberg, particularly amplitude and frequency, the discrimination of the auditor will be affected. The following summary reviews the literature with regard to frequency distortion and intelligibility of speech.

In order to determine the importance of various frequency ranges, Steinberg filtered portions of speech using two sets of low-pass and high-pass filters. The effects of frequency distortion upon articulation was tested by changing the cut-off frequency of these filters over the speech frequency range. Conclusions showed that, ". . .for the case of syllable articulation, which involves all of the speech sounds, this range extends from about 200 cps to 8000 cps. Each of the various groups of sounds does not require this whole range."[1] It was observed that in the case of the stop and fricative consonants,

> . . .the high pass filter tests indicate that these sounds have no frequencies of very great importance below 1000 cycles. However, when all frequencies above 1000 cycles are eliminated, (low-pass filter tests), articulations of an order of 50-70% are obtained, which appears inconsistent with the high-pass filter tests.[2]

---

[1] Ibid., p. 128.

[2] Ibid., p. 129.

Pollack attempted to determine the intelligibility of various ranges of low and high speech frequencies against a background of white noise. Standardized articulation testing procedures were utilized. Low-pass and high-pass filters were employed to remove various frequency ranges. Two trained talkers read lists of monosyllabic words to nine experienced listeners.

Results of this study indicated that, in general, ". . .speech intelligibility increased as (1) the intensity level of the speech signal and (2) the frequency range were increased."[1] It was observed that the contribution of the higher speech frequencies and very low speech frequencies alone was very small. When only those frequencies above 2375 cps were passed,

> . . .intelligibility in terms of word articulation was a bare 5% at maximal gain. . . .practically no words were recognized when the frequencies below 425 cps alone were heard.[2]

Closely related to Pollack's investigation of intelligibility of filtered speech in noise is that of Egan and Weiner' study. Egan and Weiner conducted articulation tests using a large number of communication

---

[1]Irwin Pollack, "Effects of High Pass and Low Pass Filtering on the Intelligibility of Speech in Noise," The Journal of the Acoustical Society of America, 20 (May, (1948), 262.

[2]*Ibid.*, p. 263.

systems having band widths ranging from about one-half octave to a system covering the entire range of speech frequencies. Two spectra of masking noise were used, and each system was tested over a wide range of speech-to-noise ratios. The speech was filtered before mixing with noise in one group of experiments and in the other both speech and noise were passed through the filter. For each of the band-pass systems a relation between syllable articulation and level of received speech was obtained. Families of equal articulation contours were derived from these gain functions. These contours showed how the gain had to be changed for a given change in the band width in order to maintain a constant articulation score.[1]

Studies have been reported in the literature on frequency and amplitude distortion with respect to intelligibility. Pollack investigated the combined effects of these two variables on the intelligibility of speech in noise. The recorded Psychoacoustic Laboratory PB Word Lists were subjected to sharp cut-off filtering, then to infinite peak clipping. The lists were then filtered again and mixed electrically with masking noise

---

[1]James P. Egan and Francis M. Wiener, "On the Intelligibility of Bands of Speech in Noise," The Journal of the Acoustical Society of America, 18 (October, 1946), 435.

and presented to earphones. Listeners responded to the distorted speech signal and the percentage of correct words was used to determine the intelligibility of speech. Results reported by Pollack were that,

> The intelligibility of unclipped speech, relative to that of the peak-clipped signal under corresponding experimental conditions, is a function of the signal-to-noise ratio under test and is, to a rough approximation, independent of the frequency range of the speech signal passed. At high S/N ratios, the intelligibility of the unclipped speech signal is higher than that of the severely peak-clipped signal. Under low S/N ratios, however, the intelligibility of the latter is considerably higher than that of the unclipped signal.[1]

In the early 1950's Hirsh, Reynolds, and Joseph reported an investigation where speech material was presented under two conditions: filtering and masking by white noise. Listeners were six male college students. The authors determined that most of the speech frequencies had to be eliminated before intelligibility of any kind of speech material is seriously impaired. When frequencies below 3200 cps were eliminated articulation scores decreased noticeably. Under low-pass filter conditions, it is only when all the frequencies above 800 cps are eliminated that the articulation decreases rapidly from its maximum.[2]

---

[1]Irwin Pollack, "On the Effects of Frequency and Amplitude Distortion on the Intelligibility of Speech in Noise." The Journal of the Acoustical Society of America, 24 (September, 1952), 538-540.

[2]I. J. Hirsh, Elizabeth G. Reynolds, and Maurice Joseph, "Intelligibility of Different Speech Materials," The Journal of the Acoustical Society of America, 26 (1954), 530-538.

Owens studied the relationship between word familiarity and intelligibility. He used seven monosyllabic word lists divided into groups of three, two and two, each group list being matched phonetically and varied systematically with respect to familiarity acccrding to the Lorge count. Each list was recorded under seven conditions of distortion achieved by low pass filtering and presented auditorily to seven listener groups of 30 college students each. Each group listened to all seven lists under a single condition of frequency distortion. The continuous, although irregular, increase in discrimination errors on all lists as frequency distortion became greater, illustrated the basic importance of the phonetic elements. As sounds were eliminated, attenuated, or distorted, all words were more difficult to discriminate.

The author concluded that although word familiarity played an important part in the discrimination of speech, phonetic content remained the dominant factor. Owens tenuously related the filter settings in his study and high frequency hearing loss. He generalized that a person with such a loss would have noticeably more difficulty discriminating speech sounds to the extent that frequencies below 1560 cps were involved.[1]

---

[1]Elmer Owens, "Intelligibility of Words Varying in Familiarity," Journal of Speech and Hearing Research, 4 (1961), 113-129.

In 1963 Giolas and Epstein compared the intelligibility scores for monosyllabic word lists with a sample of continuous discourse. The sample of continuous discourse and four word lists were reproduced on magnetic tape under seven conditions of filtering. One hundred and seventy-five normally hearing subjects served as listeners for the study. W-22 word lists yielded consistently higher scores than did the PB-50 Word Lists. In all situations, however, errors increased as distortion increased.[1]

## Summary

An overall view of the literature concerning hearing aid evaluations reveals that prior to 1946, the concept of selective amplification was predominant in the selection of hearing aids. The "Harvard Report" resulting from studies at the Psychoacoustic Laboratory at Harvard University proved revolutionary in refuting this concept. This study, also supported by further investigations, showed that a hearing aid with a relatively flat frequency response provided the most satisfactory performance for nearly all cases of hearing loss.

---

[1]Thomas G. Giolas and Aubrey Epstein, "Comparative Intelligibility of Word Lists and Continuous Discourse," Journal of Speech and Hearing Research, 6 (December, 1963), 357.

With regard to frequency distortion and listener intelligibility a general trend is evident in the literature. As the frequency distortion increases, subjects' ability to discriminate decreases. However, most of the speech frequencies must be eliminated before the ability to discriminate is severely impaired. The very high frequencies and very low frequencies appear to contribute very little to the intelligibility of speech.

# CHAPTER III

## SUBJECTS, EQUIPMENT, MATERIALS AND TESTING PROCEDURES

### Subjects

Twenty-four university students, 12 females and 12 males, were subjects for this study. It was determined audiometrically that each subject had normal hearing. A criterion in selection of subjects was that all subjects attain a discrimination score of 94% or better monaurally, sound field, at 55 decibels (sensation level). Fifty-five decibels effective masking (saw tooth noise) was introduced into the contralateral ear. Subjects responded to the CID Auditory Test W-22 Lists 3A and 3B. The age of the subjects ranged from twenty-one to thirty-two years, and all had four or more years of college education.

### Equipment

The following equipment was employed for the purpose of this investigation:

Four body-type randomly-selected hearing aids

Four body-type selected hearing aids

Plastic ear inserts of general sizes

Four band-pass filters (Model 25 Allison, Serial numbers 116, 117, 118, and 119.

One tape recorder (Ampex Model 601, Serial 2204)

One Thorens turntable and tonearm

Four Hewlett-Packard attenuators (Model 350A, Serial numbers 00305340, 00304345, 00305347, and 00305363)

Testing suite (dimensions 7'5" by 9'6")

Allison audiometer (Model 20B, serial 13)

Beltone audiometer (Model 12A, SD 1102)

One Bruel and Kjær sound level meter (Model 2203, serial number 94578)

One Bruel and Kjær volt meter (Model 2409, serial number 63297)

## Materials

The materials utilized in this study consisted of:

Magnetic tapes (3M 202)

CID Auditory Test W-22 recording (Lists 1A, 3A, and 3B)

Continuous speech--Fulton Lewis, Jr. recording

Forms for the recording of subject's responses (see Appendix D)

## Procedure

Preliminary procedures.--A 1000 cps calibration tone was recorded at the beginning of each tape in order that the speech stimulus could be presented at the same level to all subjects.

The recorded CID Auditory Test W-22 List 1A was played on the turntable. The signal was introduced to four different band-pass, filter-attenuator systems. The slope at the cut-off points was approximately 30 decibels per octave. The signals were than recombined and reproduced on magnetic tape.

The attenuators reduced the signal so that the filtered band fell on the threshold of intensity represented by typical hearing loss patterns (see Appendix A). The filter permitted a band of frequencies to be filtered to approximate the level of the band of frequencies represented on the audiogram form. The out-put meter recorded the intensity of the recombined signal and served as a means of checking the desired intensity of the filtered bands (see Figure 1. for a block diagram of arrangement of equipment).

The procedure was followed for the filtering patterns of four typical hearing loss patterns. A recording of continuous discourse by Fulton Lewis, Jr. was also passed through the filter four times to correspond to each of the W-22 word list filter patterns.

Forms for the recording of the subjects' responses were devised by the examiner and are included in Appendix D.

Testing procedure.--The following testing procedure was established.

The 24 subjects were divided according to a table of random numbers[1] into four groups of six subjects each, group

---

[1]Herbert Arkin and Raymond R. Colton, Tables for Statistics (New York: Barnes and Noble, Inc., 1950), p. 142.

