AN INVESTIGATION INTO ABBREVIATED CLINICAL PROCEDURES FOR HEARING AID EVALUATIONS

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AN INVESTIGATION INTO ABBREVIATED CLINICAL PROCEDURES FOR HEARING AID EVALUATIONS

By

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ABSTRACT

The purpose of this study was to determine if competent hearing aid evaluations can be done using only the Speech Reception Threshold (SRT) and the Speech Reception Discrimination (SRD) data.

There were four different groups of ten subjects each who were given two hearing test batteries about one week apart. The subjects were 30 males and 10 females ranging in age from 18 to 81 years, with a mean age of 39.45 years.

The tests administered were:

1. The usual battery given at the Michigan State University Hearing Clinic consisting of pure tone air and bone conduction tests, the SRT, and the SRD. This battery is known as the "Long Form."

2. An abbreviated form of the above consisting of the SRT and the SRD only. This is known as the "Short Form."

These two batteries were combined in all possible ways to expose each subject to two experimental situations.

The statistical analysis employed the Spearman Rank-order correlation coefficient to determine the degree of relationship between the Long and the Short Forms and the "t" test to obtain the degree of significance of the lowest correlation found. Following this, an observational analysis of the data was conducted to determine the consistency of the hearing aid strength and the ear choice over the two

testing situations. A validity verification was also done on 64 cases chosen from the Hearing Clinic files. The hearing aid strength was determined by two judges working independently using only the speech reception data from these 64 cases.

The results of this indicated that there was a good correlation between the Long and the Short Forms. The lowest correlation was .69.

The observational inspection of the data over the two tests which were given to each subject resulted in the same strength hearing aid being recommended for each subject on both tests. The choice of the ear upon which to put the hearing aid showed only five differences. The differences noted were all between a monaural or a binaural selection and not between each individual ear.

The validity verification resulted in only two differences of opinion between the two judges. These differences were noted in the recommendation of a moderate strength hearing aid when the original recommendation and the other judge recommended a weak hearing aid. These differences were seen in subjects whose SRT scores were on the borderline between the two classifications. The other classifications; no hearing aid, moderate hearing aid and strong hearing aid, exhibited perfect agreement between the two judges.

It can be concluded, within the limitations of this study, that effective hearing aid evaluations can be done with the elimination of the pure tone testing, providing the same clinical procedures and principles are followed as in this study.

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Dr. Frederick G. Alexander	Department of Speech
Dr. William W. Farquhar	Department of Administrative and Educational Services, College of Education
Dr. Ralph R. Leutenegger	Department of Speech
Dr. Malcolm S. MacLean, Jr.	Department of General Communication Arts
Dr. Max Nelson	Department of Speech
Dr. Charles P. Pedrey	Department of Speech

To his wife, Patricia, and his sons, Bruce and Scott, go a very special vote of thanks for their patience and understanding during the many trying hours of the preparation of this dissertation. Without them, this research could not have been completed.

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CHAPTER ONE

THE NATURE OF THE STUDY

In the area of medical research, much has been accomplished to cure illnesses and lengthen the life span of the human race; but in solving these age old problems, new problems have developed. Man is finding that the advanced years offer many other difficulties not evident in earlier times when death was expected before the age of sixty. It seems inevitable that as medical, scientific and technical knowledge increase, difficulties will arise to take the place of the solved questions.

In the field of Hearing, advancements have been made at a rapid rate since the turn of the century. Historically, the otologist made functional diagnoses of hearing acuity with a tuning fork; surgery was the exception in cases that are considered routine today; and the hearing aid was the ear trumpet. In the intervening years, and particularly since World War II, the profession of Audiology has come into being; and much has been done to understand more adequately the problems of the hard of hearing. There are now reliable tests available to assist the physician in his diagnosis; the audiometer is a highly technical, well calibrated instrument; the hearing aid is a miracle of electronics; and the techniques and methods of testing make the selection of hearing aids a much more scientific procedure than formerly.

And still research is needed to find new methods and processes to solve current problems.

In the science of Audiology, it must be recognized that the increased life span expected for the human being in the future will create hearing problems in much greater quantity than in the past. This may seem incongruous in the light of the medical and scientific advances mentioned above, but it is not. Watson and Tolan justify this stand when they say:

> Because of the constantly increasing medical care, improved living standards and sanitation measures, child care and health education, the incidence of deafness due to disease in infancy is undoubtedly decreasing. The sulfa drugs and penicillin alone have greatly reduced the danger of deafness from mastoiditis, meningitis, acute otitis and a number of other diseases. But, as if to balance this reduction in the incidence of deafness, there is inevitably an increase in total deafness accompanying the steady shift in the age of the population towards an older age level. Here the incidence of deafness is much greater, and the types of deafness most prevalent are those due primarily to the degenerative diseases of later life. These tend towards nerve impairments, greater losses proportionately in the higher tonal range, combined with perceptive and interpretive difficulties.[1]

Despite the advances in medical science which have reduced the incidence of hearing impairments among children, hearing loss will still be a very real problem in our society. It has been estimated that by the close of the present century, there will be 80% more hearing defectives than in 1945.[2] This will undoubtedly have an effect upon

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[1]L. Watson and T. Tolan, Hearing Tests and Hearing Instruments (Baltimore: The Williams and Wilkins Company, 1949), p. 203.

[2]Ibid.

the management of hearing clinics because of the increased number of persons seeking help.

It would be profitable to investigate how a person discovers an adventitious hearing loss and the means that he may use in arriving at a hearing clinic.

At first, he will probably feel that people are talking more softly to him than they previously did, and he will have to ask them to repeat. With the added attention that he gives the situation, and the conscious observation of the speaker's lips and face, he will usually understand. Gradually, however, he will feel that he must ask the speaker to talk more loudly, and this will help. In time, he will notice that he must have the television set turned up louder than others in the room appreciate. He will have trouble hearing over the telephone, in church and in group conversations. In short, hearing will actually become a chore for him. At this point, a relative or close friend may suggest to him that he may be becoming hard of hearing or "deaf." If he is a normal, well-adjusted person, there are two avenues open to him, besides ignoring the suggestion: he may go to his family physician, who will probably refer him to an ear, nose and throat specialist or he may contact a hearing clinic or a hearing aid dealer. If the physician is chosen first, he may be told: 1) to go to a hearing clinic or hearing aid dealer for a hearing aid evaluation, 2) surgery will help or 3) the problem will respond to medical treatment. Today, the latter two recommendations are becoming more common.

If the hard of hearing person chooses to contact a hearing clinic before visiting his physician, he will probably be given some preliminary testing and then referred to a physician. The testing would usually consist of a pure tone air and bone conduction examination, a speech reception threshold and a speech discrimination test. The pure tone method of testing consists of eliciting responses from the subject upon aural stimulation with pure tones which are fundamental frequencies uncomplicated by overtones or harmonics. This is done by air conduction with the tones of 250 cps, 500 cps, 1000 cps, 2000 cps, 4000 cps and 6000 cps. Earphones are used to conduct the tones to the ears. The purpose of this examination is to determine the level of loudness that is just perceptible to the ear. For bone conduction testing, a specially built oscillator is placed on the mastoid process of the temporal bone and the same tones are stimulated, with the exception of 6000 cps. The aim of bone conduction testing is to ascertain the acuity of the inner ear and to confirm hearing losses found by air conduction. The speech reception threshold and speech discrimination tests are described later.

If the hard of hearing person elects to consult a hearing aid dealer, the process should be identical with that of the hearing clinic, but it probably never is. In some instances the dealer will refer the subject to a hearing clinic.

Following the medical examination and the preliminary pure tone testing, there are many additional tests that can be administered to determine hearing acuity for speech. The type of loss, the extent of the loss, and the selection of the hearing aid best suited to the individual can be determined by the following tests:

1. The Speech Reception Threshold (SRT)*

   This test is given in two ways, one using the Spondee words and the other with connected speech, usually via a recording. The Spondee words are two syllable words with equal stress on each syllable and are all of uniform intelligibility. Usually forty-two of these words are used binaurally and monaurally. Words of this type are "railroad," "mousetrap," etc. The aim of this test is to establish the lowest level of loudness possible for the subject to understand speech at an accuracy of 50%.

2. The Most Comfortable Loudness Level

   This test is to determine the level of loudness that appears to be most comfortable for the subject.

3. The Tolerance Level

   The tolerance level is aimed at finding the level of loudness at which the subject begins to feel discomfort. This is desirable to know so that all of the succeeding tests can be given between the level of the SRT and the level of this test.

4. The Speech Reception Discrimination (SRD)*

   The goal of this test is to judge the subject's ability to understand speech at a supra-threshold

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*The Speech Reception Threshold will henceforth be referred to as the SRT and the Speech Reception Discrimination will be referred to as the SRD.

> level of loudness, about 40 db above the SRT. This is done with Phonetically Balanced words. These words, abbreviated PB, are monosyllabic words containing all of the common speech sounds in the English language in the approximate proportion found in ordinary speech (50 words in a list).

The above tests are given to the subject over a loud speaker whenever possible in order to judge his ability to hear and also to use a hearing aid effectively. At the Michigan State University Hearing Clinic, the Speech Reception Threshold (SRT) and the Speech Reception Discrimination (SRD) tests are used with good results.

At the Hearing Clinic, after it has been established that the subject's hearing level will improve with an aid, the SRT and the SRD are repeated with different test forms and using a minimum of three different hearing aids. This is done to determine the aided hearing acuity with several different combinations of hearing aids and receivers. On the basis of the preceding procedure the final recommendation is made of either 1) no hearing aid needed, 2) a hearing aid with low power, 3) a hearing aid with moderate power or 4) a strongly powered hearing aid.

Due to the fact that a hearing aid evaluation entails fine discrimination and judgment, the subjects might fatigue easily, particularly the elderly and the very young. On some occasions these age groups become inattentive and uncommunicative after long periods of such careful listening. This emotional state, of course, may reduce the reliability and validity of the testing.[3] Two and one-half hours are usually consumed for the minimum testing deemed possible for a good hearing aid evaluation at the Hearing Clinic. The clinical testing can be portioned in the following manner:

1. An interview to determine the nature of the problem, the type of person who has the loss, and the individual's concern over the problem, 15 minutes.

2. The pure tone, air conduction testing, 30 minutes.

3. The pure tone, bone conduction testing, 30 minutes.

4. The speech reception examination involving, binaurally and monaurally, both the Spondee and PB words, one hour and fifteen minutes.

The above represents only the preliminary evaluation prior to the selection of the hearing aid. In the evaluation of the aids, another two and one-half hours are usually required. It is understandable, therefore, that subjects become fatigued; although allowances can be made for this.

On the basis of the above mentioned possibility of fatigue in subjects and the anticipated 80% increase in hard of hearing persons in the future, research is needed to determine if current testing procedures can be improved, i. e., modified, shortened or perhaps eliminated. With the increased demand for hearing aid evaluations, the audiologist will have to abbreviate and condense his methods, if possible, in order to provide more effective service. Unless new

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[3] H. Newby, Audiology (New York: Appleton-Century-Crofts, Inc., 1958, p. 77.

methods, procedures or tests are devised, many people are going to have to do without an accurate, precise hearing aid evaluation.

It must be emphasized, that any research resulting in a change in the audiologist's testing regime must maintain the validity and reliability found in the present methods. Without it the audiologist will not be as effective as he is at present.

Rationale of the Present Research

This study is concerned with the total testing procedure for hearing aid evaluations. Under the present hearing examination methods, subjects are given the audiometric pure tone tests described earlier. This testing is vital if the examination is for purely diagnostic purposes. The thresholds obtained from these aural stimulations provide the physician with information upon which to determine the extent of the difficulty, plan treatment and select cases for surgery. But are they necessary for hearing aid evaluations? It has been assumed that they are, but is it definite that the information provided by the pure tone testing is not superfluous for hearing aid evaluations? The answer to that question, in the writer's opinion based upon numerous clinical observations, appears to be, "no," particularly in the light of the fact that a good deal of the information that is vital to the selection of the correct hearing aid is obtained through the speech reception testing.

The process of administering a speech reception test, following the pure tone testing, can take into account several tests, including those described above. The Hearing Clinic, however, does not, at the present time, use all of these or some of the other tests (such as the Signal-Noise Ratio), and it is found that meaningful results can be attained with the Spondee words and the PB words. The Spondee and PB words will reveal the Speech Reception Threshold (SRT) and the intelligibility of speech for the person being tested (SRD). These appear to be the most important clues, at the present time, for the determination of the correct hearing aid for a given person. The SRT assists the audiologist in deciding the power of the hearing aid the person needs. The results of the PB test will indicate the specific characteristics of the sounds of the words missed. The latter will supply information as to the response curve that the hearing aid should have, plus the features of the receiver to be put on the aid. For example, a person who consistently misses PB words containing the [s], [z], [v], [f] and [θ] sounds would in all likelihood need an instrument with a power peak close to 3200 cps and a receiver which would transmit predominantly high frequency sounds. By using such an instrument, some of the characteristics of these high frequency sounds would be re-established.

In Fig. 1,[4, 5] it can be seen that the vowel sound [ɔ] is the most powerful sound in the English language, while [θ] is the weakest. From this chart too, it can be determined that the [ʃ, shoe], [tʃ chop], [z, zip], [s, see], [v, vim], [f, fee], [ð this] and [θ, thin] sounds are in the range from 3200 cps to 6400 cps. This represents the range of hearing that is most often lost by persons with a perceptive type hearing difficulty. The loss of acuity for these sounds accounts for much misunderstanding because of poor discrimination. If this range of hearing can be improved by the proper hearing aid and receiver, intelligibility of hearing reception should improve.

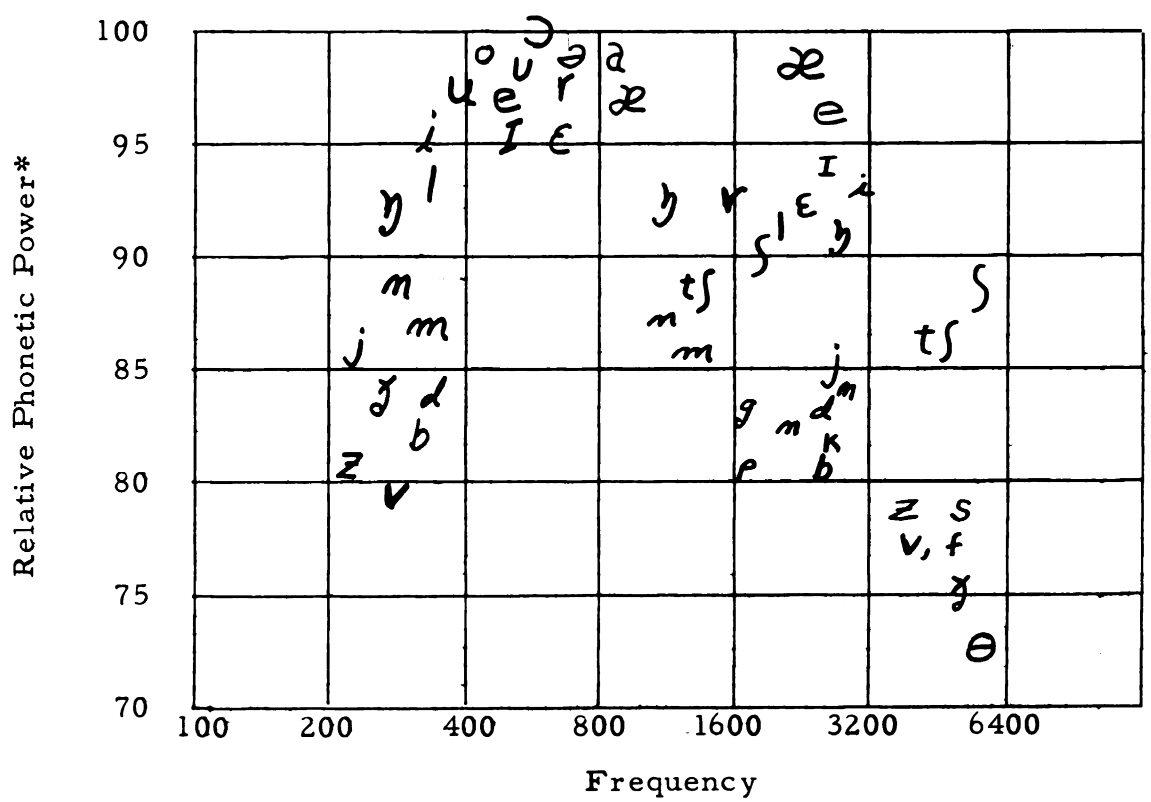

Fig. 1.--The position of the sounds of the English language in their frequency bands and in relation to their phonetic power.