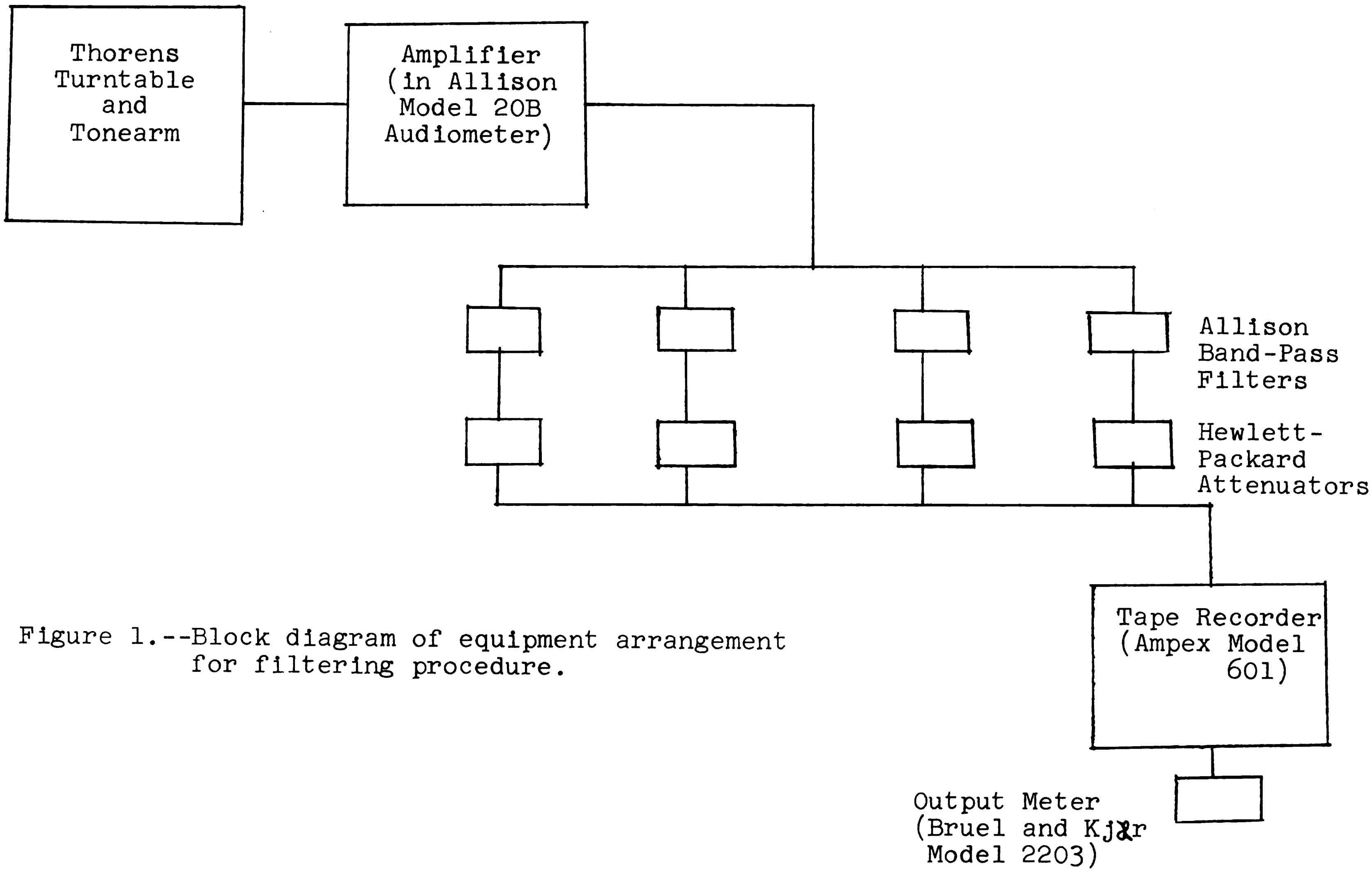



Figure 1.--Block diagram of equipment arrangement for filtering procedure.

one being assigned to filter pattern one, group two to filter pattern two, group three to filter pattern three, and group four to filter pattern four (see Appendix E). Each filter pattern was subjected to three conditions of amplification by hearing aids: (a) no amplification; (b) selected amplification; and (c) randomly-selected amplification. Two subjects, therefore, were assigned to each of the three conditions for each filter pattern (see Appendix F). Prior to testing the sound level meter was used to check the intensity of the ambient noise level in the testing suite before the speech signal was presented to the subject. This level varied from 44 to 52 decibels (re. 0.0002 dynes/$cm^2$, "C" scale) for the 24 subjects throughout the entire testing procedure. In addition, each subject who was tested under a condition requiring a hearing aid was fitted with an individual ear insert of general size ranging from small to large.

The instructions given to each subject were as follows:

> You will be listening to lists of words which have some of the phonetic elements removed through filtering. You are to listen to each word as it is said and write what you think the word is on the score sheet given to you. If you should miss a word entirely put an "X" on the space provided for that word.

Subjects who listened to the filtered word lists with amplification of a hearing aid were given these additional directions:

> You will be listening to a sample of conversational speech which has some of the phonetic elements filtered out of it. You are to adjust the volume control of your hearing aid to a level which provides a comfortable loudness for you to hear the conversation. You may not be able to understand the conversation, however do not be concerned with this aspect. Merely adjust the volume to a comfortable listening level.

The following criteria were proposed for selection of subjects in each group: Each subject was screened individually in order to meet the criterion established for a normally hearing individual. In each case the ear to be tested was that of the subject's choice.

Condition One testing.--In order to determine the discrimination ability of normally hearing subjects for the filtered word lists without amplification, each subject listened unaided to the CID Auditory Test W-22 List 1A. The filter pattern employed was that to which the subject was assigned.

Testing was carried out in a sound-treated room at Michigan State University. Each subject was tested individually and was seated a distance of eight feet from the loudspeaker of the Allison audiometer. Fifty-five decibels, effective masking (saw-tooth noise) from the Beltone 12 A audiometer, was introduced into the contralateral ear for masking.

The calibration tone of the tapes of the filtered CID lists as each was presented was set at 55 decibels (sensation level). The subject listened monaurally in sound-field to the filtered word list. Responses were recorded by the subject as the list was presented to him.

Condition Two testing.--In order to determine the effects of selected amplification on the discrimination ability of normally hearing subjects for the filtered word lists, the subjects listened with a selected hearing aid to the filtered CID Auditory Test W-22 List 1A. As in Condition One, the filter pattern employed was that to which the subject had been assigned. The hearing aids had been previously selected by the examiner on the basis of a relationship between the frequency response characteristics of the hearing aids and the filter patterns created by the filtering process. An effort was made to compensate for the particular frequency distortion created by the filtering by choosing an instrument that selectively amplified those frequencies which were removed or attenuated by the filtering process.

As in Condition One, subjects were tested individually in sound-field in the sound treated room at Michigan State University. A 55 decibel saw-tooth noise was introduced into the contralateral ear for masking. The calibration tone of the Fulton Lewis, Jr. tape was set at 55 decibels (sensation level), and the subject was instructed to adjust his hearing aid to a comfortable loudness level while listening to the tape. The tape was also filtered to correspond to the filter pattern assigned to the subject.

After the subject had adjusted his aid to a comfortable loudness level, the filtered CID Auditory Test W-22 List 1A was presented to him. The calibration tone of this tape was set at 55 decibels (sensation level), and the subject was instructed to record his responses on the form given to him.

Condition Three testing.--In order to determine the effects of randomly-selected hearing aids on the discrimination ability of normally hearing subjects for the filtered word lists, a randomly-selected instrument was employed. The subject listened and responded to the filtered CID Auditory Test W-22 List 1A corresponding to the filter pattern to which he was assigned. Identical conditions prevailed as in Condition Two except that the subjects listened with the randomly-selected hearing aid.

## Summary

In order to study the effects of amplification on normally hearing subjects while responding to filtered PB Word Lists, the following procedure was employed.

The subjects were randomly assigned to a specific filter pattern and a specific condition of amplification within the pattern. The three possible conditions of amplification employed were: (a) no hearing aid, (b) a selected hearing aid, and (c) a randomly-selected hearing aid. Subjects then listened to the word list corresponding to the filter pattern to which they were assigned and responded on the forms provided them by the examiner.

# CHAPTER IV

# RESULTS AND DISCUSSION

## Introduction

The data for this study were obtained by analyzing subjects' discrimination scores under the three conditions of amplification and four filtering patterns. The null hypotheses under investigation were:

1. There is no difference in discrimination scores among normally hearing subjects due to filter patterns (see Appendix A).
2. There is no difference in discrimination scores among normally hearing subjects due to the following conditions of amplification:
   (a) no hearing aid--listening to filtered Phonetically Balanced (PB) Word Lists.
   (b) a selected hearing aid--listening to filtered PB Word Lists with a selected hearing aid (see Appendix B).
   (c) a randomly-selected hearing aid--listening to filtered PB Word Lists with a randomly-selected hearing aid (see Appendix C).

3. There is no difference in the discrimination scores among normally hearing subjects due to interaction of filter patterns by conditions of amplification.

Appendix F contains a summary of the raw data obtained from the subjects. Since it was the desire of the investigator to determine if any significant differences existed among the discrimination scores, a two-way analysis of variance was done. The design employed is described by Blalock.[1]

Statistical analysis of the results is summarized in Table I. There is a significant difference in discrimination scores at the .01 level of confidence between the filter patterns used. An F of 5.95 or larger was necessary in order to attain significance at the .01 level. The F attained by this analysis was 47.51. This indicates that the first hypothesis can be rejected at below the .01 level of confidence. The second hypothesis states that there is no difference among discrimination scores of normally hearing subjects due to the conditions of amplification employed for the filtered word lists. An examination of Table I indicates that the second hypothesis cannot be rejected. The analysis of interaction between filter

---

[1]Hubert M. Blalock, Jr., <u>Social Statistics</u> (New York: McGraw-Hill Book Company, Inc., 1960), p. 253.

TABLE I

SUMMARY FOR ANALYSIS OF VARIANCE

| Treatments | Sum of Squares | df | Mean Square | F |
|---|---|---|---|---|
| Filter Patterns (F) | 24,965.83 | 3 | 8,321.94 | 47.51* |
| Amplification Conditions (A) | 182.33 | 2 | 91.16 | -----** |
| F x A | 1,161.67 | 6 | 193.61 | 1.10*** |
| Error (Within treatments) | 2,102.00 | 12 | 175.17 | |
| Total | 28,411.83 | 23 | | |

*With df of 3 and 12 an F of 5.95 is required for significance at the .01 level of confidence.