Therefore, obtaining the results of the pure tone tests plus the speech reception tests provides some information that is not used directly for the hearing aid evaluation. The bulk of the data needed for the hearing aid recommendation is gathered through speech reception testing. The rationale for this research, then, can be stated as follows: Because of the extremely close relationship between pure tone testing and the SRT and the SRD results, pure tone testing by the audiologist may be eliminated in a hearing aid evaluation, provided the subject has a medical recommendation for an aid.

A Broad Statement of the Hypothesis of the Research

The general hypothesis of this study is as follows: An abbreviated procedure for hearing aid evaluations using only speech reception tests, will provide statistically similar results when compared with the longer method now being used at the Hearing Clinic.

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[4] H. Fletcher, Speech and Hearing in Communication (New York: D. Van Nostrand and Company, 1953), p. 86.

[5] Revisions have been made in this chart. The major revision is the conversion of the diacritical marks used by Fletcher to the I. P. A. symbols. For an explanation of these phonetic symbols see: M. Berry and J. Eisenson, Speech Disorders: Principles and Practices in Therapy (New York: Appleton-Century-Crofts, Inc., 1956), pp. 523-24.

[*] This is measured in microwatts of power emanating from the average speaker's mouth at average intensity. See: Fletcher, op. cit., Chapter 4.

An Overview of the Research

In Chapter Two, a review of the pertinent literature is presented. Material will be correlated concerning pure tone and speech reception testing and hearing aid evaluations.

In Chapter Three, the design of the research will be discussed, including sample selection, the methods of statistical analysis, the rationale for the statistics used and the assumptions underlying the statistical models.

A concise statement of the hypotheses generated by the study will be discussed in Chapter Four, as well as an analysis of the data.

Chapter Five will contain the conclusions reached in this study.

Recommendations for future research will be presented in Chapter Six.

CHAPTER TWO

REVIEW OF THE LITERATURE

Hearing testing, as it is done today, has progressed through various stages of refinement. Among the more elementary tests have been the whisper, the watch tick and the tuning fork tests. These have serious weaknesses. Despite the fact that these tests are still used to some extent, they are gradually falling by the wayside. The audiometer, with its pure tone and speech reception circuits has taken their place. Audiometric testing is the most scientific and accurate method known today.

Immediately following World War II, much research was done on the stability of audiometric pure tone testing results. More recently, the speech reception method of testing has been subjected to scrutiny, and rightfully so, in the light of the great advances made following the advent of pure tone testing. Because the goal of Audiology is the improvement in the hearing of speech, speech reception testing may eventually supplant pure tone testing for some purposes.
It is not believed by the writer that speech reception testing will completely replace pure tone testing in the near future. It is not thorough enough for diagnostic purposes. Pure tone testing provides too many clues as to the cause of a hearing loss to be taken over by a more gross method such as speech reception testing.

The Relationship of Pure Tone Air Conduction to Speech Reception

There has been a considerable amount of work done in recent years in an attempt to determine exactly what frequencies are essential for the understanding of speech. Of the six frequencies normally tested by air conduction, from 250 cps through 6000 cps in octave steps, it appears that the 500 cps, 1000 cps and 2000 cps tones are the most useful for comprehending speech. As to the exact frequency range necessary for the intelligibility of speech, there seems to be considerable confusion. It has been stated that "a range of 750 cps to 3000 cps is all that is necessary for the recognition of speech sounds. Lower and higher frequencies influence the quality of sound perceived."[1] This range is probably adequate, but with reference to Fig. 1 presented in the first chapter, it appears that 500 cps is a better lower limit. This lower limit includes more of the essential sounds in the English language than does a range starting upwards from 750 cps. There seems to be some agreement with the upper limit of 3000 cps. If we consider that the most effective frequencies for hearing are those transmitted by the telephone, the range is from 300 cps to 3400 cps or 3500 cps.[2, 3] Visible speech, the method of

[1] W. C. Beasley, "The General Problem of Deafness in the Population," The Laryngoscope, 50: 856, 1940.

[2] F. G. Santamarina, "Practical Office Audiology," Archives of Otolaryngology, 61: 441, 1955.

[3] Vitold Belevitch, Théorie Des Télécommunication (Paris: Gauthier-Villers, 1957), p. 5.

depicting speech via Sonographic patterns, indicates that the main characteristics of speech are clearly visible on patterns with a frequency range of from 70 cps to 3500 cps. The frequencies below 500 cps, however, are used mainly to indicate the presence or absence of voice in the speech sample.[4] This tends to support the contention that the range from 500 cps to 3500 cps is all that is needed to comprehend speech, from the theoretical point of view.

In practical Audiology, however, the usual range of hearing accepted for the understanding of speech is from 500 cps to 2000 cps. This has been attested to by many people in the field of Audiology, most notably Carhart.[5] Experimentally, this range has been tested. In a study by Fowler involving 38 subjects, it was found that the means and standard deviations were lower for 500 cps, 1000 cps and 2000 cps than for all of the other frequencies usually tested. The subjects ranged from 18 to 24 years of age. This study tends to show that the range of 500 cps through 2000 cps is the most reliable and again with reference to Fig. 1, should give the best comprehension. The two

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[4] R. Potter, G. Kopp and H. Green, Visible Speech (New York: D. Van Nostrand Company, Inc., 1947), pp. 12-14.

[5] R. Carhart, "Symposium--The Physiology of Speech--Its Audiology Aspects," Archives of Otolaryngology, 46: 417-18, 1947.

[6] J. Corso and A. Cohen, "Methodological Aspects of Auditory Threshold Measurements," Journal of Experimental Psychology, 55: 8-12, 1958.

most valuable tones, according to Fowler, are 1024 and 2048.[7] (Frequencies 1024, 2048, etc. are for audiologic purposes similar to 1000 cps, 2000 cps etc.) On the basis of these studies by Carhart and Fowler, it is probably safe to consider the range of frequencies from 500 cps through 2000 cps as the most important for understanding human speech.

One question usually asked by subjects in a hearing clinic is, "What percentage of hearing loss do I have." Actually, there never has been a good answer to this question, but attempts have been made. The first was the scale devised by a committee of the American Medical Association. The method this group devised ignored the high and low frequencies. The following were the tones considered and the percentage of hearing assigned to each: 512 cps, 15%; 1025 cps, 30%; 2048 cps, 40%; and 4096 cps, 15%.[8] The percentage figures were based upon an estimate of the value of a given tone to speech intelligibility. Fowler, however, advocated a change in the above system. He wanted to reduce the percentage of hearing assigned to 4000 cps from the above 15% to 10% and make 500 cps worth 20%.[9] From either the AMA or the Fowler scale, it can be seen that the middle frequencies are

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[7] E. P. Fowler, "The Percentage of Capacity To Hear Speech and Related Disabilities," The Laryngoscope, 57: 113, 1947.

[8] Fowler, op. cit., p. 110.

[9] Ibid.

vastly more valuable than the additional higher and lower frequencies that are usually tested in hearing clinics.

A current means of answering the question concerning the percentage of hearing loss is the Social Adequacy Index (to be referred to henceforth as the SAI). The SAI is arrived at by the use of two speech reception scores--the threshold of speech and the percentage of speech intelligibility at a supra-threshold intensity. The SAI is said to indicate a person's social effectiveness. The SAI is more closely related to speech reception testing than to pure tone testing and it will be taken up in a later section of this chapter.

An interesting area of pure tone testing that has been subjected to research is the degree of correlation between the various frequencies. This area is of interest because of the fairly accurate predictive value of some frequencies in relation to others. It has been stated that:

> Correlation between hearing losses by air conduction is extremely high and regression is linear for the three tones 64, 128 and 512 cycles . . . . Any of these three tones will provide approximately equal predictive value as to acuity of hearing throughout this range.[10]

Witting and Hughson pointed out that there is a high correlation between the frequencies of 128 cps and 256 cps and that the lower limit of pure

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[10] W. C. Beasley, "Correlations between Hearing Loss Measurements by Air Conduction on Eight Tones," Journal of the Acoustical Society of America, 12: 113, 1940.

tone testing should be the latter.[11] This seems to be reasonable, assuming that the correlations hold up under most conditions. As was indicated in Chapter One, in time, the audiologist should not be gathering irrelevant information and he may have to abbreviate certain procedures.

Such correlations as cited above have not been found for the higher tones in the series tested in hearing clinics. It has been reported, however, that with a loss of hearing over 4000 cps, a person is entirely unaware of any difficulty.[12] Watson and Tolan have said that with a threshold as "high as 25 db and 30 db at the 3500 cps and 4000 cps level" individuals are not aware of any impairment of hearing.[13] With reference to Fig. 1, this is perfectly understandable; there are so few sounds in the English language that have their predominating frequency above this level. It must be understood, too, that if a child is the subject, a loss of hearing would be evident. If such is the case, the child would most certainly have trouble developing normal speech; particularly with the normal development of silibant sounds. A child must be able to hear the sounds in the language in order to reproduce them correctly.

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[11] E. Witting and W. Hughson, "Inherent Accuracy of a Series of Repeated Audiograms," The Laryngoscope, 50: 259, 1940.

[12] F. Kranz and C. Rudiger, "Relation of Audiogram Measurements to Hearing Aid Characteristics Based on Commercial Experience," Journal of the Acoustical Society of America, 13: 363-66, 1942.

[13] L. W. Watson and T. Tolan, Hearing Tests and Hearing Instruments (Baltimore: The Williams and Wilkins Company, 1949), p. 196.

It may be interesting to view the situation of troughs, or notches, that are seen sometimes on audiograms. These occur when the threshold of one frequency drops below the level of the threshold of all of the others tested. This is quite a common feature with the 4000 cps tone. Fowler stated that the trough "below 512 and above 4096 cps cause so little loss that they can be ignored for practical purposes."[14] It has also been observed by the writer that troughs at the level of 4000 cps do not present difficulties with the SRT or the SRD tests.

In terms of the reliability of the tones of 500 cps, 1000 cps and 2000 cps, it has been found that with three methods of establishing their threshold (ascending with varying lengths of pauses between stimuli, descending and ascending with a one second pause between stimuli presentations) these tones did not vary more than two decibels, while the tones of 125 cps, 250 cps, 4000 cps and 8000 cps varied more than 5 db,[15] and that the 1000 cps tone has the greatest degree of test-retest reliability.[16] As for the tones of 8000 cps and 12000 cps, there are certain physical problems to be considered. In the case of these tones, the length of the external auditory meatus

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[14] E. P. Fowler, "A Simple Method of Measuring Percentage of Capacity for Hearing Speech," Archives of Otolaryngology, 36: 874, 1942.

[15] L. L. Sawyer, "Office Procedure in Hearing Evaluation," The Laryngoscope, 60: 1074, 1950.

[16] H. Newby, Audiology (New York: Appleton-Century-Crofts, Inc., 1958), p. 75.

comes close to their wave length and standing waves are set up.[17] As a result, the tones may not be heard. This presents a difficult situation if these tones are relied upon for diagnosis. If the earphones are withdrawn slightly for a few seconds from the pinna, however, this condition may be overcome. Then, too, at these frequencies, the physical limitations of the earphones must be considered; most earphones do not have good fidelity at such high frequencies.

The above has pointed out that a definite working relationship does exist between pure tone, air conducted frequencies of 500 cps, 1000 cps and 2000 cps and speech reception. This relationship is valid and is one that is constantly used by audiologists with confidence.

The Relation of Pure Tone Bone Conduction to Speech Reception

In the area of pure tone bone conduction testing, much research has been done. This type of testing presents many problems not present with air conduction. For example, the thickness of the skin will vary with the individual; the density of the mastoid process, upon which the oscillator is placed, will vary; and the amount of fatty tissue beneath the skin will vary. All of these present variables which may tend to cause inconsistencies in bone conduction testing. It is well known, however, that an air conduction loss greater than 50 db is due, at least in part, to some degeneration of the cochlear branch of the eighth cranial nerve. In perceptive type hearing losses, the

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[17] Ibid.

"impairment by air conduction and by bone conduction should be equal."[18] This is a most valuable clue in the diagnosis of hearing difficulties.

As for the frequencies tested by bone conduction, the usual ones are in the range from 250 cps through 4000 cps in octave steps. Senturia and Thea indicate that the most desirable range would be from 250 cps through 8192 cps, but that 512, 2048 cps and 4096 cps are acceptable for sampling purposes.[19] There seems to be some disagreement about this because one authority stated that only the middle range should be tested (presumably 500 cps through 2000 cps) while another claims that only 512 cps alone is sufficient for adequate bone conduction testing.[20] The usual practice is to test the range of 250 cps through 4000 cps. It has been recommended by Newby, that testing at 250 cps should be eliminated because patients are apt to respond to the tactile sensation of the oscillator rather than the sound.[21] This may not give a true picture of the person's hearing at that frequency.

Experimentally, much has been accomplished in the area of bone conduction testing. In a study done on the records of Deshon

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[18] Santamarina, <u>op. cit.</u>, p. 44.

[19] E. Senturia and A. Thea, "Bone Conduction in Audiometry, 1. Literature Review and Report of Preliminary Observations," <u>The Laryngoscope</u>, 52: 686, 1942.

[20] A. Lewy and N. Leshin, "Progress in Otolaryngology," <u>Archives of Otolaryngology</u>, 35: 450, 1942.

[21] Newby, <u>op. cit.</u>, p. 83.

General Hospital following World War II, with a total of 2377 comparisons of bone conduction audiograms in the frequency range of 256 cps through 4096 cps, the standard deviation ranged from 7.65 db to 9.40 db. The smallest SD's were at 1024 cps and 256 cps, with the least variability falling at 1024 cps.[22] With 1024 cps having the lowest standard error of measurement, it was concluded that this would be the best tone upon which to rely for accurate testing.[23] This does not agree well with the work of Greenbaum, Kerridge and Ross in England, however. The lowest SD's that they found were 6.5 db, for 256 cps, 7.1 db for 4096 cps, and 7.0 for 8192 cps.[24] In another study done on this subject, as part of the National Health Survey, the tones with the lowest SD's were 7.4 db for 256 cps, 7.4 db for 512 cps, 5.9 db for 1024 cps.[25]

For diagnostic purposes, bone conduction testing is invaluable. In the selection of patients with otosclerosis for the fenestration operation it has been claimed that due to the downward slope of the typical bone conduction audiogram, the responses obtained

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[22] R. Carhart and C. Hayes, "Clinical Reliability of Bone Conduction Audiometry," The Laryngoscope, 59: 1093, 1949.

[23] Ibid., pp. 1096-97.

[24] D. Lierle and S. Reger, "Correlation between Bone and Air Conduction Acuity Measurements over Wide Frequency Ranges in Different Types of Hearing Impairments," The Laryngescope, 56: 219-20, 1946.

[25] Ibid.

at 2000 cps are of great importance.[26] It has been found more recently, however, that the 2000 cps tone is quite unstable, particularly following surgery.[27] This was first noted by Carhart and resulted in the Shambaugh-Carhart Formulation which calls for a correction of the preoperative bone conduction responses for the prediction of the post-operative hearing. In this formulation, the following amounts are subtracted from the obtained results: 5 db at 500 cps, 10 db at 1000 cps, 15 db at 2000 cps and 5 db at 4000 cps. It will be observed that by allowing 15 db for the 2000 cps results, the erratic behavior of this tone is taken into account. This formulation is useful for predicting the results of the stapes mobilization or the stapedectomy, also.

Presbycusis

One of the tenets of this dissertation is that in the future the population of the world will contain a great many more older people than it does now, and that this will present problems for the audiologists in the serving of their patients. It appears to be fitting, then, that the topic of presbycusis be discussed as a special form of perceptive hearing loss.

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[26] C. Koss, "A Statistical Study of Pure Tone Audiometry in Relation to the Fenestration Operation," Archives of Otolaryngology, 54: 367-77.

[27] G. Shambaugh and R. Carhart, "Contributions of Audiology to Fenestration Surgery, Including a Formula for the Precise Prediction of the Hearing Results," Archives of Otolaryngology, 54: 711, 1951.

Presbycusis, the hearing loss experienced by older people, appears to be the most common cause of perceptive hearing loss.[28] It becomes manifest when the loss of hearing invades the frequency range of the conversational voice.[29] According to some authorities, this is a very gradual deterioration process that is inevitable. It is recognized that hearing loss is not the lot of every elderly person, but it does happen often enough to make it a real concern for most older persons. It has been stated that normal hearing acuity can be considered as a curve rising from zero at birth, attaining its maximum at the completion of adolescence and gradually declining to a very low point at old age.[30] This curve, however, does not appear to be a normal one. In a large population sample aimed at determining the incidence of hearing loss, it was illustrated that "hearing loss is not normally distributed in the population as a whole . . . that the absolute hearing loss, dispersion and skewness increased with age and frequency."[31]

As a result of three surveys, it is believed that presbycusis starts after the age of fifty. This is evident from the results of the

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[28] J. Sataloff, Industrial Deafness (New York: McGraw-Hill Book Company, 1957), p. 35.

[29] K. Simonton, "Presbycusis: The Hearing Loss of Old Age," Geriatrics, 10: 756, 1957.

[30] H. Kennedy, "Maturation of Hearing Acuity," The Laryngoscope, 67: 756, 1957.

[31] A. Lansing, Editor, Cowdry's Problems of Aging (Baltimore: The Williams and Wilkins Company, 1952), p. 262.

World's Fair, San Diego County Fair and the United States Public Health Surveys. These studies indicated that the loss of hearing is not significant until the age of fifty, and then the average loss attributed to presbycusis is only 5.6% based upon the American Medical Association charts.[32] After the age of sixty, the loss is somewhat higher.[33] It has been stated that at the age of fifty the impairment of hearing is noticeable at the 2000 cps tone and that the ability to discriminate suffers when two or more persons are speaking.[34] On the PB word lists, the discriminatory ability of the presbycusic will be between 40% and 60%,[35] and the lack of attention and the slowness of cerebration make it appear worse than the test results show.[36] These are factors which make the person quite difficult to test, and which are not taken into consideration by some audiologists who attempt to rush through the testing with an older person.

The cause of this problem appears to be rather nebulous. The center of attention in all of the research appears to be in the area

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[32] M. Fox, "Evaluation of Hearing Loss in Drop Forge Workers," The Laryngoscope, 63: 969, 1953.

[33] Ibid.

[34] A. Lewy and N. Leshim, op. cit., p. 447.

[35] L. Alexander, "Diagnosis and Etiologic Considerations in Deafness in Older Persons," Journal of American Geriatric Society, 2: 390, 1954.

[36] Ibid., p. 389.

of the cochlea. Bunch felt that the loss for tones above 1000 cps is due to a lesion in the neural elements in the basal turn of the cochlea.[37] In another study done by Schuknecht, it was stated that there are two types of presbycusis. One is due to "epithelial atrophy" which is caused by degenerative changes starting at the basal end of the cochlear duct and proceeding toward the apex, affecting afferent and efferent nerves. This starts at middle age.[38] The second type is termed "neural atrophy" and is due to degeneration in the neural ganglion cells starting at the basal turn of the cochlea and superimposed upon varying degrees of epithelial atrophy. The onset of this type of loss is "late in life."[39] In another study done by Hilding, in an effort to find the cause of the 4000 cps dip so often seen on audiograms, it was found that the tactorial membrane was overextended in cases of presbycusis and hearing loss due to trauma. The site of this deviation was six to eight millimeters from the oval window, and this is the position of nerve endings for the 4000 cps and 6000 cps tones damaged so frequently in these cases.[40]

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[37] C. C. Bunch, Clinical Audiometry (St. Louis: C. V. Mosby Company, 1943), p. 109.

[38] H. Schuknecht, "Presbycusis," The Laryngoscope, 65: 418, 1955.

[39] Ibid.

[40] A. Hilding, "Studies of the Otic Labyrinth, VI Anatomical Exploration of the Hearing Dip at 4096 Characteristic of Trauma and Presbycusis," Annals of Otology, Rhinology and Laryngology, 62: 950-55, 1953.

In a great many cases of presbycusis, recruitment is found. This is the difficulty in which sensations of loudness are built up extremely rapidly from slight perception of sound to the threshold of pain. For example; if a person's response to speech at threshold is 25 db, and he reports that the same stimulus is too loud at 45 db, recruitment is said to be present. This condition is frequently seen in cases diagnosed as presbycusis. It has been claimed that:

> If, ... an old person with high tone deafness does show recruitment, it may be assumed that his aging has not affected his ganglion cells and that his hearing loss is due to hair cell damage caused--in the course of his long life--by noise, infection or drugs.[41]

This statement raises some doubt that the cause of presbycusis is aging alone. It could be as is stated in Cowdry's Problems of Aging:

> A high tone hearing loss which increases with each decade of life, . . . is characteristic of the aging. Before it can be said that aging is a cause of deafness a better understanding of the reasons for similar hearing impairments for young and middle aged groups is necessary. It is probable that impairment for high tones is established before the time of aging and processes associated with it cause further deterioration. Acoustic trauma is to be seriously considered as one of the most important contributing factors for all age groups.[42]

As has been stated earlier in this chapter, the audiogram of the individual with a perceptive loss should show equal hearing loss by bone conduction and by air conduction. There is one exception, and

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[41] M. Saltzman, "Presbycusis," Archives of Otolaryngology, 66: 68, 1957.

[42] A. Lansing, op. cit., p. 274.

that is in the possibility of the Bernero phenomenon in presbycusic subjects. In this condition, the loss by bone conduction at 500 cps is greater than it is by air conduction by 10 db to 15 db.[43] Other than this, the air conduction and bone conduction responses should agree well. The Bernero phenomenon appears to be due to a central perceptual disturbance and not solely of peripheral origin. This tends to agree with the tentative diagnosis of damage to the cerebral cortex when the subject complains of his inability to hear in groups, but who hears when under optimum circumstances of quiet, speech is delivered at a slow pace, and he is concentrating.[44]

In presbycusis, when the loss is a gradual one, there is little fear of total deafness.[45] Actually, it has been claimed that the acuity for the tones under 2000 cps does not change much with advancing age, but the losses above this frequency become more severe.[46] This, of course, fits in well with the discriminatory problems cited earlier. In situations where the low tones are affected, it is probable that the case is not one of pure presbycusis but of the

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[43] R. Carhart, "Audiometry in Diagnosis," The Laryngoscope, 68: 272-74, 1958.

[44] J. Bordley and H. Haskins, "The Role of the Cerebrum in Hearing," Annals of Otology, Rhinology and Laryngology, 64: 381, 1955.

[45] N. Canfield, "Cause and Prevention of Hearing Loss," The Hearing Dealer, 9: 28, 1959.

[46] C. Bunch and T. Raiford, "Race and Sex Variations in Auditory Acuity," Archives of Otolaryngology, 13: 433, 1931.

mixed type of hearing loss.[47]

There is much to be considered when working with an older person, but the problem is still his desire to hear speech. In this, he does not react differently from the younger person with a comparable hearing loss. The selection of a hearing aid presents basically similar problems for the two age groups.

The Relationship of the Hearing Aid to Pure Tone Testing

There appears to be a direct relationship between the hearing aid and the pure tone test results obtained on any subject, but in the actual selection of the hearing aid, the frequencies of 500 cps, 1000 cps and 2000 cps are the important ones. The whole range of hearing tested by pure tone is not of equal value in terms of discrete frequencies. This is verified by Davis when he said that the hearing aid should transmit tone from about 300 cps through 3000 cps and that the tones over 4000 cps add little to the intelligibility of speech heard and can not be heard comfortably by the hard of hearing person.[48] Therefore, it can be seen that for a hearing aid evaluation, the tones above these limits are of little value in that they are not used, and in fact, may present confusion to the aid user.

Of course, the frequencies of 300 cps through 3000 cps do not tell which of the usually tested tones should be included in the

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[47] J. Sataloff, *op. cit.*, p. 279.

[48] H. Davis *et al.*, "The Selection of Hearing Aids," *The Laryngoscope*, 56: 85, 1946.

evaluation of a hearing aid. With the strongest speech sounds clustering about 1000 cps to select an effective hearing aid for a person, there should be usable hearing at 500 cps, 1000 cps and 2000 cps.[49, 50] This is the range of hearing necessary to understand speech effectively with or without a hearing aid.

The critical frequency range of the present day hearing aids does not vary much from the recommended range of 300 cps to 3000 cps with the exception of the upper limit. In many of the newer aids, the actual upper limit is close to 4100 cps but drops off sharply after peaking at about 3200 cps. This, naturally mitigates against the subject receiving the maximum value of those tones over 3200 cps.

With reference to the bone conduction receivers for hearing aids, a much different problem is presented than with air conduction receivers. This is true not only because of the variables presented in the section of this chapter on bone conduction testing, but also for reasons peculiar to the oscillator which is necessary to transmit the speech. In discussing these receivers, West says:

> High frequency sounds projected through this type of receiver are too largely absorbed by the tissues of the mastoid prominence, to which it is attached, and are not transmitted to the cochlea. Thus are lost some of the most necessary and least dispensable components of speech sounds--components that a well designed air

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[49] L. Watson and T. Tolan, _op. cit._, p. 279.

[50] _Ibid._, p. 355.

> conduction receiver can transmit to the cochlea of the wearer.[51]

This fact has been put in another way. It has been estimated that 15% of the intensity generated by the hearing aid reaches the cochlea through bone conduction and the rest through air conduction.[52] Therefore, it can be seen that if a subject is given a bone conduction receiver, his hearing would be quite limited without a very powerful instrument. Even with a powerful aid, the range of usable hearing is restricted. "The frequency response of most bone conduction units is limited to the range between 256 and 2048 double vibrations per second,"[53] but the higher of these tones is not powerfully transmitted. These are probably some of the reasons that this type of aid is not being recommended as often as formerly.

In summary, it can be said that there is a positive relationship between the hearing aid characteristics and the pure tones usually tested. As indicated above, the relationship seems to be primarily in the middle frequencies. It is also true that

> In selecting a hearing aid, the audiogram is most useful as a guide to how powerful an instrument will probably be needed--not as a guide to the best frequency characteristics. The audiogram also reveals the cases of abrupt high tone nerve deafness that can not be helped much by a any hearing aid because their abilities to hear high tones has been lost completely.[54]

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[51]R. West, A. Ansberry and A. Carr, The Rehabilitation of Speech (New York: Harper & Brothers, 1957), p. 242.

[52]L. Watson and T. Tolan, op. cit., p. 395.

[53]L. Hedgecock, "A University Hearing Aid Clinic," Journal of Speech and Hearing Disorders, 12: 326, 1947.

[54]H. Davis, Hearing and Deafness (New York: Rinehart & Company, 1947), p. 209.

Speech Reception Testing for Threshold (SRT)

The process of speech reception testing was not used to any great extent before the advent of the profession of Audiology. Since the Second World War, much has been accomplished to develop this method of hearing testing to a high degree of accuracy. It seems that as a result of the research, some question is being raised relative to the value of pure tone testing except for original diagnosis. As Hirsh said:

> Although a measure of a person's sensitivity to pure tones of different frequency tells us a good deal about the characteristics of his auditory system, such measurement is too limited to describe the same individual's ability to understand the speech of his fellow communicators.[55]

and that:

> The analysis of a patient's hearing loss for pure tones at different frequencies probably gives us the most detailed information possible, so far as otologic diagnosis is concerned. But there is a seeming lack of validity in the hearing of pure tones, especially since most humans use their auditory systems to hear speech and other more complicatėd stimuli. Although many attempts have been made to calculate or estimate the ability to hear speech on the basis of the ability to hear pure tones, the most promising measure seems to be that of the hearing of speech itself.[56]

This view has also been taken by Sataloff, and he claims that this is one of the most important points to be considered in the evaluation of

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[55] I. Hirsh, The Measurement of Hearing (New York: McGraw-Hill Book Company, 1952), p. 119.

[56] Ibid., p. 268.

any audiogram.[57] Because the SRT is a rather new method of testing the hearing function of the human, some question of its reliability is sure to be raised. Properly administered, the SRT procedure is as reliable and provides the same degree of precision as is found in pure tone tests done with a clinical audiometer.[58]

Testing a subject's speech reception threshold abilities is done in several ways. It can be done with standardized sentences to be answered; a running commentary to which the subject will say, "Yes, I can still hear it," or "No, I can not hear it," as the level of the intensity is reduced; or with the Spondee words described in Chapter One. The latter is the usual means of testing at the Hearing Clinic. These words are read to the subject over the speech circuit of the speech audiometer starting with an intensity loud enough for the subject to hear adequately. After the first three of six words have been successfully identified by the subject, the intensity is reduced by ten decibels. This procedure is repeated until the subject misses approximately 50% of the six words in one group. The intensity is then increased by five decibels to determine if the threshold is between the level of the last most successful group of six words and the more recent group in which more than three words were incorrectly identified.

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[57] Sataloff, op. cit., p. 288.

[58] H. Davis, Hearing and Deafness, op. cit., p. 140.

The lowest level at which 50% of the words are repeated correctly is the subject's threshold of hearing for speech. It has been determined in this type of testing that the acuity at 1000 cps has the most influence on the Spondee words at threshold level.[59] As for the rest of the frequencies usually tested, the pure tones, "above and below 500 cps and 2000 cps have no significant influence upon the predicted value of hearing loss for . . . spondee speech."[60]

In order to predict a subject's speech reception threshold, it is necessary to look first at the characteristics of the audiogram in the area of 500 cps through 2000 cps. If this area shows a rather flat pattern with nearly equal loss at all three frequencies involved, the responses are added and then divided by three. The resulting quantity is the predicted value of the SRT. If, however, the pattern is a sloping one, the best two responses are added and divided by two to obtain the predicted value of the SRT. Although it has been found that there is a high degree of correlation between the average response value in the frequency range of 500 cps through 2000 cps and the predicted SRT value, the prediction is not always precise. In cases of high tone hearing loss involving 2000 cps, the predicted value obtained by the above methods is likely to be poorer than the actual SRT. This is due to the fact that the SRT is less dependent upon the 2000 cps tone

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[59] R. Quiggle et al., "Predicting Hearing Loss for Speech from Pure Tone Audiograms," The Laryngoscope, 67: 13, 1957.

[60] Ibid., p. 10.

than on 500 cps and 1000 cps.[61] If a pattern shows a sharp loss above the 2000 cps level, the predicted SRT will correlate well with the obtained SRT.[62] This means, then, that with a conductive hearing loss, which is usually represented by a flat pattern, the SRT can be predicted quite well; but the perceptive hearing loss, which normally has a sloping pattern, will be more difficult to predict accurately.[63] Since the predicted value of the SRT and the obtained SRT serve as a check upon each other, a discrepancy of more than 10 db should be investigated.[64] This may result from inaccurate pure tone or SRT testing or a psychological problem within the subject.

In the past, several correlational studies have been conducted, aimed at determining the relationship between the results of the Spondee word tests (SRT) and the average threshold obtained as cited above for a flat audiometric pattern. Among these studies it has been found that Product-Moment Correlations of .85 and .75 were obtained.[65, 66] This indicates a good relationship. In another study

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[61] R. Carhart, "Speech Reception in Relation to Pure Tone Loss," Journal of Speech and Hearing Disorders, 11! 107, 1946.

[62] Ibid.

[63] A Juers, "Pure Tone Threshold and Hearing for Speech-Diagnostic Significance of Inconsistencies," The Laryngoscope, 66: 1956.

[64] F. Weille, "Speech Audiometry in Practical Use," Archives of Otolaryngology, 55: 663, 1952.

[65] J. Sullivan, "A Statistical Analysis of Audiometric Surveys in the Royal Canadian Air Force," Annals of Otology, Rhinology and Laryngology, 55: 839, 1946.

done by Thurlow *et al.*, using the tones of 512 cps, 1024 cps, 2048 cps and 2896 cps on 110 ears, it was found that the tones and the Spondee word tests (SRT) agreed to the degree of .74. Despite this fairly good correlation, it was reported that the authors felt that the Spondee word tests (SRT) were more reliable than the pure tone tests.[67]

In various instances, subjects have been tested with the same Spondee words after a lapse of a relatively short period of time, and the effect of this upon the obtained threshold has been questioned. Recently, it was shown that a short term practice with the Spondee words, as in the usual testing situation, had no appreciable influence on the threshold of normal hearing subjects and prior knowledge of the Spondee vocabulary improved the threshold by only 4 or 5 db.[68] This, of course, does not tell how the short term practice would effect the hard of hearing subject. Until more information is forthcoming, it must be considered suspect.

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[66] R. Carhart, "Monitored Live-Voice as a Test of Auditory Acuity," *Journal of the Acoustical Society of America*, 17: 344, 1946.

[67] W. Thurlow *et al.*, "Further Statustical Study of Auditory Tests in Relation to the Fenestration Operation," *The Laryngoscope*, 59: 119, 1949.

[68] T. Tillman and J. Jerger, "Some Factors Affecting the Spondee Threshold in Normal Hearing Subjects," *Journal of Speech and Hearing Research*, 2: 141-46, 1959.

Speech Reception Testing for Discrimination (SRD)

More important than hearing speech is the ability to understand what is said. Without this ability, a person's communication with his fellows is lost. Therefore, testing the discrimination of the subject is very important and should never be omitted or slighted. The procedure for establishing the SRD was described in Chapter One. Suffice to say here that a level of about 40 db above threshold is used because it has been found that the ability to understand speech does not improve appreciably above this intensity level.