**With df of 2 and 12 an F of 6.93 is required for significance at the .01 level of confidence.

***With df of 6 and 12 an F of 4.82 is required for significance at the .01 level of confidence.

patterns and conditions of amplification also reveals no significant F. This indicates that the third hypothesis of no interaction is not rejected.

## Discussion

The analysis of the data showed that the first null hypothesis was rejected. This hypothesis concerned the discrimination scores of normally hearing subjects for the four different filter patterns employed (see Figure 2). These results support the findings of Pollack, Owens, and Giolas and Epstein as reviewed in Chapter II. As frequency distortion is increased errors in discrimination seem to increase also. Analysis of Figure 2 and Appendix A shows that when all frequencies above 250 cps are eliminated, subjects obtained a mean discrimination score of less than one per cent. A study by French and Steinberg demonstrated similar results. From this study they derived articulation curves based on a computational formula showing the relationship between the speech components and intelligibility.[1]

When a relatively uniform filter pattern for all frequencies was employed in the present investigation, subjects were able to attain a mean discrimination score

---

[1] N. R. French and J. C. Steinberg, "Factors Governing the Intelligibility of Speech Sounds," The Journal of the Acoustical Society of America, 19 (January, 1947), 90.

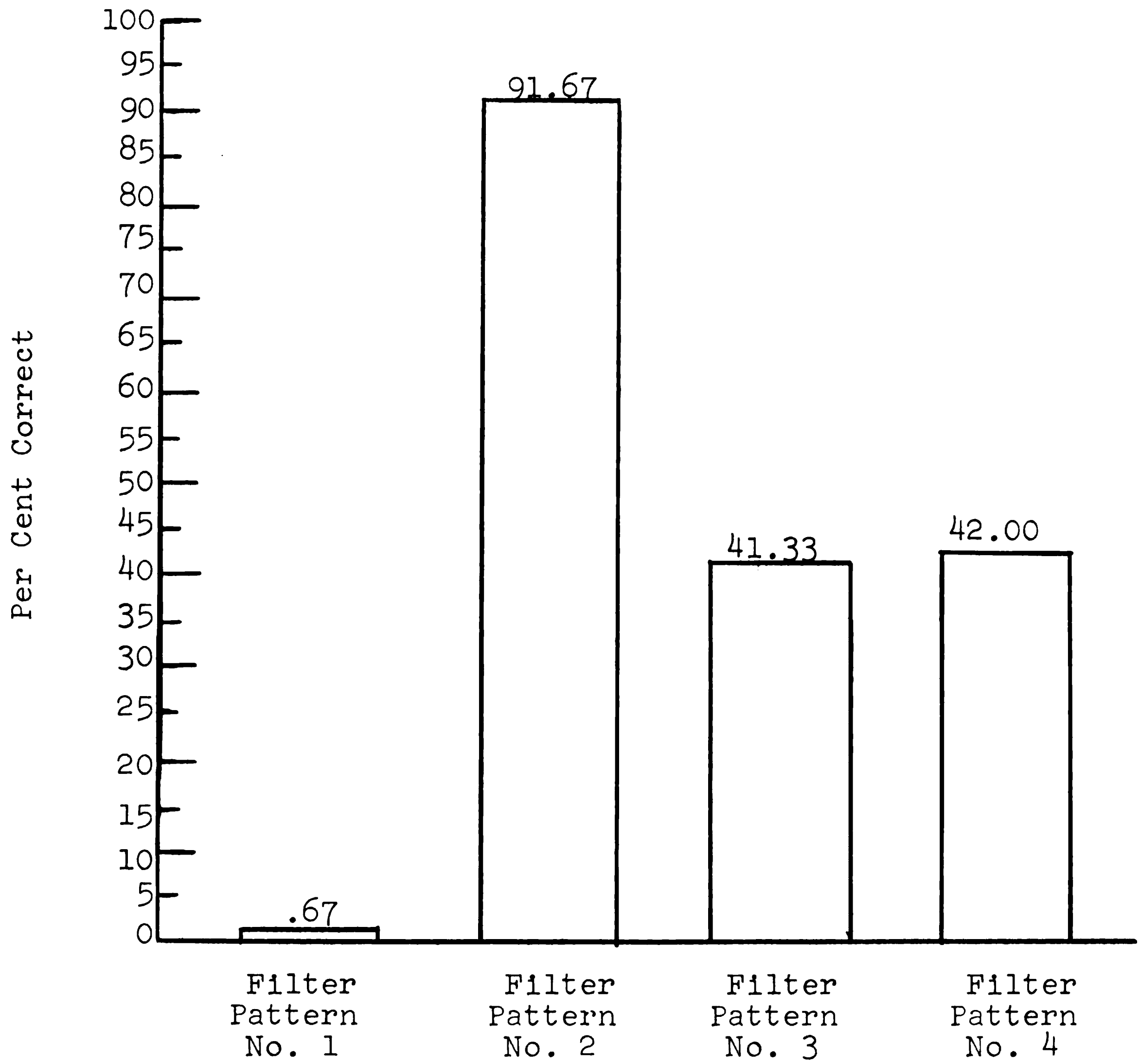



Figure 2.--Mean Per Cent Scores for Filter Patterns.

of approximately 92 per cent (see filter pattern-number 2, Appendix A). Filter pattern number four (Appendix A) yielded a mean discrimination score of 42 per cent for normally hearing subjects. This is somewhat lower than what might be expected in that only the frequencies above 3000 cps were distorted most by the filtering process. These results also compared with French and Steinberg's.[1]

Filter pattern number three yielded a mean discrimination score of approximately 42 per cent. This pattern followed a gradual slope above 250 cps. Though the mean scores for patterns three and four were approximately equal, more of the frequencies in the middle of the speech range (500 to 2000 cps) were distorted in filter pattern number three. This inconsistency appears to indicate the relative importance of the higher speech frequencies with reference to this particular study.

No significant differences were found among the conditions of amplification used in this study. Subjects appeared to discriminate equally well without a hearing aid as when listening with the benefit of amplification. The superiority of selected hearing aids over randomly selected aids or vice versa was not demonstrated. A very slight difference in favor of selected hearing aids over the conditions of randomly-selected aids and no hearing

---

[1] *Ibid.*

aids was illustrated by the mean discrimination scores of each of these three conditions (see Figure 3). This difference, however, was not statistically significant at the .01 level. For the conditions imposed by this study, no indication is given that selected hearing aids are of greater benefit to normally hearing subjects when listening to filtered word lists. This adds support to evidence presented by the "Harvard Report" that the principle of selective amplification for hearing impairment is fallacious.[1]

No interaction was demonstrated for filter patterns by conditions of amplification. Non-significant interaction indicates that any observable differences among cells due to combination of filter pattern and conditions of amplification cannot be attributed to anything other than sampling fluctuation.

---

[1]Davis, et al., op. cit., p. 103.

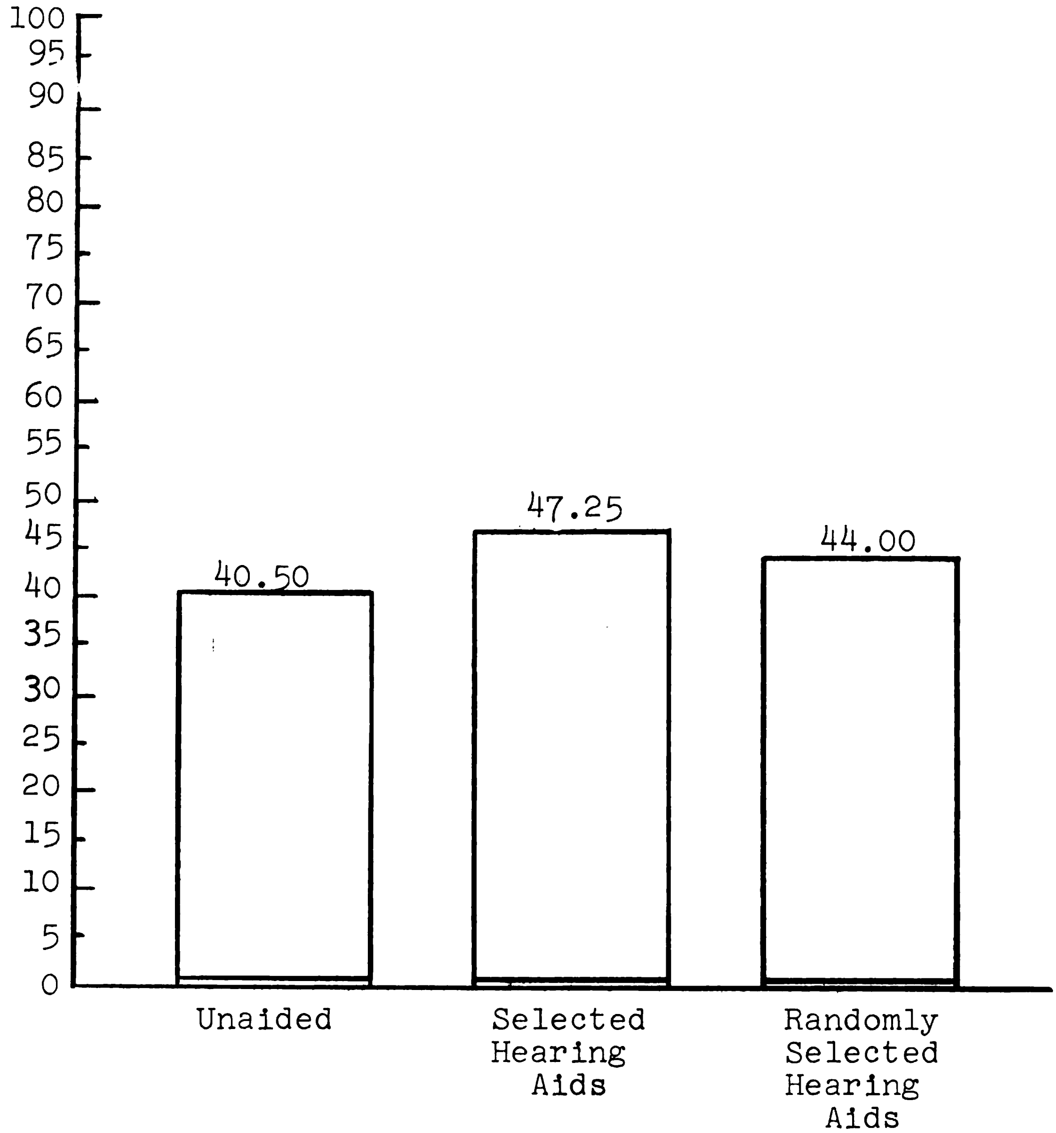



Figure 3.--Mean Per Cent Scores for Conditions of Amplification.