In Chapter One, it was stated that the results of the SRT and the SRD appear to be all that is needed to do an adequate hearing aid evaluation. The SRT can indicate the power and the response curve of the aid and the SRD the characteristics of the receiver. It has been reported that the "Spondee words emphasize the vowel sounds from 1500 cps, whereas the PB, or phonetically balanced, words emphasize the consonant sounds from 1500 cps to 3000 cps."[69] It has also been shown that good correlations (.84 and .81) exist between the tones of 1000 cps and 2000 cps and vowels and that the frequencies of 500 cps, 1000 cps and 2000 cps are equally highly correlated with consonants.[70] For monosyllabic words such as those used in PB testing, Hirsh feels that the range from 1500 cps to 2500 cps is the

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[69]J. Sataloff and S. Belasco, "Audiology," Archives of Otolaryngology, 60: 83, 1954.

[70]Jean Utley, "The Relation between Speech Sound Discrimination and Percentage of Hearing Loss," Journal of Speech and Hearing Disorders, 9: 103-113, 1944.

most important for good intelligibility.[71] From this it can be concluded that the shape of the pure tone audiogram will reveal much about discrimination, as it does about threshold. A flat audiogram will show that there should be little trouble with understanding speech as long as the speech is loud enough. A loss which is characterized by a slope toward the lower right hand corner of the audiogram will show that the subject will probably have discriminatory trouble.

In the area of diagnosis, speech reception testing is of value, also. In selecting subjects for the fenestration operation on the basis of the PB scores achieved, Silverman and Walsh stated that, "It should be pointed out that the suggested diagnostic procedure does not detect nerve deafness above approximately 3500 cps, but this area is of little practical significance for the purpose of the test," and that it does away with the tuning fork and bone conduction testing.[72] It has been claimed, too, that "word hearing tests demonstrate in otosclerosis . . . a great degree of deafness for words falling within the lower frequencies."[73]

The SRT is useful in determining the power of the hearing aid because of its close relationship to the pure tone responses in the critical area of 500 cps through 2000 cps, and the SRD can be

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[71] I. Hirsh, op. cit., p. 141.

[72] S. Silverman and T. Walsh, "Diagnosis and Evaluation of Fenestration," The Laryngoscope, 56: 547, 1946.

[73] J. Ersner and M. Saltzman, "Speech Hearing in Otosclerosis," Archives of Otolaryngology, 46: 754, 1947.

used to determine the area of the range of hearing that needs improvement. Indeed, much information is gathered by speech reception testing that is being ignored by the audiologist. For example, how many audiologists take the time to write down the words that a subject misses during the SRD testing? These words could be carefully analyzed in a relatively short period of time to determine just what the pattern of missed words tell as to the consonants mis-heard. In practice, however, this may increase considerably the time for diagnosis.

<u>The Social Adequacy Index (SAI)</u>

In an earlier section of this chapter, the percentage of hearing loss as advocated by a committee of the American Medical Association was discussed and dismissed as being inadequate. Recently, another method was devised which provides a measure of social adequacy of the subject. This is a much more meaningful scale; and it is based upon the results of the SRT and the SRT tests. Hirsh has indicated:

> The Social Adequacy Index for hearing, . . . represents a more recent attempt to assess a man's ability to hear with respect to everyday communication. The SAI is . . . a percentage, but this percentage is not intended to be related to a unidimensional total capacity to hear. Rather this percentage refers to the average percentage of words that will be repeated correctly by a listener at three levels which correspond to weak, moderate and loud conversation.[74]

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[74] I. Hirsh, op. cit., p. 294.

All that is needed to compute the SAI is the hearing loss for speech as determined by the SRT and the percentage of words missed in the SRD. These scores are then applied to a specially compiled table.[75] In this table, the abscissa represents the SRT scores and the ordinate, the SRD scores. The point where these cross is the SAI for the person in question. In this table, a percentage of 67% will mean that the subject will have some trouble hearing and understanding speech but will be able to get by in a social sense. With a percentage of 33, he will find it impossible to understand in conversations and in business. Between these percentages, he will have varying degrees of trouble.

Although a sufficient amount of research has not been done to ascertain the exact usability of the SAI, it appears obvious that this method of determining social adequacy is more acceptable than the American Medical Association Scale. It seems to discriminate better between individuals with different audiograms. It is possible that it can be used to illustrate the amount of hearing trouble a person will have, and it may be useful to show the degree of improvement in social adequacy that a person can obtain with a hearing aid.

Summary

In this chapter, the literature pertaining to pure tone and speech reception testing has been reviewed to determine their

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[75] For the Table used in computing the SAI, see Newby, *op. cit.*, p. 116.

relationship to each other. It has been found that a very definite correlation exists between the 500 cps, 1000 cps and 2000 cps tones and the threshold of intelligibility obtained by SRT. Through the relationship between the vowels and consonants and the pure tones, there is a possibility that the SRD can estimate the slope of the audiogram.

Because it seems to be quite important for many subjects entering a hearing clinic for a hearing aid evaluation, the percentage of hearing loss was discussed in the light of the A. M. A. scale and the newer Social Adequacy Index (SAI) devised by Davis et al. at Central Institute for the Deaf. Although research appears to be lacking on the SAI, it seems to have good potential for the determination of a person's social adequacy. At any rate, it appears much more useful than the A. M. A. scale.

In the area of bone conduction testing, it was found that some confusion exists as to the frequencies to be tested, but there does seem to be a general agreement among the various authorities that the middle range, from 500 cps through 4000 cps, proves to be the most stable. It was also pointed out that the 250 cps tone may not be reliable because the subject is apt to respond not to the auditory sensation but to the cutaneous sensation caused by the oscillator.

Included in the section on bone conduction was a discussion of the perceptive hearing loss of presbycusis. This was included because one of the tenets of this study is that the population of this country is gradually shifting to an older age level, and that this shift will, in time, cause the audiologist difficulties unless preparations are made now to cope with it.

Following a rather brief discussion of the relationship of the hearing aid to pure tone testing, in which it was found that the audiogram is quite limited in its usefulness, the SRT and the SRD were analyzed. The literature of recent years questions pure tone testing for hearing aid evaluations. The general reaction observed in the literature has been summed up by Newby:

> The speech audiogram can be used in much the same manner (as the pure tone audiogram) but with much more assurance since with the pure tone audiogram only speculation is possible, whereas the speech audiogram shows this effect.[76]

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[76] Newby, op. cit., p. 128.

CHAPTER THREE

DESIGN OF THE STUDY

Two procedures were followed in this study to determine the effectiveness of the Long and the Short Forms. The first procedure was to administer two tests to each of 40 subjects; one consisting of a pure tone air conduction test, a pure tone bone conduction test, a Speech Reception Threshold test, and a Speech Reception Discrimination test. The other test consisted of the Speech Reception Threshold (SRT) and the Speech Reception Discrimination (SRD) tests. These two forms of the test were combined in four different ways to provide four testing situations. The findings were statistically analyzed. A description of the two tests and the statistical methods followed.

A second procedure consisted of an independent validity verification of the Short Form described above as the SRT and SRD tests only. To accomplish this, two judges were presented with the speech reception data only from 64 cases chosen from the files of the Michigan State University Hearing Clinic. The judges were requested to classify the persons in terms of the hearing aid strength (strong, moderate, weak, no hearing aid) needed on the basis of the SRT and SRD scores only.

Experimental Design Procedures

The purpose of this study is to determine if a competent hearing aid evaluation can be done by using only the SRT and the SRD to judge the instrument to be recommended, and the ear upon which to put it. The selection of the type of instrument (i. e., air conduction or bone conduction) depends to some extent upon the score obtained on the Speech Reception Discrimination (SRD) test. If the SRD score is below 75%, the indication is that the subject has a perceptive hearing loss which will not be helped by a bone conduction hearing aid, assuming that the PB words have been read to the subject at an intensity of approximately 40 db above the SRT. With the perceptive type of hearing loss, the subject would probably never attain a PB score above 75%. On the other hand, if the subject's SRD score was close to 100%, the indication is that the loss is being overridden by the supra-threshold intensity, and the loss is conductive. With a conductive hearing loss, a bone conduction hearing aid may benefit the subject as much, or more, than an air conduction aid. If the audiologist has reason to believe that the subject has a conductive hearing loss, a bone conduction hearing aid is certainly worthy of consideration. The ear upon which the hearing aid will be placed is to be discussed in a later section of this chapter.

The individual tests used in this study are part of the usual battery administered to all persons given a hearing aid evaluation at Michigan State University Hearing Clinic, it is necessary to compare the results obtained with (1) the SRT and the SRD, and (2) the results obtained with the entire battery. The usual tests given are:

1. The pure tone air conduction test.
2. The pure tone bone conduction test.
3. The Spondee word lists to determine the threshold for speech (SRT).
4. The phonetically balanced (PB) word lists to determine the comprehension of speech at a supra-threshold intensity of about 40 db over the SRT. This is the SRD test.

This battery (tests 1, 2, 3 and 4) will be referred to henceforth as the "Long Form," and the term "Short Form" will refer to only the SRT and the SRD.

The Long Form and the Short Form were combined in all possible ways to obtain the desired comparisons. The subjects were required to take two tests, each one about a week apart. Table 1 illustrates this plan.

TABLE 1.--The audiometric test combinations

Tests	Groups			
	I	II	III	IV
First test	A	A	a	a
Second test	A	a	A	A

Key: A = Long Form

a = Short Form

In Table 1, it can be seen that all possible test-retest combinations of the two tests are incorporated in the research.

The ten subjects in each group were randomly assigned to their groups. As the subjects reported for their first test, a coin was tossed. If the coin landed "heads," the subject was put into either group I or II. If the coin landed "tails," the subject was put into either group III or IV. The coin was tossed a second time to determine the exact group into which the subject would be placed. Depending upon the results of the first toss, "heads" indicated group I or III and "tails," group II or IV. This provided randomization except for the last subject.

Selection of the Subjects

The subjects for this study were selected primarily from the existing records of the Michigan State University Hearing Clinic. The records were examined for persons over the age of 18 who were living in or close to Lansing, Michigan, and students and faculty members at the University. A total of 55 of the "off campus" people were selected randomly and contacted by letter. The letter stated that a retesting service was being offered by the Hearing Clinic. It was felt that regardless of the actual reason for the testing, although a follow-up service in the Clinic has been desired, they were receiving a service and that their lack of knowledge of the ultimate use of the results would not bias the study. If they had been told of the actual use of the results, they may have thought of themselves as "guinea pigs" and probably would have rejected the service. (See Appendix A for the letter.) Besides feeling that they were "guinea pigs," the subjects may exhibit the "Placebo" effect. By this is meant the difficulty of ascertaining the effect of the test upon them. They may not respond in such a way as to give a true picture of their hearing. For example, the subject may not respond to the least intensity to which he is capable. It is highly unlikely, however, that the opposite would be true in that he would respond to intensities below that set by the physical limitations of his hearing loss, no matter how hard he may listen.

The "on campus" people were contacted by telephone and told the reason for the testing. With the extent of research being conducted in a University, this procedure was thought to be advisable. There were 21 such subjects, and 19 actually used in the study.

Two of the subjects were not selected in the manner described above. One was referred by a Lansing physician and the other by a hearing aid dealer. Both subjects were 64 year old males.

Taking part in the research were 30 males and 10 females. Their ages ranged from 18 to 81 years with a mean age of 39.45 years. In Table 2, the test combinations, the age range and the mean age by groups are summarized.

TABLE 2. --Tests given, age range, and mean age by groups

Groups	Tests 1	Tests 2	Age range	Mean ages
I	A	A	18-81	37.7
II	A	a	18-64	41.0
III	a	A	19-79	40.4
IV	a	a	22-61	38.5

Key: A = Long Form a = Short Form

Equipment and Materials--Testing Facilities

The testing facilities were identical with those used in testing the hearing of any person who comes to the Michigan State University Hearing Clinic. There is a two room arrangement consisting of a control room measuring 10 feet by 7 feet 10 inches and a sound room which is 9 feet 6 inches by 7 feet 6 inches and 10 feet 6 inches from the ceiling to the floor. There is a window between the two rooms which measures 23 inches by 12 inches in the control room and 32 inches by 12 inches in the sound room. This window has two perpendicular panes of glass separated by a third pane set at about a 60 degree angle.

The control room contains an Allison 20-A audiometer. The sound room is a quiet room lined with acoustic tiling, with the exception of a strip of plaster three feet wide extending upward from the floor. The floor is heavily carpeted. The Riverbank door is three inches thick. The ambient sound level in this room is approximately

25 db as measured with a Type 759-B General Radio Company sound level meter.

All of the pure tone testing was done in the sound room with the door closed. This provided a quiet situation for accurate testing.

The speech reception testing was done with the Allison unit using the two room arrangement. This setting provided good visibility of the subject by the tester through the window mentioned above. The subject's responses were heard by the tester over the subject talk-back earphone.

Equipment

The pure tone air and bone conduction testing was done with a standard Beltone Model 12-A audiometer modified only by the addition of a special circuit to allow the instrument to be used for group hearing testing as well as for individual testing. This circuitry was inactive. There are two TDH-39 earphones with this machine which have MX-41/AR rubber pads. This is a new audiometer and is in good calibration.

The speech reception testing was done with the Allison 20-A audiometer with earphones which are type PO-H-3/ARR-3 CTE with MX-41/AR rubber pads. Because of the possibility of feedback from the loudspeaker when the intensity of the output exceeded 50 db, all subjects were tested with earphones. This allowed the intensity to be maximum (110 db) if necessary.

Materials

The materials used were four lists of Spondee words, two lists of PB words, and the usual audiogram form used with all clinical subjects. (See Appendix B.) Two of the Spondee word lists were used randomly for the initial testing (see Appendices C and D), and two were used in the same manner for the second testing situation (see Appendices E and F). The PB list presented in Appendix G was used in the first test, and the PB list seen in Appendix H in the second. The two separate sets of lists were necessary because several of the subjects had been tested, on three or four occasions, with the set used in the first testing situation. It was believed that the introduction of the second set of lists would tend to substantiate the first test results. This was borne out by the good speech reception correlations obtained between the two testing situations for all four groups (to be discussed in detail in Chapter Four). Therefore, it is believed that bias was not introduced by the inclusion of the second set of Spondee and PB words.

Clinical Procedure--Long Form

The procedure used in giving the Long Form of the research was the same as that generally used at the Michigan State University Hearing Clinic. Because all but two of the subjects were known to the tester, the initial interview was reduced to a few minutes. The two new subjects were interviewed for fifteen minutes. The subject was then conducted to the sound room and seated with his back to the side of the Beltone 12-A audiometer so that his profile could be clearly seen by the tester. He was then told that he would hear a series of faint tones of different pitch, and he was asked to raise his hand every time that he could detect a tone. He was also told that the test would begin with the right ear. The earphones of the 12-A were then put into place with the opening in the rubber pad directly over the external auditory meatus. The testing was begun with the presentation of the 1000 cps tone well above the estimated threshold for that sound, or, failing to gain a response, the intensity of the sound was increased until a response was obtained. The threshold was attained by decreasing the intensity of the sound in 10 db steps until there was no response. The intensity was then increased 5 db to determine if the threshold was between the two previous stimulations. When the subject responded at least fifty percent accurately to a group of stimulations at 1000 cps, the threshold was considered to have been found. The thresholds for 2000 cps, 4000 cps, 6000 cps, 1000 cps (for verification of the first threshold), 500 cps and 250 cps were obtained in the same manner.

The bone conduction testing was done in a manner similar to that of the air conduction testing. The oscillator was placed over the mastoid process. The subject was told that the sounds that he would hear would be identical to those heard by air conduction and to respond in the same manner, by raising his hand. The order of the sound stimulations was the same as those presented above with the exception of the 6000 cps tone which is never tested by bone conduction. Masking was not done during this testing because none of the subjects showed audiometric patterns resembling shadow curves or asymmetrical patterns that would indicate a need for masking.

When the pure tone testing terminated, the subject was asked to move to a chair facing the window between the control room and the sound room. He was told that the next phase of the testing consisted of the repetition of words said by the tester and that these would gradually be reduced in intensity until he would not be able to identify the words. He was also told that he would hear the words first with both ears and then with just the right ear and then the left. In order to conserve time, the subject was told that following this test, another test would be given in which the voice of the tester would be loud enough for him to hear comfortably and that these words would be short, one syllable words spoken in the same manner as the two syllable words. Obviously, the first test utilized the Spondee words and the second the PB words. The tester then entered the control room and talked to the subject over the earphones until he indicated that he could hear the tester fairly well. The test then began with the tester reading the first six two-syllable words into the microphone one at a time with his lips and lower face shielded to give the subject no visual cue to the words. Each word was preceded by the carrier phrase, "The next word is . . . ." Following the first six words, the intensity of the output was reduced 10 db for every six words until the subject failed to respond correctly to 50% of the words or better. The intensity was then increased by 5 db and the next six words read. If the subject responded with the correct word at least 50% of the time, this was recorded as the threshold for speech. If he did not, the last intensity at which 50% of the words were correctly identified was considered the threshold. For example, if the subject responded to at least 50% of the words correctly at an intensity of 40 db, the output of the Allison unit was reduced to 30 db. At this intensity, if he missed more than 50% of the words, the output was increased to 35 db. If he correctly said at least 50% of the words at 35 db, this was considered his threshold. If he did not, 40 db was the recorded threshold.

The output selector was then turned to the right ear, and this ear was tested. The intensity of the output was increased until the subject indicated that he could hear the tester talking fairly well. With this intensity, the test began and continued as described above until the threshold for the right ear was obtained.

The testing of the left ear was begun with the increase of the intensity of the output until the subject could, again, hear the tester's voice well. From this reference point, the first six two-syllable words were read to the subject in the manner described above.

When the threshold for the left ear was found, this phase of the procedure ended.

It has been stated by Newby that masking should be done if, by pure tone air conduction, the poorer ear is 40 db below the better ear.[1] He also indicates that masking should be carried out during the speech reception testing if the need for it is determined by air conduction.[2] In these statements, however, he does not mention the approximation of the SRT by the pure tone air conduction test described earlier. There is a strong possibility that, if masking is necessary, the SRT and the pure tone air conduction test will not be in agreement. This condition would present doubts in the mind of the audiologist as to the validity of the two tests and masking would be called for. In the present study, there were four individuals who illustrated air conduction patterns in which the poorer ear was at least 40 db below the better ear. In each instance, though, the SRT was in agreement with the pure tone air conduction test results, and masking was not needed.

When the threshold for speech was established binaurally and monaurally, the output of the Allison unit was increased by about 40 db above the SRT. The PB word list was then read to the subject one word at a time binaurally with the carrier phrase, "The next word is . . . ." preceding all fifty words. After the subject had responded

[1]Newby, _op. cit._, p. 78.

[2]_Ibid._, p. 119.

to all fifty words, the selector was turned to the right ear and the fifty words for that ear were read to the subject with the carrier phrase. Following the completion of these words, the selector was turned to the left ear and the fifty words for that ear were read to the subject with the same carrier phrase. For both the right and the left ear, the approximately 40 db supra-threshold intensity was maintained. In two instances the supra-threshold intensity could not be adhered to. The subjects stated that this level was uncomfortable. This illustrated the phenomenon of recruitment in which the sensation of intensity increases rapidly, and the threshold of pain is reached more quickly than in a person without recruitment. In these cases a 35 db threshold was used.

Following the completion of the PB word lists, the percentage of correct responses was calculated. To do this, each word was worth two percentage points. The number of correct responses was added and multiplied by two. This was done for the binaural and monaural responses.

At this point, the testing was terminated. The results were discussed with the subject to inform him of the stability of his hearing since his last test. A second appointment was made to complete the experimental procedure.

Clinical Procedure--Short Form

The Short Form of the study was done in an identical manner to the speech reception procedures described above.

Analysis Procedures

The analysis procedures used in this study were directed at determining whether a real difference existed between the results obtained by the Long Form and the Short Form. A second goal, that of a difference in the hearing aid recommended by the Long and Short Forms, was done through observational analysis of the data.

The population of this study consisted of adults living in the Lansing area who have been given hearing tests at the Michigan State University Hearing Clinic and showed some degree of hearing loss. The sample consisted of those persons taken from the population who partici pated in the study.

In order to ascertain if a difference did exist between the Long and the Short Forms of the hearing aid evaluational procedures, it was necessary to determine the degree of correlation between the two tests. This was done with the use of the Spearman Rank-order correlation coefficient (r). To obtain this correlation coefficient, the subjects were ranked according to their scores on the two SRT tests. These rankings were then compared and the difference in rankings obtained through subtraction. Differences were then squared to eliminate minus signs. The squared differences were then added. This sum (Σ) was entered into the formula:

$$r = 1 - \frac{6\Sigma D^2}{N(N^2 - 1)}$$

In the above formula, N equals the number of subjects in the group, and D^2, the squared differences in the ranks obtained on the first and second tests.[3]

The assumptions of the Spearman Rank-order correlation coefficient are:

1. The scores must be derived from a continuous distribution. This assumption is satisfied in the present research by the fact that the hearing acuity of any subject could have been measured to closer than 1 db. However, 5 db steps were used because most commercial audiometers are calibrated in 5 db steps, only, and this is the usual increment used in clinical audiometry. For example, a subject's SRT may be recorded at 25 db. It is known that his actual SRT may be 21 db, 22 db etc. to 25 db. Or it may be between 21 db and 22 db. Therefore, there is a continuous distribution presented by the decibel. The percentage figures that are presented by the SRD test are also on a continuum. For example, if a subject scores 78% correctly identified words, it is known that the actual percentage may be 74%, 76%, or 78%. This, too, presents a continuous distribution.

2. The two groups must be drawn from the same population.

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[3]S. Siegel, Non-Parametric Statistics for the Behavioral Sciences (New York: McGraw-Hill Book Co., Inc., 1956), pp. 202-13.

In the usual situation in which the Spearman Rank-order correlation coefficient is used, there are two separate groups of subjects--one group taking the first test and another taking a modification of the first. In the present research, the same subjects took the first and the second tests. Therefore, the subjects for this study were drawn from the same population.

3. The scale used in the study must be at least an ordinal scale. In statistics there are four scales of measurement varying in complexity. They are the nominal, ordinal, interval and ratio. The characteristics of these scales are as follows:[4]

   a. Nominal Scale: Numbers are used for the purpose of identification, such as the number on a football player's uniform.

   b. Ordinal Scale: Order is present in the rating of groups, items, or individuals. For example, if the football players were arranged not according to numbers but according to the weight of each man. With this, a "greater than" and "less than" relationship is established. An ordinal scale has all of the qualities of a nominal scale, also.

   c. Interval Scale: A common and constant unit of measurement is present which assigns real numbers to all pairs of objects in an ordered series. An interval scale has all of the qualities of the above two scales.

   d. Ratio Scale: A ratio scale possesses all of the qualities of the above three scales as well as a true zero as its origin.

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[4] Ibid., pp. 22-28.

Since the decibel scale presents an orderable arrangement of intensities, an ordinal scale is present. When an ordinal scale is present, a nominal scale is also. The intervals between each decibel are not equal, consequently, an interval scale is not seen. Since there is no absolute zero point at which the audiometer is not emitting sound, the ratio scale cannot be considered. The Spearman Rank-order correlation coefficient was used because of the small sample sizes involved in each group. A more powerful parametric statistic was not used because the assumption concerning normality of distribution could not safely be met with these small samples.

The advantages of the Spearman Rank-order correlation coefficient are as follows:[5]

1. This is one of the best tests for determining differences when subjects can be ranked in two ordered series.
2. The test establishes the closeness of the relationship between variables; in the present study these variables were the Long and the Short Forms.

The limitations of this correlational procedure are:[6]

1. A Pearson Product moment correlation coefficient (r) is estimated slightly high by the Spearman Rank-order

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[5] Ibid., p. 202.

[6] Ibid., p. 213.

correlation coefficient.

2. The efficiency of the Spearman is .91 when compared with the Pearson Product-moment correlation. This means that in using the Spearman more subjects would have to be used in order to obtain the same correlation (r) that could be had with the Pearson.

The lowest Spearman correlation for the four groups under study was also subjected to a test of significance to determine the probability under the hypothesis of no test difference (null) of obtaining any value as extreme as the lowest value found. The lowest correlation was used because if it proved to be significant at the 5% level of confidence (meaning that a correlation as low as this would be found only five times per one hundred tests, by chance alone) then, because "n" was constant, all of the higher correlations would also be significant. This was done with the following formula:

$$t = r\sqrt{\frac{n-2}{1-r^2}}$$

In this formula, "t" is the symbol used to designate the "Student" test of significance, "r" is the symbol for the obtained correlation by the Spearman formula and "n" is the symbol for the number of subjects in the group.[6]

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[6] *Ibid.*, p. 212.

The assumptions of the "t" test are:[7]

1. The observations must be independent.
2. The observations must be drawn from normally distributed populations.
3. These populations must have the same variances.
4. The variables involved must have been measured on at least an interval scale (as described above).

The advantages of the "t" test are:[8]

1. It is an extremely powerful test to determine the probability of an obtained "r" (correlation) being equal to zero.
2. There is an exact, known distribution for the "t" ratio, and it applies to samples as small as ten.

The limitations of the "t" test are:

1. When the sample is small, there is a greater chance of of error in estimating the probability than with larger samples.

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[7] *Ibid.*, p. 19.

[8] *Ibid.*, p. 212.

In order to determine test differences between the experimental groups, it was decided to use the Sign Test. However, because the assumption concerning ranking of the data could not be met, the test was rejected.

Observation of the Data

Following the statistical analysis of the results, the raw data were inspected to determine the hearing aid strength to be recommended for each subject plus the ear upon which to put the hearing aid. This was done through the use of the SRT and the SRD scores obtained for each subject binaurally and monaurally.

Validating Procedure

Sample

All files of the Michigan State University Hearing Clinic which contained complete speech reception data according to the design criteria were drawn. This resulted in four groups: those for whom the original recommendation was for no hearing aid, those for whom a weakly powered hearing aid was recommended, those needing moderately powered hearing aids, and those needing strong hearing aids. The minimum number in these classifications was 20 with the exception of those needing strong hearing aids; in this group there were four. It was decided to retain the four persons needing strong hearing aids and put 20 persons into each of the other three groups.

This required a random selection of persons needing no hearing aid and moderately powered hearing aids. The speech reception data were taken from these 64 case files and recorded on 4x5 cards and coded by a paid assistant. The same code symbol was placed on the card and on the file folder. Each card was given to two judges who did not know the meaning of the code. The data consisted of the Speech Reception Threshold test scores, binaurally and monaurally, and the Speech Reception Discrimination scores binaurally and monaurally. The information cards were then completely shuffled.

Clinical Diagnosis

From the data on the cards, the writer and the other judge,[9] independently determined the power of the hearing aid that should be recommended for each of the 64 persons represented by the cards. These judgments were then checked with the Long Form recommendation made at the time of the original hearing aid evaluation.

Interpretation of the Results

The goal of this procedure was to arrive at an estimate of the percentage of correct recommendations that could be expected with the Short Form of the present research. The ideal situation, of course, would be for each of the judges to classify the data on the cards according to the original recommendation. However, this may not

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[9] Associate Director of the Hearing Clinic and holding Advanced Hearing Certification from the American Speech and Hearing Association.

happen because of the factor of each judge's interpretation of the data. In some instances in which the SRT may be near the borderline between two classifications or hearing aids, his judgment may tell him to place the card in a higher or a lower powered hearing aid group. In most instances, such as this, any difference from the original recommendation would be in the direction of a more powerful hearing aid. This condition would provide the subject with more auditory gain but could not be considered as a vastly incorrect recommendation. However, if the judge's recommendation was for a weaker aid than the original one, the subject would not have enough auditory gain to improve his acuity appreciably. By the same token, if the judge's recommendation was for a hearing aid that was too powerful, the gain could not be reduced enough to make the aid functional for the subject.

Summary

In this chapter will be found a description of the design of the study. The subjects were selected mainly from the files of the Michigan State University Hearing Clinic and ranged in age from 18 to 81 years with a mean age of 39.45 years.

The equipment used consisted of a Beltone 12-A audiometer and an Allison 20-A audiometer with a speech reception circuit. The 12-A was used for all of the pure tone testing and the Allison for all of the speech reception testing. The speech reception testing was done with the Spondee and PB word lists.

The experimental design consisted of four groups of ten subjects in each who were given two tests about a week apart. The tests were pure tone air and bone conduction tests, and speech reception tests, known as the "Long Form" and speech reception testing only, known as the "Short Form." These two tests were united to form four different test combinations. Test combination "Long Form--"Long Form" served as the control for the experimental "Short Form--"Short Form."

The clinical and statistical procedures were then described. The statistical methods consisted of the Spearman Rank-order correlation and the "t" test to determine the test agreements.

Inspection of the data was used to determine the hearing aid power and the ear upon which the hearing aid would be put.

In order to establish an estimate of the percentage of correct recommendations that can be expected by using only the Short Form of this study, two judges determined independently the hearing aid that should be recommended for 64 cases taken from the Hearing Clinic files.

CHAPTER FOUR

RESULTS AND ANALYSIS OF THE DATA

The broad statement of the hypothesis for this study was as follows: "An abbreviated clinical procedure for hearing aid evaluations using only speech reception test scores will provide statistically similar results when compared with the longer methods now being used at the Michigan State University Hearing Clinic." In this chapter will be found the specific hypotheses to be tested, the analysis of the data, and a verification of the validity of the Short Form using data from the Hearing Clinic general files.

Hypotheses To Be Tested

There were two specific hypotheses generated by this study. To be tested statistically, they were formulated into operational null hypotheses based on the principle of no significant differences. The null hypothesis for this study was that there was no difference between the Long and the Short Forms of the measuring instrument. In the testing of the basic hypothesis, one sub-factor was considered--the relative effectiveness of the Short Form. Each of these hypotheses is formulated below.

Hypothesis I

The Short Form of the present study is not significantly less reliable than the Long Form.

This was tested by using the Spearman Rank-order correlation coefficient.

Hypothesis II

Hearing aid predictions can be made with equal accuracy using the Long or the Short Form of the evaluation. This was tested through inspection of the data. The strength of the hearing aid to be recommended will be determined as well as the ear upon which to put the aid.

Results

Statistical Results

The Spearman Rank-order correlation coefficient, described in Chapter Three, was used to ascertain the relationship between the first and second administration of the test. In two instances, groups I and II, the Long Form was given first; in two instances, groups III and IV, the Short Form was given first. The correlations obtained for the Speech Reception Thresholds (SRT) are shown in Table 8. The correlations for the Speech Reception Discrimination (SRD) are shown in Table 4.

TABLE 3.--Spearman Rank-order correlations between first and second Speech Reception Threshold evaluations--Short and Long Forms

Test combinations	n	Right ear	Left ear	Binaural
A-A	10	.95	.99	.98
A-a	10	.95	.86	.82
A-A	10	.97	.99	.90
a-a	10	.97	.96	.95

Key: A = The Long Form a = The Short Form

TABLE 4. --Spearman Rank-order correlations for first and second Speech Reception Discrimination evaluations--Long and Short Forms

Test combinations	n	Right ear	Left ear	Binaural
A-A	10	.85	.90	.95
A-a	10	.92	.94	.89
a-A	10	.80	.99	.80
a-a	10	.81	.81	.69

Key: A = The Long Form a = The Short Form

With a correlation (r) of 1.00 indicating a perfect relationship between any two variables, it is evident from an inspection of Table 3 that there was a high relationship between the scores that the subjects obtained on their first and second tests. This relationship would mean that the two tests were almost identical in their assessment of the subject's hearing ability.

Table 4, the Spearman Rank-order correlations for the Speech Reception Discrimination scores, indicated an acceptable relationship between the first and second tests. The lowest correlation (.69) was for the binaural results in the Short Form-Short Form (a-a) combination. Reliabilities of this magnitude were of questionable value in individual diagnosis. However, it was important to remember that the results of this study were based on relatively small samples and slight deviations may introduce wide variations. It was important to note that the reliabilities of the analysis of each ear separately were within the acceptable range. From the clinician's point of view, this factor was important to weigh. It will be seen in subsequent analysis that the Short Form assessment had fairly high predictability for individual classifications of hearing aids.

Particular attention should be given to the reliability estimates between identical test combinations (A-A and a-a). These coefficients represent an estimate of the consistency of the measurement of either the Long of the Short Forms. As noted above, all of the coefficients exceed the acceptable .80, except the binaural Short Form-Short Form evaluation.

Following the determination of the Rank-order correlations, it was deemed advisable to find the level of significance from zero of the lowest obtained correlation. The lowest correlation was chosen because if it was significant at the 5% level of confidence, all of the others that were higher must be significant. The 5% level of confidence indicated that the probability of obtaining a figure as low as, in this case, .69 by chance alone would be 5 times in 100 chances, or less. This was done through the use of the "t" test and the formula given in Chapter Three. The "t" obtained was 2.67. It was concluded that all of the correlations in Tables 3 and 4 were also significant at the 5% level of confidence or less.