# CHAPTER V

## SUMMARY AND CONCLUSIONS

### Summary

During the past twenty-five years investigators have been interested in achieving greater social adequacy for the hard-of-hearing person by means of amplification with a hearing aid. One of the difficulties involved is that the ability to discriminate speech is not always improved when a hearing aid is utilized. This problem may arise from distortion factors present in the pathological ear, or those present in the hearing aid, or both. Most of the studies which have been reported in the literature concerning the evaluation of hearing aids have involved hard-of-hearing subjects. It appeared logical that additional information might be gained from normally hearing subjects. By testing their ability to discriminate filtered PB Word Lists under several conditions of amplification, an objective evaluation could be made of the effects of amplification without the influence of other factors of distortion present in the pathological ear. Thus, the purpose of this study has been to determine if conditions of amplification, (a) no hearing aid, (b) a selected hearing aid, or (c) a randomly-selected hearing aid, influence a normally hearing person's ability to discriminate filtered PB Word Lists. The CID Auditory Test W-22 List 1A was filtered to approximate the frequency distortion typical of four hearing loss patterns.

Twenty-four university students participated as subjects for the study. Subjects were randomly assigned to the four different filter patterns, six subjects to each pattern. Each of three conditions of amplification was assigned to two of the subjects under each filter pattern. A screening test for normal discrimination of speech eliminated all subjects whose ability to discriminate was not within the defined limits of normality. Subjects assigned to Condition One listened without a hearing aid to the filtered PB Word List. Subjects assigned to Condition Two listened with a selected hearing aid to the filtered PB Word List. Subjects in Condition Three listened to the filtered PB Word List by means of a randomly-selected hearing aid. Subjects utilizing a hearing aid adjusted the volume control to the most comfortable loudness level as determined by a recording of continuous speech. The continuous speech was also filtered to correspond to the filter pattern for the W-22 Word List. The speech signal was presented at 55 decibels (sensation level) for all conditions. Under each condition the subjects responded to the filtered word list and recorded their responses on forms provided for them.

A two-way analysis of variance was employed. The results of the analysis showed that in comparing the discrimination scores of normally hearing subjects, a difference exists at the .01 level of confidence between the filter patterns employed.

In comparing the discrimination scores of the subjects for the three conditions of amplification, no significant differences were revealed. An inspection of the subjects' mean discrimination scores revealed a very slight difference in favor of the selected hearing aids, however this difference was not statistically significant. No interaction appeared to result from the filter patterns by conditions of amplification.

## Conclusion

Within the limits of this study the following conclusion was derived:

There is a significant difference in the speech discrimination scores of normally hearing subjects as a result of listening to PB Word Lists under conditions of four different filter patterns. This conclusion appeared obvious from the beginning, and the results of this study reaffirm an already well-established fact. The study was undertaken to test other hypotheses as well (see Chapter I), but no definite conclusions were reached concerning them.

## Implications for Further Research

This study suggests several areas for continued research. Since there was a significant difference in discrimination scores for the filter patterns employed, further study could be done to test this trend. What is the functional relationship between the amount of frequency distortion and auditory discrimination of the speech signal? Would such a functional relationship vary depending on the population sampled?

No significant differences in discrimination scores were found to exist due to the conditions of amplification employed. Would significant differences have been found at other levels of intensity if articulation curves had been plotted for all the subjects? Would binaural hearing aids improve the ability to discriminate filtered word lists? If visual cues were presented simultaneously with the filtered word lists to untrained subjects, would significant differences in discrimination scores be revealed?

With information available as might be revealed from such studies, answers might be obtained as to the ability of the normal ear to discriminate speech under several different circumstances. It is hoped that, ultimately, this information might be related to the hard-of-hearing individual so that amplification might be of greater benefit to him.

Several obvious difficulties were apparent from this study which should be considered in future research. The inadequacy of the specifications provided by the manufacturers of hearing aids was clearly demonstrated. Comparisons between instruments were difficult to make from these specifications in that reference levels varied among hearing aids. Information as to derivation of acoustical characteristics was insufficient and, in some cases, completely lacking. One possible solution would be to obtain specific response characteristics by means of an artificial ear for each hearing aid employed in the study. This would permit the experimenter to make more valid comparisons among instruments by controlling the conditions under which the response curves are derived.

The "most comfortable listening level" should be more clearly defined in studies with hearing aids. Since this obviously covers a range, volume is difficult to control between aids. This is suggestive of implications for future research in this area.

In this study normally hearing subjects responded to the filtered speech signal under conditions of amplification by hearing aids. Under these conditions, the ambient noise level in the room would have been amplified also, creating lower signal-to-noise ratios than might be encountered with hard-of-hearing subjects. If further research is to be done in the manner described in this thesis with normally hearing subjects, it would be necessary first to determine what the maximum ambient noise level could be without producing a serious artifact in the study.

The difficulties encountered in this study might well be found in similar studies. These problems, however, should not be considered barriers to research but could, in themselves, offer many possibilities for continued experimentation.

BIBLIOGRAPHY

## Books

Arkin, Herbert, and Colton, Raymond R. Tables for Statistics. New York: Barnes and Noble, Inc., 1960.

Audio Cyclopedia. Indianapolis 6, Indiana: Howard W. Sams and Co., 1959.

Blalock, Hubert M. Social Statistics. New York: McGraw-Hill Book Co., 1960.

Davis, Hallowell, and Silverman, S. Richard. Hearing and Deafness. New York: Holt, Rinehart and Winston, Inc., 1960.

Davis, Hallowell, Stevens, S. S., Nichols, R. H. Jr., Hudgins, C. V., Marquis, R. J., Peterson, G. E., and Ross, D. A. Hearing Aids: An Experimental Study of Design Objectives. Cambridge, Massachusetts: Harvard University Press, 1947.

Portmann, Michael, and Portmann, Claudine. Clinical Audiometry. Springfield, Illinois: Charles C. Thomas, 1961.

## Articles and Periodicals

Carhart, Raymond. "Hearing Aid Selection by University Clinics," Journal of Speech and Hearing Disorders, 15 (1950), 106-113.

Davis, Hallowell. "The Articulation Area and the Social Adequacy Index for Hearing," Laryngoscope, 58 (1948), 761-778.

Davis, Hallowell, Hudgins, C. V., Marquis, R. J., Nichols, R. H. Jr., Peterson, G. E., Ross, D. A., and Stevens, S. S. "The Selection of Hearing Aids," Laryngoscope, 56 (1946), 85-115, 135-163.

Egan, James P., and Wiener, Francis M. "On the Intelligibility of Bands of Speech in Noise," The Journal of the Acoustical Society of America, 18 (October, 1946), 435-441.

French, N. R., and Steinberg, J. C. "Factors Governing the Intelligibility of Speech Sounds," The Journal of the Acoustical Society of America, 19 (January, 1947), 90-119.

Giolas, Thomas G., and Epstein, Aubrey. "Comparative Intelligibility of Word Lists and Continuous Discourse," Journal of Speech and Hearing Research, 6 (December, 1963), 349-357.

Hirsh, Ira J., Davis, Hallowell, Silverman, S. Richard, Reynolds, Elizabeth G., Eldert, Elizabeth, and Benson, Robert W. "Development of Materials for Speech Audiometry," Journal of Speech and Hearing Disorders, 17 (1952), 321-337.

Hirsh, I. J., Reynolds, Elizabeth G., and Joseph, Maurice. "Intelligibility of Different Speech Materials," The Journal of the Acoustical Society of America, 26 (1954), 530-538.

Hudgins, C. V., Marquis, R. J., Nichols, R. H., Peterson, G. E., and Ross, D. A. "The Comparative Performance of an Experimental Hearing Aid and Two Commercial Instruments," The Journal of the Acoustical Society of America, 20 (May, 1948), 241-258.

Jeffers, Janet. "Quality Judgment in Hearing Aid Selection," Journal of Speech and Hearing Disorders, 25 (1960), 259-266.

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

Knudsen, Vern O. "An Ear to the Future," The Journal of the Acoustical Society of America, 11 (July, 1939), 29-36.

Menzel, Otto J. "Auditory Discrimination," Eye, Ear, Nose, and Throat Monthly, 41 (October, 1962), 827-828.

"Methods for Measurement of Electroacoustical Characteristics of Hearing Aids," American Standards Association Bulletin, S3.3 (1960), 7-15.

Owens, Elmer. "Intelligibility of Words Varying in Familiarity," Journal of Speech and Hearing Research, 4 (1961), 113-129.

Pollack, Irwin. "Effects of High Pass and Low Pass Filtering on the Intelligibility of Speech in Noise," The Journal of the Acoustical Society of America, 20 (May, 1948), 259-266.

______. "On the Effects of Frequency and Amplitude Distortion on the Intelligibility of Speech in Noise," The Journal of the Acoustical Society of America, 24 (September, 1952), 538-540.

Shore, Irvin, Bilger, Robert C., and Hirsh, Ira J. "Hearing Aid Evaluation: Reliability of Repeated Measurements," Journal of Speech and Hearing Disorders, 25 (1960) 152-170.

Shore, Irvin, and Kramer, Joan C. "A Comparison of Two Procedures for Hearing Aid Selection," Journal of Speech and Hearing Disorders, 28 (May, 1963), 159-165.

Steinberg, John C. "Effects of Distortion Upon the Recognition of Speech Sounds," The Journal of the Acoustical Society of America, 1 (1929) 121-137.