An investigation of Tables 3 and 4 revealed that the lowest correlation for monaural scores was .80 for the right ear of the test combination a-A in Table 4. (The other correlations ranged upwards to .99.

On the basis of the Spearman Rank-order correlations, it was concluded that a high relationship existed between the Long and the Short Forms of the test. This appeared to be particularly true of the monaural scores which were the more important for hearing aid evaluations. It would appear that because of this high similarity of the two forms, the Long Form did not introduce fatigue, emotional or physical factors, into the assessment which affected the final results. Therefore, the first hypothesis is accepted.

Observational Results

The second hypothesis, that of the accuracy of the hearing aid prediction, was tested by inspection of the data. There were two factors involved in the acceptance or rejection of this hypothesis. They were:

1. The consistent choice of the ear upon which the hearing aid was placed. This necessitated a choice between a right ear, a left ear, or a binaural selection.

2. A consistent choice of a hearing aid with the same power through the course of the two tests.

The criteria, arbitrarily set by the examiner, for the power of the hearing aid to be recommended are in Table 5.

TABLE 5.--Criteria of power for hearing aid selection

Hearing aid power	Speech Reception Threshold
No hearing aid	Under 25 db
Weak hearing aid	25 db to 35 db
Moderate hearing aid	30 db to 60 db
Strong hearing aid	Over 60 db

The establishment of the hearing aid power for each subject was done by a careful inspection of the monaural SRT results for each subject. Depending upon these scores, the power of the aid was chosen. In some cases, the aid was recommended on the basis of the better ear score and, in some cases, on the basis of the poorer ear score. If the poorer ear acuity was reduced so that it could not be improved to the point of usefulness for the subject, the better ear SRT was used. If the better ear was useful for the subject, unaided, but still reduced in acuity, the poorer ear SRT was used as the basis for the power of the hearing aid. If the SRT and the SRD for the two ears were similar, a binaural selection was made.

The matter of which ear to put the hearing aid on necessitated an inspection of both the SRT and the SRD. The SRT had to be taken into account because of the factors involved in the selection of the hearing aid power. The SRD inspection was necessary because hearing aid selection results are not usually successful if the hearing aid is placed on an ear with poor speech discrimination. This is determined by the percentage of PB words that are identified incorrectly.

In Table 6, there was one difference. Subject 2 was recommended for a moderately powered hearing aid on both ears on the first test and the same power aid on only the left ear on the second test. The reason for this was the drop in the right ear SRD from 64% on the first test to 42% on the second test. The SRT remained the same for both ears. All of the other recommendations for this test combination were identical from the first to the second test.

TABLE 6.--Ear choice and power of hearing aid recommended based upon Speech Reception Threshold and Speech Reception Discrimination scores

Long Form-Long Form--experimental data

Subject	Long Form--first test				Long Form--second test			
	No aid	Right ear	Left ear	Binaural	No aid	Right ear	Left ear	Binaural
1	X				X			
2				Mod.*			Mod.*	
3				Weak				Weak
4			Mod.				Mod.	
5	X				X			
6	X				X			
7		Weak				Weak		
8				Mod.				Mod.
9	X				X			
10	X				X			

Key: * = Discrepancy between tests
Mod. = A moderately powered hearing aid
Weak = A weakly powered hearing aid

In Table 7, there were no differences in ear choice or the strength of the hearing aid recommended. In no instance did the SRT or the SRD shift sufficiently on the second test to call for an alteration of the aid recommended on the first test.

TABLE 7.--Ear choice and power of hearing aid recommended based upon Speech Reception Threshold and Speech Reception Discrimination scores

Long Form-Short Form--experimental data

Subject	Long Form--first test				Short Form--second test			
	No aid	Right ear	Left ear	Binaural	No aid	Right ear	Left ear	Binaural
1		Mod.				Mod.		
2	X				X			
3				Weak				Weak
4				Mod.				Mod.
5	X				X			
6				Mod.				Mod.
7	X				X			
8		Mod.				Mod.		
9		Mod.				Mod.		
10	X				X			

Key: Mod. = A moderate power hearing aid
Weak = A weak power hearing aid

One discrepancy was noted in Table 8. The third subject needed a weak hearing aid on both ears on the second test but no hearing aid on the first test. This was due to the fact that the SRT for the right ear improved 5 db on the second test and the left ear showed a poorer SRT by 5 db on the second test. This brought the loss in the two ears close together and just within the range of a weak hearing aid. The SRD remained the same for this subject on both tests. All of the other nine subjects showed the same recommendation on both tests.

TABLE 8.--Ear choice and power of hearing aid recommended based upon Speech Reception Threshold and Speech Reception Discrimination scores

Short Form-Long Form--experimental data

Subject	Short Form--first test				Long Form--second test			
	No aid	Right ear	Left ear	Binaural	No aid	Right ear	Left ear	Binaural
1	X				X			
2		Mod.				Mod.		
3	X*							Weak*
4	X				X			
5	X				X			
6			Mod.				Mod.	
7	X				X			
8				Weak				Weak
9			Mod.				Mod.	
10	X				X			

Key: Mod. = A moderate power hearing aid
Weak = A weak power hearing aid
* = A discrepancy between the first and second tests

There were three discrepancies in Table 9. They were the second, eighth, and tenth subjects. The second and the tenth altered their SRD scores enough on the second test to call for a shift in ear choice. The eighth subject improved his SRT score for his right ear on the second test enough to recommend a binaural selection.

TABLE 9.--Ear choice and power of hearing aid recommended based upon Speech Reception Threshold and Speech Reception Discrimination scores

Short Form-Short Form--experimental data

Subject	Short Form				Short Form			
	No aid	Right ear	Left ear	Binaural	No aid	Right ear	Left ear	Binaural
1	X				X			
2				Mod.*			Mod.*	
3				Mod.				Mod.
4				Weak				Weak
5	X				X			
6	X				X			
7	X				X			
8		Mod.*						Mod.*
9			Mod.				Mod.	
10			Mod.*					Mod.*

Key: Mod. = A moderate power hearing aid
Weak = A weak power hearing aid
* = A discrepancy between the first and second tests

It will be noted that in Table 9, the ear choice and the hearing aid power recommendations based on the test combination Short Form-Short Form present more discrepancies than any of the previous combinations of the Long and Short Form tests. It will be noted, however, that the hearing aid strength was identical in each instance of difference. The discrepancies were concerned with the ear the hearing aid should be placed on. This represented slight SRT and/or SRD score shifts which could be seen with either the Long or the Short Forms of the test due to normal daily fluctuations in hearing. However, these differences caused some concern as to the validity of the use of the Short Form. This question is considered in the following section.

Analysis of the Short Form Validity

The investigation of the Short Form validity described in Chapter Three, revealed almost complete agreement between the two independent judges on the hearing aid power needed by 64 subjects. The same criteria were used as in the previous section (see Table 5). It will be recalled that there were 20 case files chosen from the Hearing Clinic files in each of the following classifications: no hearing aid, a weak power hearing aid, and a moderately powered hearing aid. There were also four cases of persons needing strong hearing aids. From these files, all of which were compiled using the Long Form, only the speech reception data were used in the rating. This constituted a Long Form vs. Short Form validity verification.

In Table 10A, it will be noted that there were no clinical differences between the two judges. In all twenty cases, no hearing aids were recommended via the Long Form or the Short Form.

TABLE 10A. --Predictive validity of the Short Form
Precision of the no hearing aid recommendation

Recommendation resulting from the Short Form	Judge 1	Judge 2	Percentage of shift
No hearing aid	20	20	0%

TABLE 10B. --Predictive validity of the Short Form
Precision of the weakly powered hearing aid recommendation

Recommendation resulting from the Short Form	Judge 1	Judge 2	Percentage of shift
Weak hearing aid	18	20	0%
Moderate hearing aid	2	0	10

In Table 10B is revealed a 10% shift in the recommendations for Judge 1 and 0% for Judge 2. In both instances in which Judge 1 recommended a moderately powered hearing aid, the subjects were on the borderline between the weak and the moderately powered aids.

TABLE 10C. --Predictive validity of the Short Form
Precision of the moderately powered hearing aid recommendation

Recommendation resulting from the Short Form	Judge 1	Judge 2	Percentage of shift
Moderate hearing aid	20	20	0%

In Table 10C, concerning the recommendations for moderately powered hearing aids, is illustrated 100% agreement between the two judges. Both judges, using the Short Form, were in complete independent agreement with the original recommendation made using the Long Form.

TABLE 10D. --Predictive validity of the Short Form
Precision of the strongly powered hearing aid recommendation

Recommendation resulting from the Short Form	Judge 1	Judge 2	Percentage of shift
Strong hearing aid	4	4	0%

In Table 10D as can be seen, there was, again, complete agreement between the judges.

Analysis of the Data

An inspection of the data from the previous section reveals many interesting facts. Of the total of forty subjects used in this study, only three made binaural SRT scores which differed by 10 db on the two tests and 16 made binaural SRT scores which differed by 5 db. All of the others had the same binaural scores on both tests. This fact illustrated the stability of the hearing thresholds obtained by the two tests. Monaurally, the SRT scores in 10 instances shifted 10 db and in 26 cases the threshold shifted 5 db. It must be remembered that these were monaural scores, and, therefore, there were eighty comparisons to be made instead of 40 as with the binaural comparisons. Since shifts of 5 db are considered common in Audiology, the only ones that were significant were in excess of 5 db. Therefore, of the total of 120 comparisons for monaural and binaural scores, there were only 13 significant alterations in Speech Reception Threshold scores. These differences did not cluster in any one test combination.

The Speech Reception Discrimination percentages varied slightly more than the SRT scores. Of 40 binaural comparisons, seven altered their percentages by 8% or more. (The range of these percentages was from 8% to 16%.) For the 80 monaural comparisons, there were 14 subjects who altered their scores by 12% or more. (The range of these percentages was from 12% to 34%.) There could have been many reasons for this. Among them, the normal fluctuation in hearing, emotional or physical upset within the subject unknown to the tester, more external noise on one test than on the other, but this would be slight due to the construction of the room, or a difference in the PB lists used.

Considering the high correlations found by the Spearman Rank-order test and the few shifts in the data described above, it was concluded that any differences noted in the research were differences that could have been seen in two successive administrations of the Long Form as it is usually given in the Hearing Clinic. The variations were not great enough to be due solely to the Short Form administration. Therefore, Hypothesis I, that the Short Form of the present study is not less reliable than the Long Form, is accepted.

An observational analysis of the accuracy of the hearing aid selection made by the Long Form and the Short Form of the test revealed minor variations. In all, there were five deviations from one Form to another. In four cases, the shift represented a change from a monaural selection to a binaural one. In one instance, no hearing aid was recommended on the first test and a weakly powered binaural selection on the second. In no instance did the power of the aid differ from one test to the other. Probably what is more important is that none of the changes resulted in the recommendation of a hearing aid that would be nonfunctional for the subject. The deviations seen in these data were probably no greater than could be expected with the use of only the Long Form over a period of time. Therefore, Hypothesis II is accepted.

The verification of the Short Form validity by means of the speech reception data from 64 Hearing Clinic files revealed nearly complete agreement between the two independent judges using only these data. The same criteria were used as in the selection of the hearing aid power (see Table 5). Differences were seen in only one hearing aid classification--the weakly powered hearing aid recommendation via the original clinical data (Long Form). Due to the 5 db overlap between the criteria for the weak hearing aid and the moderately powered aid, Judge 1 recommended a moderately powered hearing aid for two persons while the original recommendation was for a weak hearing aid. Judge 2 recommended weakly powered hearing aids for all 20 persons in the group which was in agreement with the Long Form classification. Such decisions ultimately depend upon clinical judgment. In both cases, the subjects had SRT scores of 35 db in the better ear. This score was on the borderline between the two strengths of hearing aids in question, and, therefore, either recommendation must be considered correct. For all of the other 62 cases the recommendations were identical to the original recommendations made by using the Long Form in a clinical setting.

Summary

The Spearman Rank-order correlation coefficient was used to test Hypothesis I, which stated that there was no statistical effect of the length of the test upon the results obtained by using the Long or the Short Forms. The Rank-order correlations were shown previously in this chapter to be quite good and demonstrated a high degree of relationship between the two tests.

There were very minor differences seen in the selection of the hearing aids via the Long Form and the Short Form of the test. In four cases, the ear choices differed between a monaural and a binaural selection, but the power of the aid remained stable. For one person, on the first test, no aid was recommended and a weakly powered binaural selection on the second test.

In the judgmental classification of hearing aids from 64 cases chosen from the files of the Hearing Clinic, two judges agreed

on all but two. Both differences occurred in the recommendation of a moderately powered hearing aid when the original recommendation was for a weakly powered aid. The original recommendations were made under the usual clinical conditions using the Long Form of the present research. Both differences were seen in cases in which the SRT's were 35 db. This placed the subjects on the borderline between the weak and moderate hearing aids. Because these were borderline cases, both recommendations were considered clinically correct.

CHAPTER FIVE

CONCLUSIONS

There were two hypotheses generated by the present study. They can be stated as follows:

1. If the Short Form of the present research is not less reliable than the Long Form, then, hearing aid evaluations can be done using only the SRT and the SRD.
2. If only the speech reception could be used, would the hearing aid recommended be the same as with the complete battery of tests?

These hypotheses can now be answered within the limitations of the present study.

Based upon the present research, it appears that hearing aid evaluations can be done using only the Speech Reception Threshold (SRT) and the Speech Reception Discrimination (SRD) scores. It was seen by using the Spearman Rank-order correlation coefficient that the Long Form-Short Form test combinations illustrated a high relationship between the two tests. The lowest correlation seen was a binaural SRD of .69. This proved to be significant at the 5% level when subjected to a "t" test of significance of difference. It must be remembered that all statistical results in this study are based upon relatively small samples and, therefore, slight shifts in test scores take on greater meaning than with large samples.

It can be concluded that because the correlations between the tests were uniformly high, Hypothesis 1, concerning the feasibility of doing a hearing aid evaluation with only the speech reception data, can be answered affirmatively.

Hypothesis 2, concerning the hearing aid recommendation that would ensue from the use of only the speech reception data, presents a problem that is solvable in terms of the accuracy of hearing aid classification. With this Hypothesis, the clinical judgments of the audiologist take on significance. It will be remembered that in Chapter Four, there were no differences noted in the selection of the hearing aid strength for the subjects involved in this study. For each subject, two hearing aid recommendations were made; one on the basis of the first test results and one on the basis of the second test. This presented 80 separate recommendations, and for the 40 subjects the recommendation was for the same power hearing aid on both tests. Thus, it is safe to conclude that the hearing aid strength recommended, based upon the Short Form, would probably be identical with that recommended by the Long Form.

Before Hypothesis 2 could be accepted, it was necessary to consider the choice of ear upon which the hearing aid would be placed. For the 40 subjects involved in this study, there were five instances in which the ear choice was not the same on the first and second tests. It did not appear, however, that this was a matter of great importance.

All differences, except one, were due to shifts between a monaural and a binaural hearing aid selection. With either selection, the subject would function on a more adequate level than previously. It is granted that a binaural selection is usually more effective, if the conditions call for it. The single exception to this ear shift was a difference between no hearing aid and a weak binaural selection. In this case, in which the Short Form indicated no hearing aid, retesting with the Long Form would be possible if and when the subject should return to the clinic and request a re-evaluation. In the meantime, he would not be too handicapped. It can be concluded too, that if this subject's SRT is so close to normal, a hearing aid is likely not to be recommended for him by use of either Form on successive hearing aid evaluations.

From the observational analysis of the data and the consistency of the hearing aid power and ear choice, it can be concluded that hearing aids recommended via the Short Form do not differ significantly from those recommended with the Long Form. Therefore, Hypothesis 2 can be accepted.

With the subjects represented in this study, it appeared that the Short Form was equally as good as the Long Form for the selection of hearing aids, and the Short Form was nearly as reliable as the Long Form. In order to obtain further verification of the validity of the Short Form, it was decided to draw all cases from the

Hearing Clinic files for whom complete hearing aid evaluations of a similar clinical procedure had been done using the Long Form. There were 64 such cases chosen which resulted in the following classes: 20 for whom no hearing aid had been recommended, 20 for whom a weakly powered hearing aid was recommended, and 20 who were given a moderately powered aid. Four cases were also drawn for whom a strong hearing aid was needed. These 64 cases were placed into classifications of hearing aid power based on the Short Form evaluation by two judges working independently. In all cases except two, the judges placed the persons in the classification of the original recommendation using only the speech reception data from each of the files. The criteria used were the same as presented in Table 5. The two case files which were interpreted differently by the same judge, were on the borderline between a weak and a moderate hearing aid. In this judgmental process, they were given moderate hearing aids whereas in the original one they were provided with weak hearing aids. The audiologist must judge which power aid is needed by this person with a specific set of objective scores and his clinical acumen. In many instances, the level at which the person is functioning is taken into account as well as the objective scores and this is as it should be. For the two persons whose speech reception data were classed differently, no such interpersonal qualities were present. With the two SRT's being right on the borderline between a weak and moderate hearing aid, the subject would be benefited by either aid and, therefore, both classifications could be considered correct. It can be said, then, that for the 64 persons chosen from the Hearing Clinic files, the two judges were in complete agreement.

In the final analysis, it can be concluded that the Short Form presents definite advantages over the Long Form in situations in which only a hearing aid evaluation is needed. The Speech Reception Threshold and the Speech Reception Discrimination tests provide all of the information needed, following a recommendation for a hearing aid by a physician.

CHAPTER SIX

RECOMMENDATIONS FOR FUTURE RESEARCH

Future research in the area of hearing aid evaluations is needed. The evaluational procedures used today are much improved over what they were before World War II, but the desired precision of hearing aid selection has not been attained. In the light, too, of the increase expected in the population of older persons, hearing aid evaluational procedures will have to be more accurate and more concise. The present study is an attempt in this direction.

The following recommendations are made for future study in the area of hearing aid evaluation.

1. Using only the Short Form of this study, the SRT and the SRD, determine the hearing aid receiver that should be recommended. The subjects for this study could be persons obtaining their first hearing aid. Follow this procedure with the Long Form to determine the accuracy of the receiver recommended based on the Short Form. This could be done by keeping a close record of the sound substitutions that a person makes during the PB testing.
2. Select a group of hearing aid users who feel that they can function adequately with their hearing aids under most

circumstances. Using the same methods recommended in 1 above, find the hearing aid receiver with which they obtain the best results. Check the resulting receiver against the one that they are using.

3. Repeat the present study with a population from a different clinical setting. This would be meaningful in that it would tend to substantiate the present work.

4. Repeat the present study using identical Spondee and PB word lists for both testings.

5. Repeat the present study using an older age group. This could be done with the geriatric subjects found in almost any clinic.

6. Repeat the present study with children or adults.

7. Investigate the feasibility of binaural hearing aids for persons with dissimilar monaural hearing thresholds.

8. Investigate the current local criterion of 25 db in conjunction with the SRD scores for the recommendation of a hearing aid in conjunction with the SAI to determine the criterion for PB scores below which an aid should be recommended.

9. Investigate the use of the Most Comfortable Loudness Level (MCL) and the tolerance level tests in addition to the SRT and the SRD to find out if, and how, the results differ when used for hearing aid evaluations.

10. Do a follow-up study on all persons for whom a hearing aid has been recommended at the Michigan State University Hearing Clinic during the past five years to determine if the aid has been purchased. If the aid has been obtained, retest the person with and without the aid to determine the accuracy of the recommendation. This could best be done with the cooperation of the local hearing aid dealers, because any alterations in the aid would affect the dealers directly.

11. If the hearing aid recommended in 10 above, has not been obtained an additional study to determine the reasons would be valuable.

12. Investigate the improvement or reduction on the SAI following the purchase of the initial hearing aid followed by an intensive period of auditory training and speech-reading lessons.

13. Do the same as the preceding, with auditory training and speechreading before the purchase of the hearing aid.

14. Investigate the effects of 12 and/or 13 above when combined with counseling.

15. Repeat the present study with equal loudness, tape recorded Spondee and PB word lists. This would eliminate any speech variations in the examiner from the study.

16. Repeat the verification of the validity of the Short Form by using between 50 and 100 subjects in each hearing aid power classification.

17. Have an experimental group try several hearing aids before they begin the evaluational procedures to determine which hearing aid they would select as the most comfortable and usable. Follow this by a careful hearing aid evaluation to ascertain the effectiveness of an individual self-selection of hearing aid power.

18. Investigate the use of the signal to noise ratio testing for its usefulness in hearing aid evaluations.

APPENDIX A

LETTER TO SUBJECTS

Dear ______________________:

We have recently been reviewing our case files with the idea of retesting certain of the individuals. We feel that you would benefit from this service. There will be no charge for this retesting service.

Since we are planning on starting this service very soon, if you are interested, would you please call the Hearing Clinic at ED 2-1511, Ext. 2071 as soon as possible.

Sincerely,

Donald G. Williamson, M. A.
Audiologist
Hearing Clinic

Department of Speech
Hearing Clinic

East Lansing

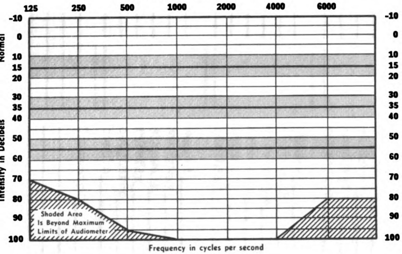
33 Auditorium
ED 2-1511, Ext. 2071

HEARING EVALUATION
APPENDIX B

Name: ______ Address: ______ Telephone: ______

Date: ______ Age: ______ Sex: ______ Rhinitis: Yes ☐ No ☐ Other ______ (Street) (City) Hearing today: As usual ☐ Better ☐ Worse ☐

AIR CONDUCTION



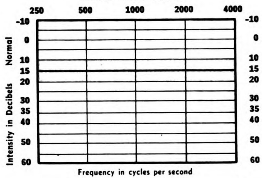
Frequency in cycles per second

KEY:				
RIGHT EAR	RED	○	△ - - w/masking at ______ db	
LEFT EAR	BLUE	×	☐ - - w/masking at ______ db	
↓ If no response at maximum intensity				

Validity of test:
Decisive ☐ Uncertain ☐
Examiner: ______
Audiometer: ______

Observations: ______

BONE CONDUCTION



Frequency in cycles per second

KEY:			
RIGHT EAR	RED	>	w/masking at ______ db
LEFT EAR	BLUE	<	w/masking at ______ db
↓ If no response at maximum intensity			

Validity of test: Decisive ☐ Uncertain ☐
Examiner: ______ Audiometer: ______
Observations: ______

SPEECH RECEPTION

	Binaural	Right	Left
Spondee	___ db	___ db	___ db
PB	___ db	___ db	___ db
Object Identification	___ db	___ db	___ db
______	___ db	___ db	___ db

Validity of test: Decisive ☐ Uncertain ☐
Examiner: ______ Allison Unit: ______
Observations: ______

Comments: ______

Recommendations: ______

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______
Signature

HC-1-56 O-2504

APPENDIX C

SPEECH RECEPTION
SPONDEE

Free-Field
Unaided
List A

Name ____________________
Date ____________________
Clinician ____________________

	Binaural Errors	Decibels	Right Errors	Decibels	Left Errors	Decibels
1.	sunset ____		bloodhound ____		earthquake ____	
2.	whitewash ____		shipwreck ____		firefly ____	
3.	drawbridge ____		bagpipe ____		northwest ____	
4.	armchair ____		cupcake ____		hedgehog ____	
5.	wildcat ____		cowboy ____		hardware ____	
6.	birthday ____	____	wigwam ____	____	stairway ____	____
7.	bonbon ____		dovetail ____		oatmeal ____	
8.	bloodhound ____		earthquake ____		watchword ____	
9.	sidewalk ____		inkwell ____		bagpipe ____	
10.	shipwreck ____		airplane ____		doorstep ____	
11.	cupcake ____		hedgehog ____		sunset ____	
12.	cowboy ____	____	hardware ____	____	wigwam ____	____
13.	dovetail ____		oatmeal ____		bobwhite ____	
14.	earthquake ____		watchword ____		shotgun ____	
15.	firefly ____		blackboard ____		inkwell ____	
16.	airplane ____		doorstep ____		hothouse ____	
17.	hedgehog ____		woodwork ____		shipwreck ____	
18.	hardware ____	____	playground ____	____	baseball ____	____
19.	oatmeal ____		bobwhite ____		eggplant ____	
20.	watchword ____		shotgun ____		eyebrow ____	
21.	coughdrop ____		backbone ____		blackboard ____	
22.	doorstop ____		hothouse ____		railroad ____	
23.	woodwork ____		buckwheat ____		headlight ____	
24.	playground ____	____	baseball ____	____	mousetrap ____	____
25.	bobwhite ____		eggplant ____		outlaw ____	
26.	shotgun ____		eyebrow ____		whitewash ____	
27.	wigwam ____		northwest ____		backbone ____	
28.	hothouse ____		railroad ____		armchair ____	
29.	buckwheat ____		headlight ____		wildcat ____	
30.	baseball ____	____	mousetrap ____	____	birthday ____	____
31.	eggplant ____		outlaw ____		bloodhound ____	
32.	eyebrow ____		whitewash ____		sidewalk ____	
33.	stairway ____		drawbridge ____		airplane ____	
34.	railroad ____		armchair ____		cupcake ____	
35.	headlight ____		wildcat ____		cowboy ____	
36.	mousetrap ____	____	birthday ____	____	dovetail ____	____
37.	outlaw ____		sunset ____		buckwheat ____	
38.	bagpipe ____		stairway ____		playground ____	
39.	inkwell ____		sidewalk ____		bonbon ____	
40.	blackboard ____		firefly ____		coughdrop ____	
41.	backbone ____		coughdrop ____		woodwork ____	
42.	northwest ____	____	bonbon ____	____	drawbridge ____	____

Comments: ____________________ (Binaural)

Comments: ____________________ (Right)

Comments: ____________________ (Left)

[illegible]

APPENDIX D
SPEECH RECEPTION
SPONDEE

Free-Field
Unaided
List B

Name ____________________
Date ____________________
Clinician ____________________

	Binaural Errors	Decibels	Right Errors	Decibels	Left Errors	Decibels
1.	watchword ____		shotgun ____		firefly ____	
2.	coughdrop ____		wigwam ____		shotgun ____	
3.	inkwell ____		blackboard ____		inkwell ____	
4.	woodwork ____		buckwheat ____		wigwam ____	
5.	playground ____		baseball ____		cowboy ____	
6.	airplane ____	____	drawbridge ____	____	blackboard ____	____
7.	bobwhite ____		eggplant ____		dovetail ____	
8.	shotgun ____		eyebrow ____		buckwheat ____	
9.	northwest ____		backbone ____		doorstep ____	
10.	hothouse ____		railroad ____		baseball ____	
11.	earthquake ____		mousetrap ____		earthquake ____	
12.	eggplant ____	____	stairway ____	____	drawbridge ____	____
13.	eyebrow ____		outlaw ____		coughdrop ____	
14.	backbone ____		whitewash ____		eggplant ____	
15.	railroad ____		bagpipe ____		woodwork ____	
16.	buckwheat ____		headlight ____		eyebrow ____	
17.	mousetrap ____		birthday ____		hardware ____	
18.	outlaw ____	____	shipwreck ____	____	backbone ____	____
19.	whitewash ____		sunset ____		oatmeal ____	
20.	armchair ____		sidewalk ____		railroad ____	
21.	headlight ____		cupcake ____		hothouse ____	
22.	birthday ____		wildcat ____		mousetrap ____	
23.	doorstep ____		bonbon ____		watchword ____	
24.	bonbon ____	____	airplane ____	____	stairway ____	____
25.	blackboard ____		bloodhound ____		bloodhound ____	
26.	cupcake ____		firefly ____		northwest ____	
27.	baseball ____		inkwell ____		outlaw ____	
28.	cowboy ____		cowboy ____		airplane ____	
29.	bagpipe ____		dovetail ____		hedgehog ____	
30.	dovetail ____	____	doorstep ____	____	whitewash ____	____
31.	firefly ____		earthquake ____		bonbon ____	
32.	hedgehog ____		coughdrop ____		playground ____	
33.	birthday ____		woodwork ____		bagpipe ____	
34.	hardware ____		hardware ____		wildcat ____	
35.	sunset ____		oatmeal ____		bobwhite ____	
36.	oatmeal ____	____	hothouse ____	____	headlight ____	____
37.	bloodhound ____		watchword ____		cupcake ____	
38.	stairway ____		northwest ____		armchair ____	
39.	sidewalk ____		hedgehog ____		birthday ____	
40.	wigwam ____		playground ____		sidewalk ____	
41.	shipwreck ____		bobwhite ____		sunset ____	
42.	drawbridge ____	____	armchair ____	____	shipwreck ____	____

Comments: ____________________ (Binaural)

Comments: ____________________ (Right)

Comments: ____________________ (Left)

Free Field
List C

SPEECH RECEPTION (Spondee)
Hearing Aid Evaluation

APPENDIX E

Name______
Date______ Clinician______

Hearing Aid______	Hearing Aid______	Hearing Aid______
Model______	Model______	Model______
Receiver: Air___ Bone___	Receiver: Air___ Bone___	Receiver: Air___ Bone___
Ear: Right___ Left___	Ear: Right___ Left___	Ear: Right___ Left___
Intensity Setting:	Intensity Setting:	Intensity Setting: ....

		Errors	Decibels		Errors	Decibels		Errors	Decibels
1.	toothbrush			woodchuck			yardstick		
2.	midway			doormat			schoolboy		
3.	blackout			jackknife			vampire		
4.	sundown			scarecrow			beehive		
5.	nutmeg			playmate			starlight		
6.	footstool			whizzbang			workshop		
7.	cookbook			farewell			iceberg		
8.	woodchuck			yardstick			cargo		
9.	padlock			mushroom			jackknife		
10.	doormat			hotdog			grandson		
11.	scarecrow			beehive			toothbrush		
12.	playmate			starlight			whizzbang		
13.	farewell			iceberg			mishap		
14.	yardstick			cargo			eardrum		
15.	schoolboy			pinball			mushroom		
16.	hotdog			grandson			outside		
17.	beehive			duckpond			doormat		
18.	starlight			washboard			although		
19.	iceberg			mishap			pancake		
20.	cargo			eardrum			housework		
21.	therefore			soybean			pinball		
22.	grandson			outside			platform		
23.	duckpond			greyhound			lifeboat		
24.	washboard			although			daybreak		
25.	mishap			pancake			horseshoe		
26.	eardrum			housework			midway		
27.	whizzbang			vampire			soybean		
28.	outside			platform			sundown		
29.	greyhound			lifeboat			nutmeg		
30.	although			daybreak			footstool		
31.	pancake			horseshoe			woodchuck		
32.	housework			midway			padlock		
33.	workshop			blackout			hotdog		
34.	platform			sundown			scarecrow		
35.	lifeboat			nutmeg			playmate		
36.	daybreak			footstool			farewell		
37.	horseshoe			toothbrush			greyhound		
38.	jackknife			workshop			washboard		
39.	mushroom			padlock			cookbook		
40.	pinball			schoolboy			therefore		
41.	soybean			therefore			duckpond		
42.	vampire			cookbook			blackout		

Comments:______	Comments:______	Comments:______

Free Field
List D

SPEECH RECEPTION (Spondee)
Hearing Aid Evaluation

Name________________
Date______ Clinician________

APPENDIX F

Hearing Aid________	Hearing Aid________	Hearing Aid________
Model________	Model________	Model________
Receiver: Air___ Bone___	Receiver: Air___ Bone___	Receiver: Air___ Bone___
Ear: Right___ Left___	Ear: Right___ Left___	Ear: Right___ Left___
Intensity Setting:_____	Intensity Setting:_____	Intensity Setting:_____

	Errors	Decibels	Errors	Decibels	Errors	Decibels
1.	cargo		outlaw		eggplant	
2.	therefore		whitewash		eyebrow	
3.	mushroom		backbone		northwest	
4.	duckpond		armchair		railroad	
5.	washboard		wildcat		headlight	
6.	hotdog		birthday		mousetrap	
7.	mishap		bloodhound		outlaw	
8.	eardrum		sidewalk		whitewash	
9.	vampire		airplane		drawbridge	
10.	outside		cupcake		armchair	
11.	blackout		cowboy		wildcat	
12.	yardstick		dovetail		birthday	
13.	pancake		buckwheat		sunset	
14.	housework		playground		stairway	
15.	soybean		bonbon		sidewalk	
16.	platform		coughdrop		firefly	
17.	greyhound		woodwork		coughdrop	
18.	daybreak		drawbridge		bonbon	
19.	horseshoe		earthquake		bloodhound	
20.	midway		firefly		shipwreck	
21.	sundown		northwest		bagpipe	
22.	lifeboat		hedgehog		cupcake	
23.	nutmeg		hardware		cowboy	
24.	grandson		stairway		wigwam	
25.	cookbook		oatmeal		dovetail	
26.	pinball		watchword		earthquake	
27.	scarecrow		bagpipe		inkwell	
28.	although		doorstep		airplane	
29.	playmate		sunset		hedgehog	
30.	jackknife		wigwam		hardware	
31.	farewell		bobwhite		oatmeal	
32.	schoolboy		shotgun		watchword	
33.	beehive		inkwell		blackboard	
34.	footstool		hothouse		doorstep	
35.	starlight		shipwreck		woodwork	
36.	toothbrush		baseball		playground	
37.	iceberg		eggplant		bobwhite	
38.	woodchuck		eyebrow		shotgun	
39.	workshop		blackboard		backbone	
40.	padlock		railroad		hothouse	
41.	whizzbang		headlight		buckwheat	
42.	doormat		mousetrap		baseball	