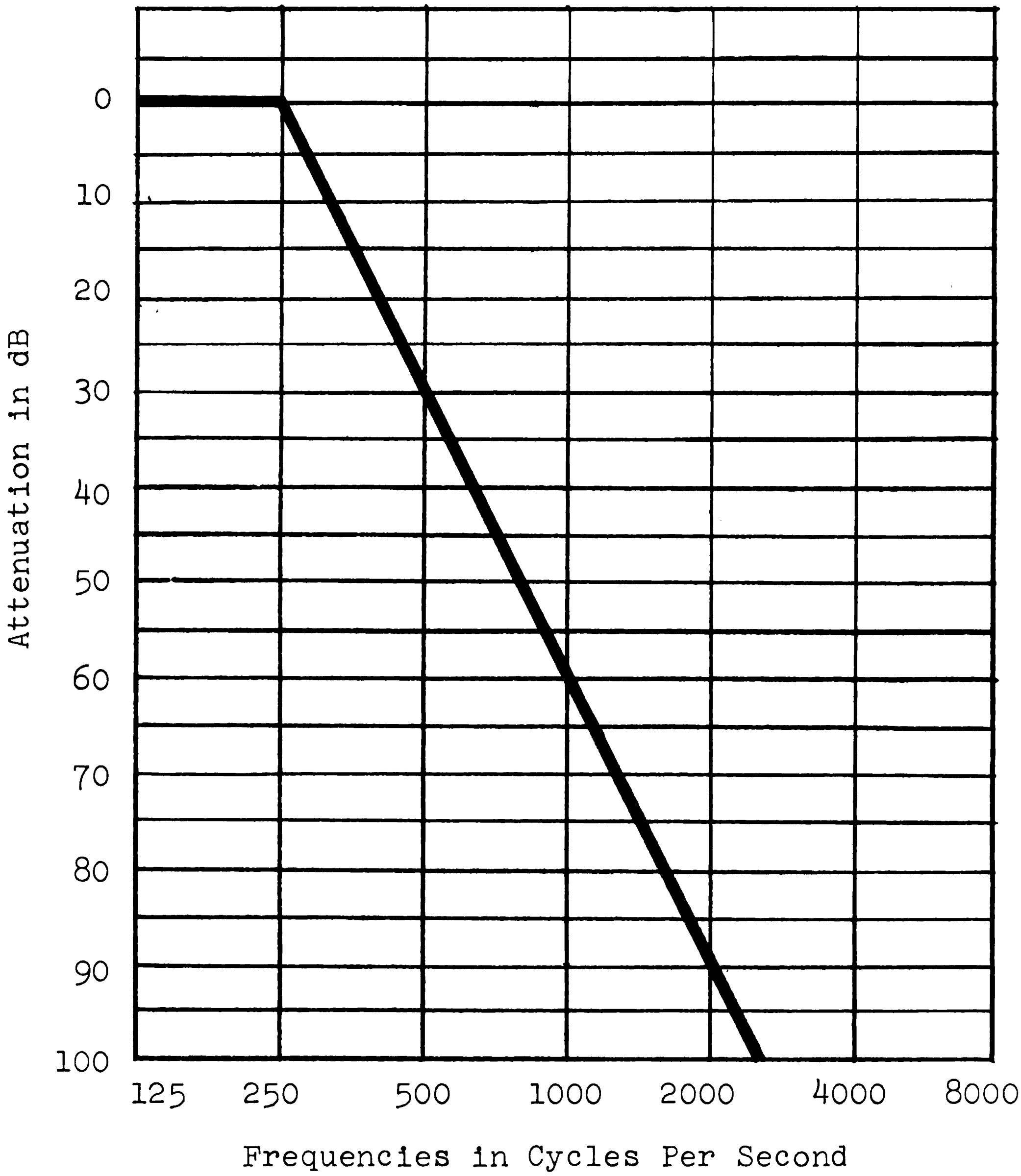
Watson, N. A., and Knudsen, V. O. "Selective Amplification in Hearing Aids," The Journal of the Acoustical Society of America, 11 (April, 1940), 406-419.

Zerlin, Stanley. "New Approach to Hearing Aid Selection," Journal of Speech and Hearing Research, 5 (1962), 370-376.

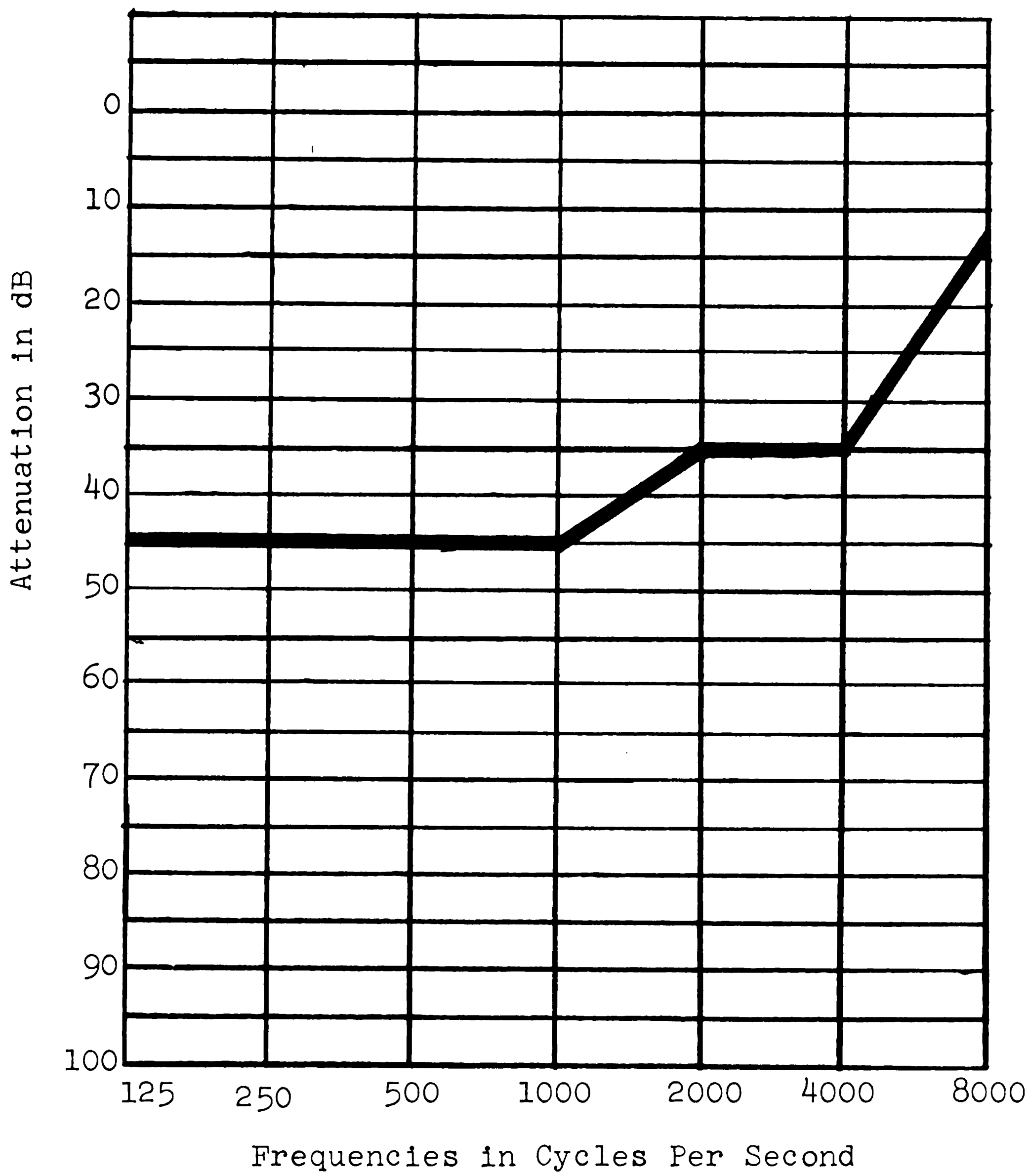
# APPENDICES

APPENDIX A

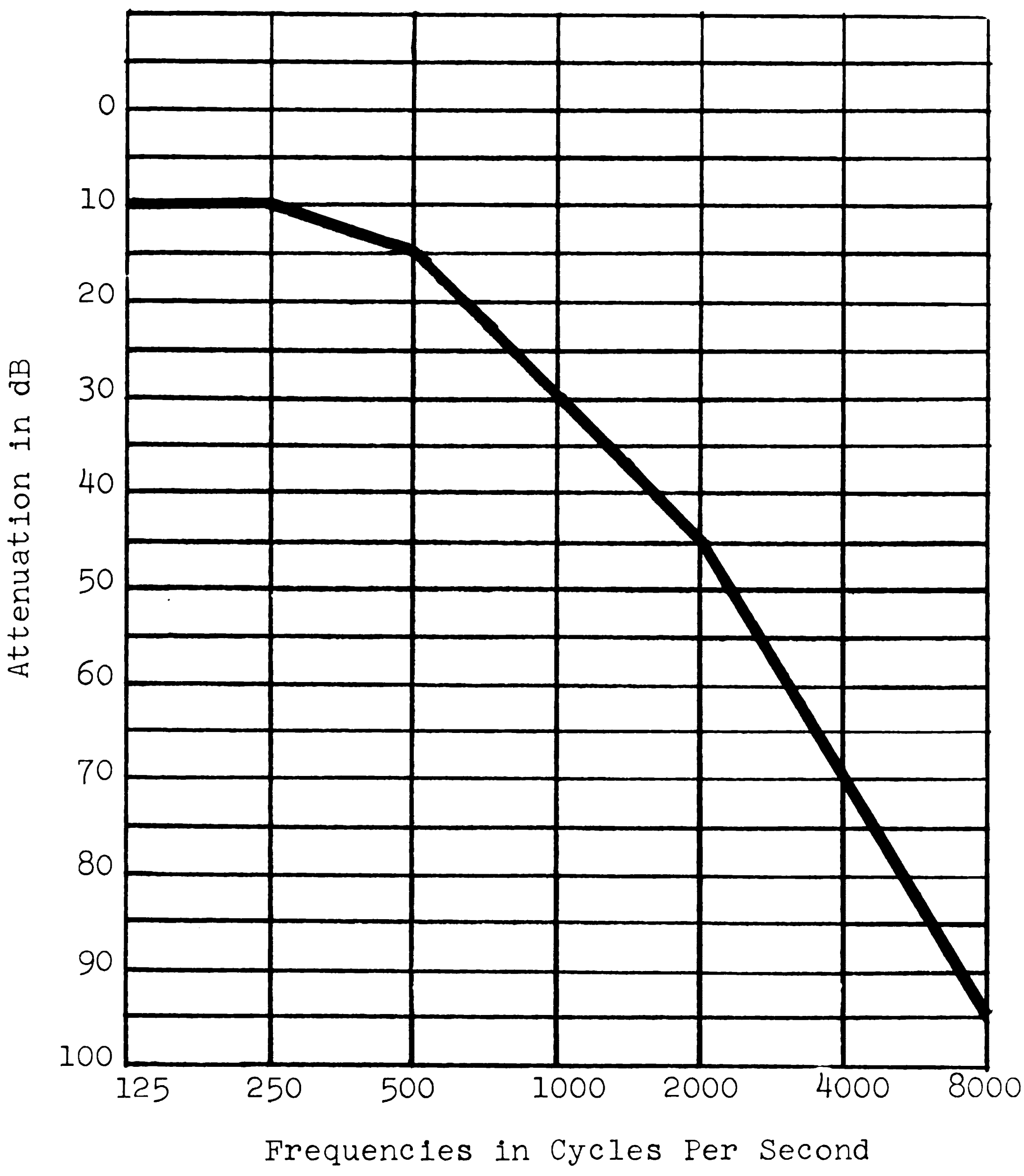
Filter Pattern Number 1.



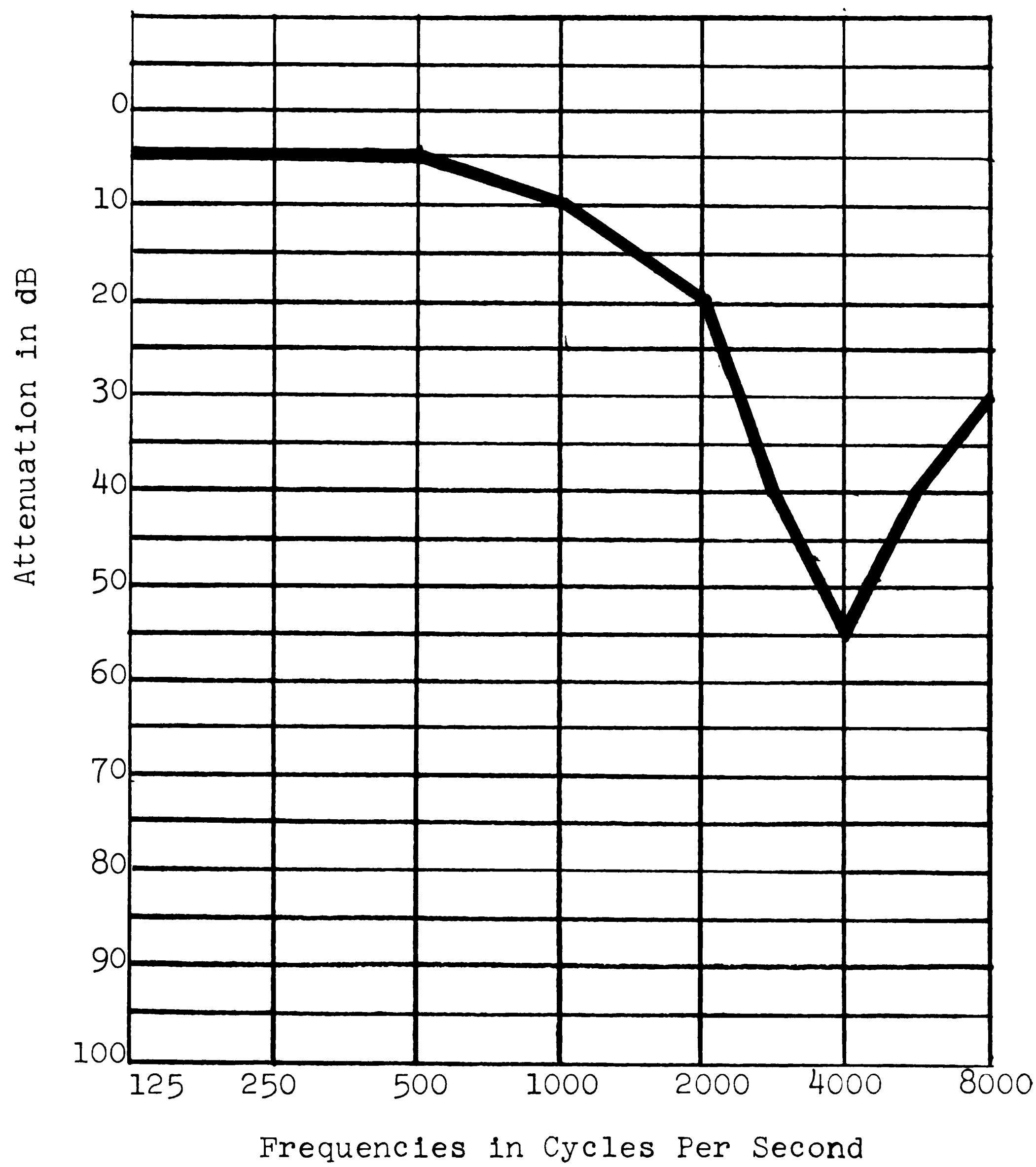
Filter Pattern Number 2



Filter Pattern Number 3



Filter Pattern Number 4



## APPENDIX B

## SELECTED HEARING AIDS

The following acoustical characteristics for the selected hearing aids used in this study were transposed from manufacturer's brochures.

All curves represent Full-On Acoustic Gain. When brochures failed to specify input signal to the hearing aid, American Standards Association specifications[1] were assumed. These are as follows:

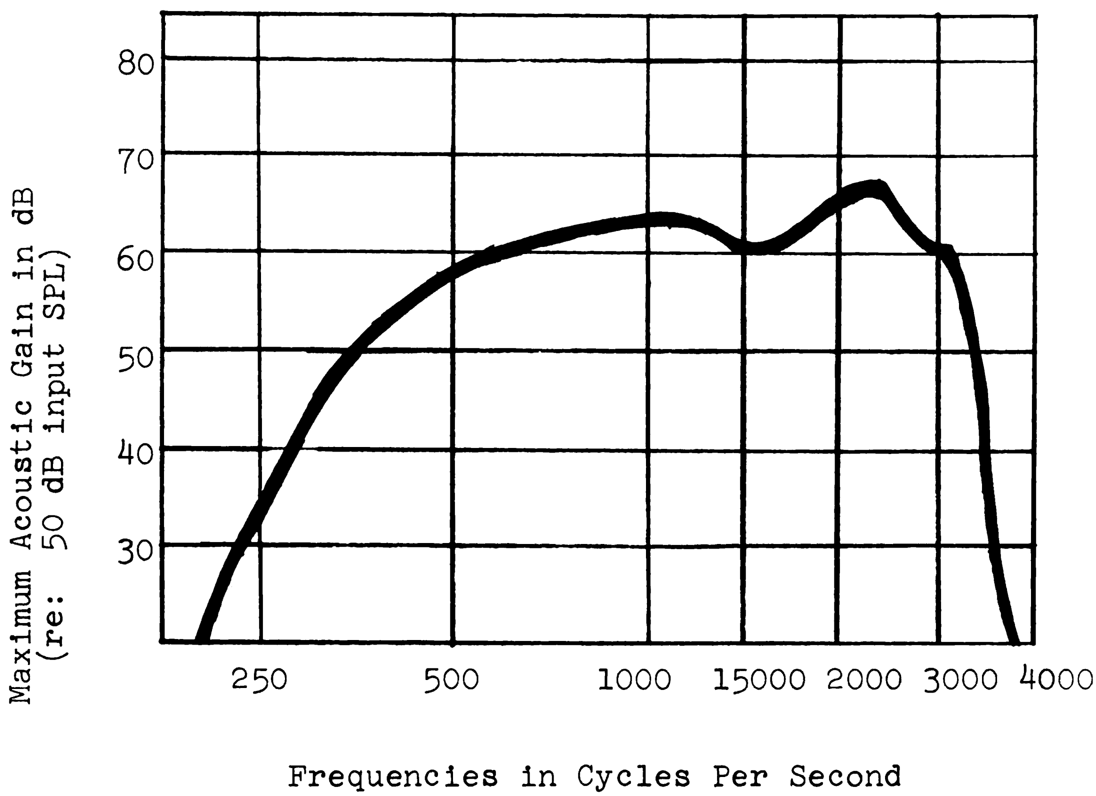
50 db input SPL

Volume control full-on

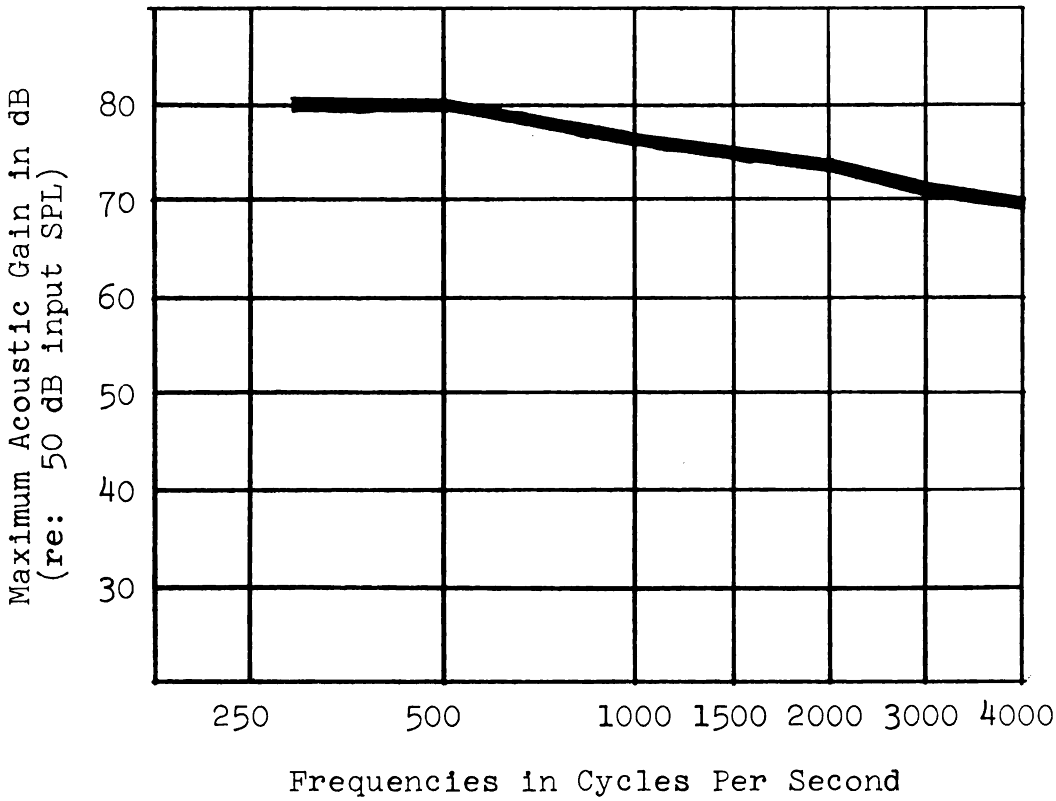
---

[1]"Electroacoustical Characteristics of Hearing Aids," op. cit., 13.