Comments:________________

Comments:________________

Comments:________________

THE

SPEECH RECEPTION

PB

APPENDIX G

Free Field
Unaided (List E)

Name________________________
Date________________________
Clinician____________________

	Binaural	Errors	Decibels	Right	Errors	Decibels	Left	Errors	Decibels
1.	mange			niece			nest		
2.	box			bought			bead		
3.	toe			vast			wharf		
4.	pest			quart			rouse		
5.	rat			shoe			sob		
6.	ford			hire			flush		
7.	is			need			neck		
8.	use			ways			who		
9.	bask			death			blush		
10.	crime			dodge			blonde		
11.	strife			tang			slap		
12.	grove			jam			how		
13.	hive			mute			lush		
14.	crash			bounce			cape		
15.	then			cane			trash		
16.	vow			class			starve		
17.	plush			rib			sit		
18.	ride			sludge			sped		
19.	end			five			drop		
20.	fern			gill			far		
21.	clove			nook			charge		
22.	path			check			peck		
23.	pan			such			pick		
24.	pulse			turf			sour		
25.	slip			fraud			hit		
26.	gnaw			thrash			hiss		
27.	hid			moose			leave		
28.	wheat			wish			why		
29.	cleanse			bud			cast		
30.	there			bad			strap		
31.	bait			air			vamp		
32.	pile			rap			shout		
33.	rag			scythe			raw		
34.	dike			else			earn		
35.	dig			glass			fig		
36.	heap			creed			kite		
37.	law			log			no		
38.	crave			oak			court		
39.	are			not			awe		
40.	please			ache			pert		
41.	smile			rub			tan		
42.	sketch			take			shed		
43.	deed			fuss			earl		
44.	hurl			deck			dupe		
45.	neat			hunt			muck		
46.	pants			bar			rate		
47.	bee			pit			bald		
48.	rise			snuff			stag		
49.	fame			dill			feast		
50.	eel			frog			fate		

Comments:________________ Comments:________________ Comments:________________

Free-Field
List F

SPEECH RECEPTION (PB)
Hearing Aid Evaluation

APPENDIX H

Name______
Date____ Clinician______

Hearing Aid______	Hearing Aid______	Hearing Aid______
Model______	Model______	Model______
Receiver: Air___ Bone___	Receiver: Air___ Bone___	Receiver: Air___ Bone___
Ear: Right____ Left____	Ear: Right____ Left____	Ear: Right____ Left____
Intensity Setting:____	Intensity Setting:____	Intensity Setting:____

	Errors	Decibels		Errors	Decibels		Errors	Decibels
1. add			ray			dwarf		
2. zone			eat			range		
3. puff			flick			gasp		
4. hill			shank			siege		
5. choose			gap			though		
6. solve			wart			jug		
7. road			jag			nine		
8 flap			writ			roar		
9. mast			kept			coast		
10. beck			ode			but		
11. rear			cab			pig		
12. greek			chart			cook		
13. shove			rooms			quiz		
14. lend			thigh			fling		
15. watch			hitch			scout		
16. feed			rough			gun		
17. browse			fall			sledge		
18. scare			prime			shaft		
19. thud			mash			fort		
20. pass			hull			phase		
21. high			wasp			aim		
22. curse			fee			wire		
23. row			pus			knit		
24. gape			fowl			rash		
25. bronze			slouch			dose		
26. sick			gage			by		
27. true			thus			sin		
28. rind			wife			grade		
29. cheat			reap			him		
30. kid			crib			whiff		
31. odds			prig			plod		
32. wrath			dad			chop		
33. punt			eyes			pent		
34. sly			flop			dope		
35. good			nigh			off		
36. love			sup			cut		
37. beach			leg			woo		
38. most			grape			moat		
39. wink			tongue			south		
40. owls			deep			mud		
41. shine			pun			rich		
42. inch			cloth			fake		
43. tug			best			pounce		
44. thick			raise			woe		
45. face			bog			comes		
46. pipe			clothes			raid		
47. yawn			forge			sag		
48. bathe			scan			am		
49. grudge			as			sniff		
50. trade			badge			act		

Comments:______ Comments:______ Comments:______

APPENDIX I. --Pure tone test results

First test--Long Form (I)
Second test--Long Form (II)

Group I: Long Form Air Conduction Results

Subject	Test	Ear	250 cps	500 cps	1000 cps	2000 cps	4000 cps	6000 cps
1	I	R	20 db	15 db	20 db	15 db	25 db	30 db
		L	40	35	30	25	30	45
	II	R	15	10	10	10	25	25
		L	35	30	30	20	35	40
2	I	R	45	45	55	50	70	85
		L	20	35	50	70	75	85
	II	R	40	45	50	50	65	85
		L	20	40	55	70	70	85
3	I	R	15	15	30	35	55	70
		L	20	10	40	50	65	80
	II	R	15	10	15	30	40	65
		L	25	10	15	45	45	70
4	I	R	40	40	35	25	35	45
		L	60	55	40	60	75	70
	II	R	35	45	35	25	40	45
		L	50	45	45	55	70	70
5	I	R	10	10	30	45	50	90
		L	10	10	25	40	55	85
	II	R	10	10	35	40	50	90
		L	10	10	25	35	55	90
6	I	R	30	25	35	30	30	40
		L	45	65	70	65	75	70
	II	R	15	20	30	25	25	25
		L	65	80	75	75	100	95
7	I	R	10	15	15	15	50	65
		L	35	40	30	45	65	80
	II	R	15	15	15	20	55	65
		L	30	25	30	35	60	75
8	I	R	35	50	50	45	50	65
		L	25	40	45	50	50	60
	II	R	20	40	45	45	50	65
		L	20	40	40	45	55	55
9	I	R	10	10	10	10	45	45
		L	10	10	10	15	50	50
	II	R	10	10	10	10	40	50
		L	10	10	10	10	45	55
10	I	R	10	10	10	45	65	70
		L	10	10	10	50	65	70
	II	R	10	10	10	45	65	65
		L	10	10	10	50	65	75

APPENDIX I. --Pure tone test results (continued)

First test--Long Form (I)
Second test--Long Form (II)

Long Form Bone Conduction Results

Subject	Test	Ear	250 cps	500 cps	1000 cps	2000 cps	4000 cps
1	I	R	10 db	10 db	15 db	10 db	10 db
		L	10	10	15	25	15
	II	R	10	10	10	10	10
		L	10	10	15	20	15
2	I	R	NR*	45	NR*	45	NR*
		L	NR*	40	NR*	45	NR*
	II	R	NR*	45	NR*	40	NR*
		L	NR*	45	NR*	45	NR*
3	I	R	10	10	25	20	40
		L	10	10	35	35	45
	II	R	10	10	15	25	45
		L	10	10	15	30	40
4	I	R	10	10	10	10	15
		L	10	10	10	20	25
	II	R	10	10	10	10	15
		L	10	10	10	25	25
5	I	R	10	10	30	40	40
		L	10	10	25	35	45
	II	R	10	10	25	35	35
		L	10	10	20	35	40
6	I	R	20	20	30	30	30
		L	NR*	40	35	40	40
	II	R	20	15	30	25	25
		L	25	25	30	35	NR*
7	I	R	15	20	10	20	30
		L	NR*	25	25	25	45
	II	R	20	10	10	15	30
		L	NR*	35	20	30	45
8	I	R	NR*	NR*	NR*	50	45
		L	NR*	NR*	45	45	50
	II	R	NR*	NR*	NR*	45	45
		L	NR*	NR*	40	40	50
9	I	R	10	10	10	10	35
		L	10	10	10	10	40
	II	R	10	10	10	10	35
		L	10	10	10	10	35
10	I	R	10	10	15	40	45
		L	10	10	20	NR*	45
	II	R	10	10	10	45	NR*
		L	10	10	15	50	NR*

NR* = No response

APPENDIX I. --Speech reception test results (concluded)

First test--Long Form (I)
Second test--Long Form (II)

Speech Reception Results
Speech Reception Threshold (SRT)
Speech Reception Discrimination (SRD)

Subject	Test	Right	Left	Binaural	Right	Left	Binaural
1	I	10 db	25 db	10 db	100%	96%	98%
	II	10	25	10	94	100	98
2	I	50	45	45	64	64	70
	II	50	45	45	42	78	78
3	I	30	25	25	88	74	88
	II	35	25	25	94	84	86
4	I	40	55	40	100	100	100
	II	40	55	40	96	100	100
5	I	20	10	15	64	42	64
	II	10	10	15	42	56	74
6	I	20	65	20	98	96	100
	II	20	75	20	100	98	100
7	I	30	40	30	88	50	88
	II	20	35	25	92	48	92
8	I	55	50	50	90	90	90
	II	45	50	45	90	72	90
9	I	10	10	10	100	100	100
	II	10	10	10	98	100	100
10	I	10	10	10	70	76	76
	II	10	20	15	84	86	88

APPENDIX J.--Pure tone test results

First test--Long Form (I)
Second test--Short Form (II)

Group II: Long Form Air Conduction Results (I)

Subject	Ear	250 cps	500 cps	1000 cps	2000 cps	4000 cps	6000 cps
1	R	20 db	30 db	30 db	35 db	45 db	50 db
	L	15	20	30	30	40	55
2	R	10	10	10	20	35	50
	L	30	30	40	50	65	60
3	R	10	15	30	35	45	65
	L	15	15	25	35	55	55
4	R	15	20	45	65	65	65
	L	15	25	60	60	70	70
5	R	10	10	10	10	10	55
	L	15	25	10	10	35	55
6	R	25	20	25	35	35	55
	L	35	30	30	35	45	40
7	R	10	10	25	35	55	65
	L	10	10	30	70	70	75
8	R	45	40	45	35	50	60
	L	20	10	20	20	25	40
9	R	15	20	40	55	75	85
	L	70	80	90	70	NR*	NR*
10	R	10	10	10	30	30	30
	L	10	10	15	40	40	15

NR* = No response

APPENDIX J. --Pure tone test results (continued)

First test--Long Form (I)
Second test--Short Form (II)

Long Form Bone Conduction Results (I)

Subject	Ear	250 cps	500 cps	1000 cps	2000 cps	4000 cps
1	R	20 db	30 db	30 db	25 db	30 db
	L	20	25	30	25	30
2	R	10	10	10	20	35
	L	15	15	25	25	40
3	R	10	15	25	25	45
	L	15	10	30	30	45
4	R	20	25	NR*	NR*	NR*
	L	30	30	NR*	NR*	NR*
5	R	10	10	10	10	10
	L	20	10	10	10	30
6	R	25	25	20	30	30
	L	NR*	30	25	25	30
7	R	10	15	25	35	NR*
	L	10	20	25	45	NR*
8	R	10	10	10	15	10
	L	10	10	10	15	10
9	R	20	20	40	NR*	NR*
	L	NR*	35	NR*	NR*	NR*
10	R	10	10	10	25	30
	L	10	10	10	35	25

NR* = No response

APPENDIX J.--Speech reception test results (concluded)

First test--Long Form (I)
Second test--Short Form (II)

Speech Reception Results

Subject	Test	SRT Right	SRT Left	SRT Binaural	SRD Right	SRD Left	SRD Binaural
1	I	45 db	35 db	35 db	100%	92%	100%
	II	40	25	25	100	98	100
2	I	10	50	10	96	50	98
	II	10	50	15	94	72	98
3	I	30	25	25	90	94	96
	II	35	30	30	90	94	90
4	I	35	35	35	92	84	98
	II	35	40	35	94	96	98
5	I	10	10	10	98	98	98
	II	10	15	10	100	100	100
6	I	35	30	30	82	60	86
	II	35	35	35	80	88	92
7	I	25	20	20	86	52	76
	II	20	30	25	84	86	92
8	I	45	25	25	98	96	100
	II	45	20	20	100	98	100
9	I	35	80	30	70	20	74
	II	30	90	35	64	22	68
10	I	10	10	10	90	96	98
	II	10	15	10	98	100	100

APPENDIX K. --Speech reception test results

First test--Short Form (I)
Second test--Long Form (II)

Group III: Speech Reception Results

Subject	Test	SRT Right	SRT Left	SRT Binaural	SRD Right	SRD Left	SRD Binaural
1	I	10 db	40 db	10 db	96%	98%	96%
	II	10	35	10	98	100	100
2	I	55	55	55	84	62	80
	II	45	55	45	78	64	78
3	I	35	20	20	96	100	100
	II	30	25	30	98	100	100
4	I	30	10	10	100	100	100
	II	25	10	10	100	100	100
5	I	10	75	10	100	96	98
	II	10	70	15	100	98	100
6	I	80	50	50	24	68	78
	II	80	50	50	48	78	86
7	I	40	20	20	80	92	96
	II	35	20	25	74	86	94
8	I	30	30	30	80	82	86
	II	30	30	25	70	92	86
9	I	25	40	25	96	98	100
	II	20	40	25	92	96	100
10	I	65	10	10	72	98	100
	II	65	10	10	98	96	96

APPENDIX K. --Pure tone test results (continued)

First test--Short Form (I)
Second test--Long Form (II)

Long Form Air Conduction Results (II)

Subject	Ear	250 cps	500 cps	1000 cps	2000 cps	4000 cps	6000 cps
1	R	20 db	15 db	10 db	10 db	10 db	25 db
	L	45	40	35	25	20	35
2	R	20	25	45	55	70	60
	L	40	40	50	65	70	75
3	R	10	20	40	30	40	50
	L	15	15	25	30	45	35
4	R	30	30	25	30	55	70
	L	10	10	10	10	40	60
5	R	10	20	25	10	10	15
	L	50	85	85	65	70	85
6	R	75	75	65	80	90	85
	L	35	35	45	65	55	70
7	R	30	35	35	30	45	50
	L	20	15	20	35	60	85
8	R	20	15	20	55	45	45
	L	20	15	10	55	45	45
9	R	15	10	30	45	50	55
	L	40	35	55	60	45	55
10	R	30	10	65	70	95	90
	L	10	10	10	10	15	40

NR* = No response

APPENDIX K. --Pure tone test results (concluded)

First test--Short Form (I)
Second test--Long Form (II)

Long Form Bone Conduction Results (II)

Subject	Ear	250 cps	500 cps	1000 cps	2000 cps	4000 cps
1	R	15 db	10 db	10 db	10 db	20 db
	L	20	15	20	25	30
2	R	15	30	30	45	NR*
	L	NR*	40	35	NR*	NR*
3	R	10	25	30	25	30
	L	15	15	20	25	35
4	R	10	10	10	10	40
	L	10	10	15	10	30
5	R	25	35	35	15	10
	L	45	40	45	25	35
6	R	NR*	45	50	35	50
	L	NR*	35	40	35	NR*
7	R	25	20	40	25	45
	L	25	20	25	30	35
8	R	10	10	10	25	40
	L	10	10	10	NR*	40
9	R	10	10	35	30	35
	L	15	10	35	35	50
10	R	20	10	20	35	30
	L	10	10	10	10	15

NR* = No response

APPENDIX L. --Speech reception test results

First test--Short Form (I)
Second test--Short Form (II)

Group IV: Speech Reception Results

Subject	Test	SRT Right	SRT Left	SRT Binaural	SRD Right	SRD Left	SRD Binaural
1	I	25 db	15 db	15 db	90%	96%	92%
	II	25	15	10	100	100	100
2	I	55	45	50	68	72	74
	II	60	50	55	60	78	78
3	I	55	40	40	94	84	90
	II	55	50	45	96	98	98
4	I	30	30	25	98	100	98
	II	30	25	25	96	96	96
5	I	30	10	10	96	90	96
	II	35	15	15	96	98	96
6	I	10	20	10	70	70	74
	II	10	20	10	78	82	76
7	I	10	10	10	84	92	96
	II	10	10	10	72	94	94
8	I	40	25	30	100	100	100
	II	35	25	25	100	100	100
9	I	50	100	50	84	NR*	86
	II	50	100	50	74	NR*	84
10	I	35	45	35	98	74	100
	II	40	40	35	96	80	98

NR* = No response at upper limits of the Allison 20-A Audiometer

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