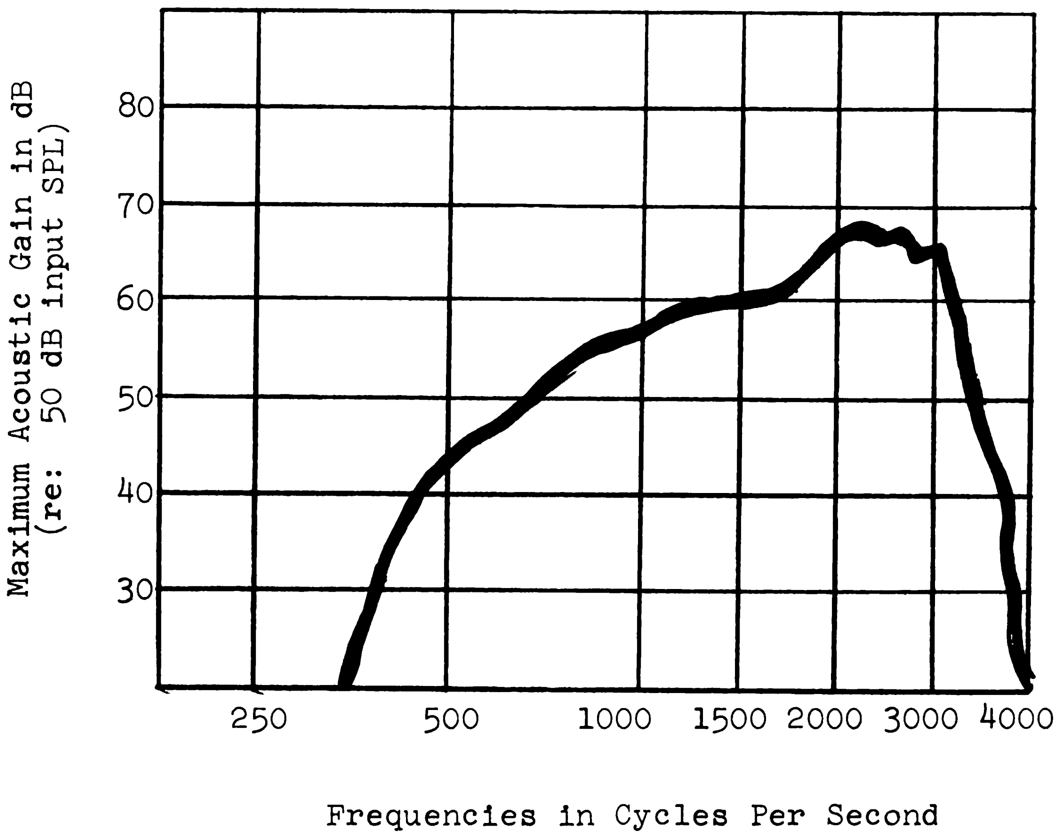
Selected Hearing Aid "A"



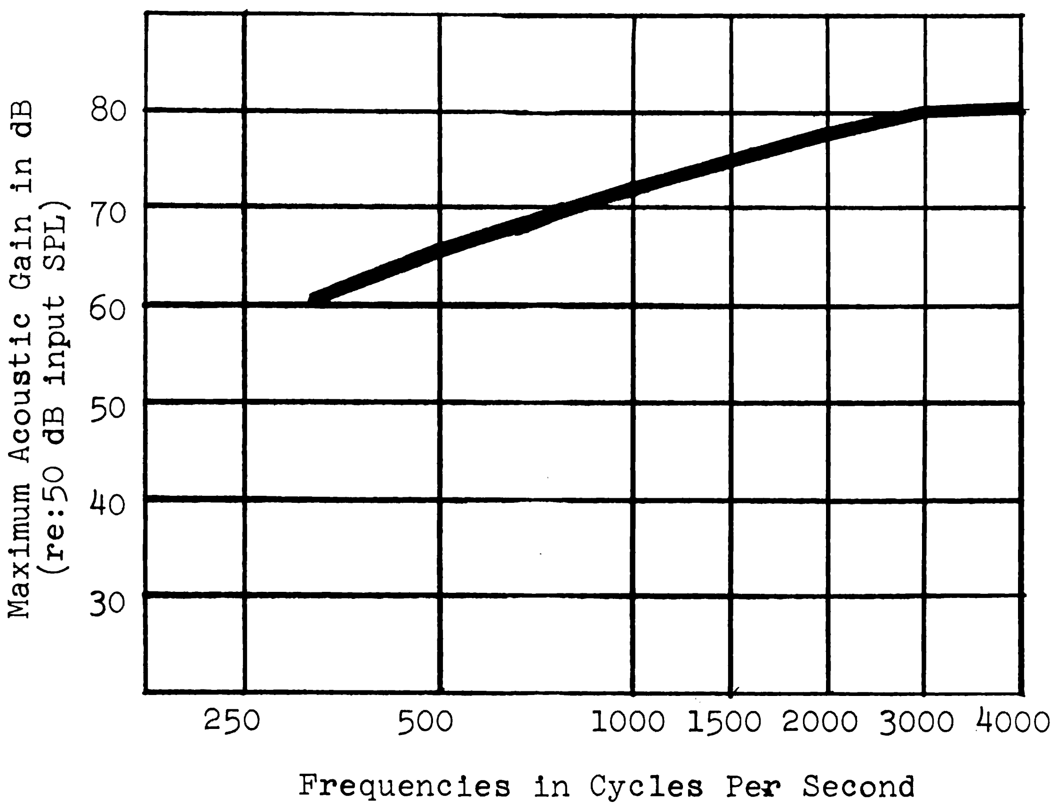
Selected Hearing Aid "B"



Selected Hearing Aid "C"



Selected Hearing Aid "D"



## APPENDIX C

## RANDOMLY-SELECTED HEARING AIDS

The following acoustical characteristics for the randomly selected hearing aids used in this study were transposed from manufacturer's brochures.

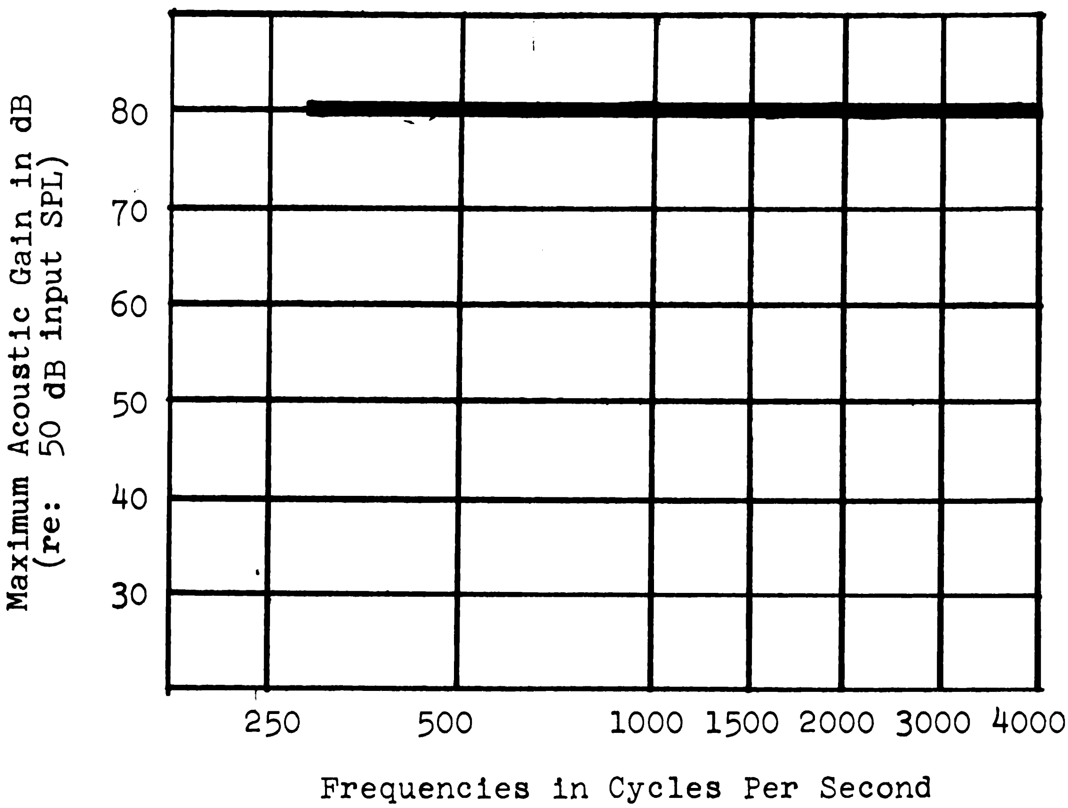
All curves represent Maximum Acoustic Gain. When brochures failed to specify input signal to the hearing aid, American Standards Association specifications[1] were assumed. These are as follows:

50 db input SPL

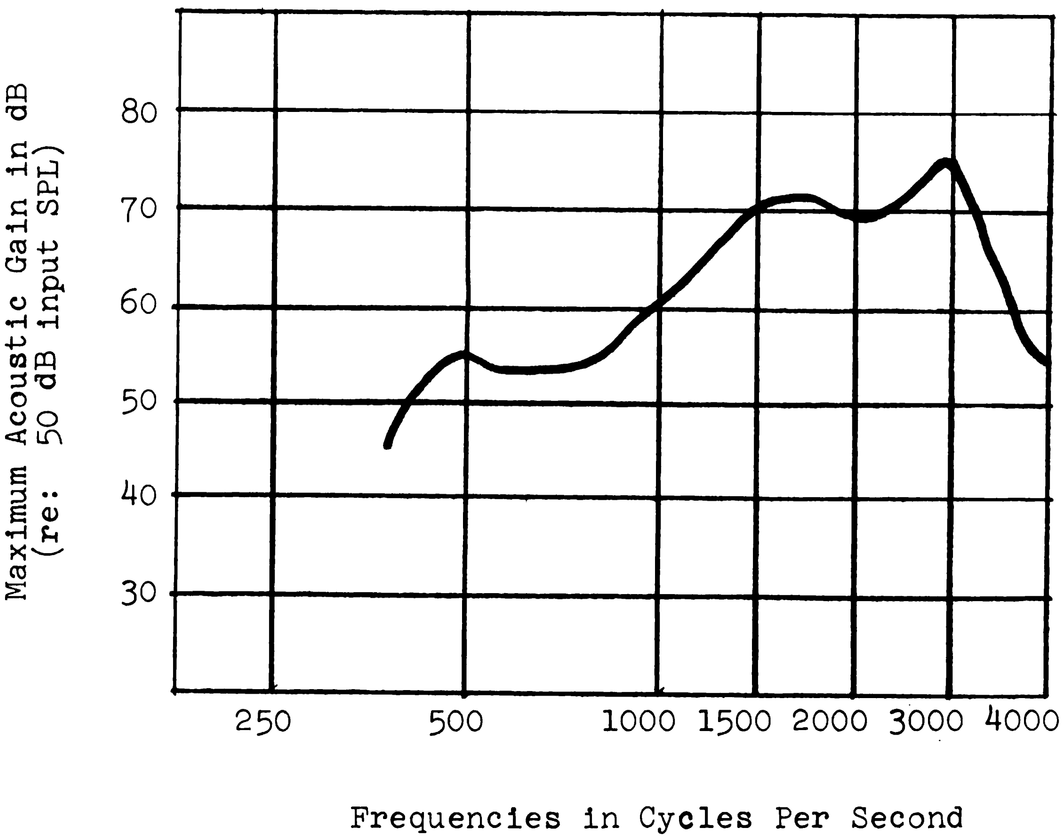
Volume control full-on

[1] *Ibid*.

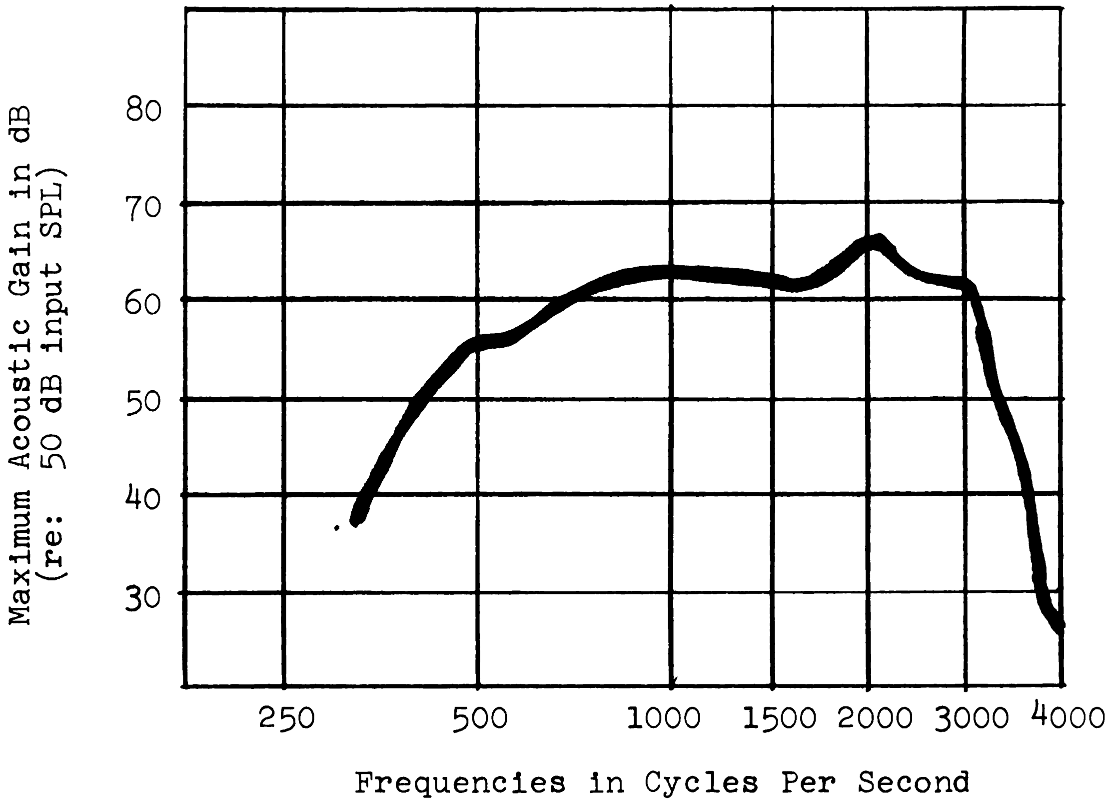
Randomly-Selected Hearing Aid "E"



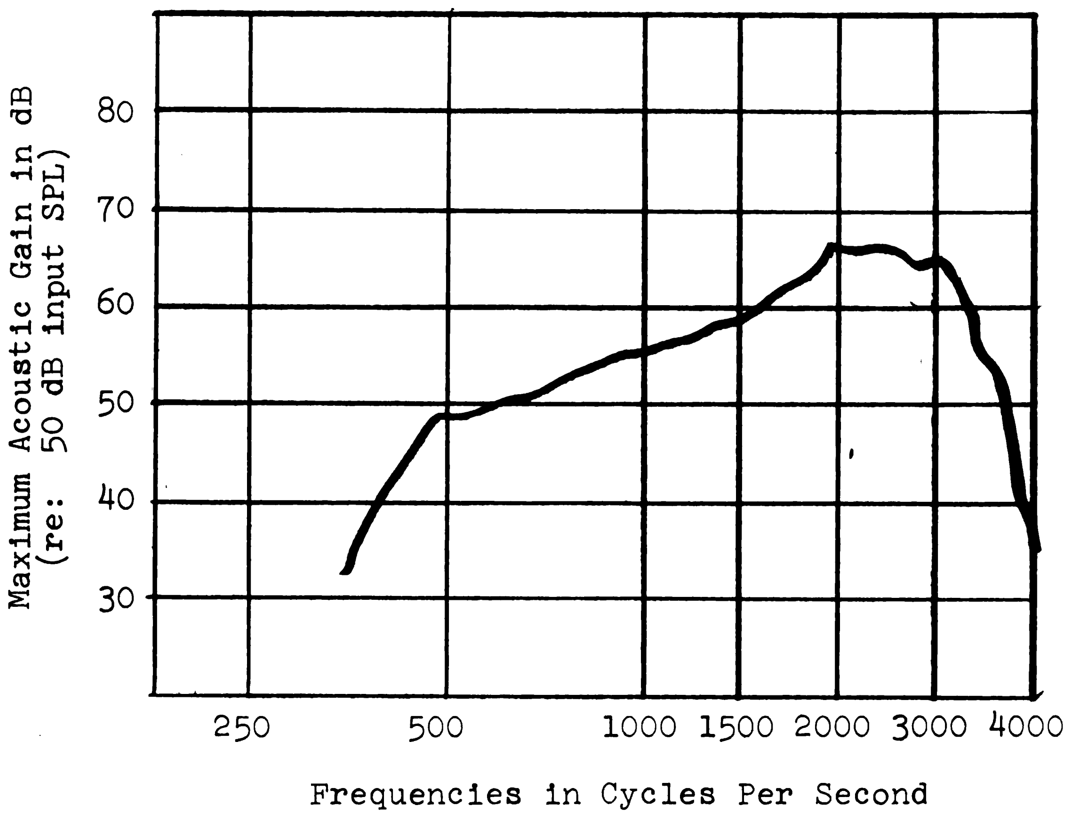
Randomly-Selected Hearing Aid "F"



Randomly-Selected Hearing Aid "G"



Randomly-Selected Hearing Aid "H"



APPENDIX D

Subject Response Form

Name: ____________________ Subject Number: ______
Age: ________
Discrimination Score at Screening: right ear:____left ear____
Condition: ____________________
Filter Pattern: __________
Hearing Aid: __________
Ear Tested: __________

| | | |
|---|---|---|
| 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 E

ASSIGNMENT OF SUBJECTS ACCORDING TO
CONDITION AND FILTER PATTERN

| Subject Number | Condition | Filter Pattern Number |
|---|---|---|
| 1 | No hearing aid | 1 |
| 2 | No hearing aid | 1 |
| 3 | No hearing aid | 2 |
| 4 | No hearing aid | 2 |
| 5 | No hearing aid | 3 |
| 6 | No hearing aid | 3 |
| 7 | No hearing aid | 4 |
| 8 | No hearing aid | 4 |
| 9 | Selected hearing aid - "A" | 1 |
| 10 | Selected hearing aid - "A" | 1 |
| 11 | Selected hearing aid - "B" | 2 |
| 12 | Selected hearing aid - "B" | 2 |
| 13 | Selected hearing aid - "C" | 3 |
| 14 | Selected hearing aid - "C" | 3 |
| 15 | Selected hearing aid - "D" | 4 |
| 16 | Selected hearing aid - "D" | 4 |
| 17 | Randomly-selected aid - "E" | 1 |
| 18 | Randomly-selected aid - "E" | 1 |
| 19 | Randomly-selected aid - "F" | 2 |
| 20 | Randomly-selected aid - "F" | 2 |
| 21 | Randomly-selected aid - "G" | 3 |
| 22 | Randomly-selected aid - "G" | 3 |
| 23 | Randomly-selected aid - "H" | 4 |
| 24 | Randomly selected aid - "H" | 4 |

APPENDIX F

RAW SCORES PER CENT CORRECT FOR EXPERIMENTAL CONDITIONS

| | Filter Pattern No. 1 | | | Filter Pattern No. 2 | | | Filter Pattern No. 3 | | | Filter Pattern No. 4 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No aid | Selected aid | Randomly-sel. aid | No aid | Selected aid | Randomly-sel. aid | No aid | Selected aid | Randomly-sel. aid | No aid | Selected aid | Randomly-sel. aid |
| Odd No. Subj. | 0 | 0 | 2 | 100 | 82 | 98 | 34 | 34 | 46 | 30 | 38 | 58 |
| Even No. Subj. | 0 | 2 | 0 | 90 | 92 | 88 | 30 | 86 | 18 | 40 | 44 | 42 |

MICHIGAN STATE UNIVERSITY LIBRARIES
3 1293 03177 9915