Comparison of Auditory Acuity to Pure Tones and the Ability to Discriminate Between Sixteen English Consonants.

Robert Newcomb Plummer
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COMPARISON OF AUDITORY ACUITY TO PURE TONES AND THE ABILITY TO DISCRIMINATE BETWEEN SIXTEEN ENGLISH CONSONANTS

A Dissertation

Submitted to the Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College in partial fulfillment of the requirements for the degree of Doctor of Philosophy in

The Department of Speech

By

Robert Newcomb Plummer
B. S., Oklahoma A. and M. College, 1935
M. A., George Peabody College for Teachers, 1936
1940
ACKNOWLEDGMENT

To

Dr. Claude K. Kantner

for his willing and valuable assistance
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ABSTRACT

The individual with articulatory defects is a common figure in the speech clinic. In many of these cases there is no apparent physiological nor anatomical cause for the defect. Speech correctionists have heretofore contended that such defects may be caused by a special type of deafness which made it impossible to hear, and therefore to learn to articulate, certain of the sounds used in speech. One type of such deafness is that in which an individual cannot hear high frequency sounds, and therefore, it has been assumed, cannot hear or distinguish between the consonants which are said to depend upon these high frequencies for their distinguishing characteristics. There has been devised no complete test, however, the sole purpose of which is to determine ability to discriminate between the sounds supposedly using high frequencies, and consequently no check of such ability against an objective test of hearing. The purpose of this study has been (1) to construct a speech sound discrimination test involving sixteen consonants said to depend upon the high frequencies of from 1000 to 2000 cps. upward for their recognition, i.e., (p, t, k, f, s, θ, s, tʃ, b, d, z, v, z, ɣ, ʒ, dʒ); (2) to compare the ability of a group of individuals to discriminate between these sounds and their ratings on a 6E Western Electric audiometer test.

The speech sound discrimination test was constructed and administered to 395 Louisiana State University undergraduates. The first testing was done in large classroom groups. Upon the basis of two testings for 70 of these subjects, a retest reliability of .75 ±.03
was determined for the test. Fifty-two subjects were then selected from the original 393 and given the discrimination test again, this time under more favorable conditions, i.e., in small groups and in a smaller, quieter room. These 52 were next given a very thorough 60 audimeter test over 28 frequencies within the range from 125 to 9747 cps.

By an analysis of the data derived from this testing procedure the following conclusions were reached:

1. The speech sound discrimination test constructed for this experiment is related closely to hearing ability as determined by the audimeter. A correlation of .73 ±.04 was found between audimeter ratings and discrimination over-all test scores made in small group testing.

2. The discrimination test is reliable as a general test of hearing for discovering a great majority of the cases with normal or better hearing ability in large or small groups of subjects. All those cases in this study who made scores of nine or less in either small or large group testing were found to have superior or normal hearing. While it is true that large group test scores of 51 or above, and small group scores of 16 or above indicated defective hearing, the available number of such cases for this experiment was too small for final, conclusive evidence as to scores which definitely indicate defective hearing. The score ranges of 10 to 14 and 12 to 50 for small and large groups, respectively, may be said to be the border lines for normal and defective hearing.

1. The score on the discrimination test was the number of errors.
defective hearing. Subjects within these ranges were approximately equally divided between defective and normal cases. However, the chances as based upon the findings are three to one that scores not higher than from 12 to 25 made in large group testing indicate normal or better hearing.

3. Neither mild nor severe high frequency losses in hearing can account for any appreciable difficulty in discriminating the consonants which have been said to depend largely upon the frequencies above 2000 cps. for their distinguishing characteristics.

4. There is no relationship between hearing losses at specific frequencies and ability to discriminate between specific consonants.

5. Contrary to former opinion, combinations made up of stop-fricative sounds are relatively difficult to discriminate. Considering the proportionate number of times each occurred in the test, fricative-fricative combinations were missed only 25 percent more often than stop-fricatives, and the latter were missed 8 percent more often than stop-stop combinations.

6. It is approximately one-third more difficult to discriminate between two sounds which are different than it is to determine that two sounds are the same.

7. The eleven most frequently missed pairs of sounds were, in the order of least to greatest number, (af-as, 2 ad=a, 2 ag=a, va=ga, aw=aw, 3 ad=aw, 3 a-d, aw=aw, aw=aw) and (af=a).

2. Missed an equal number of times.
3. Missed an equal number of times.
8. In the order of least to greatest difficulty in discrimination, the sixteen consonants fell as follows: (s, tj, dʒ, ʃ, s, p, ɡ, t, d, ʒ, b, k, ɡ, v, f) and (ʌ).

9. In terms of combined consonant position and the element of voice, errors occurred from the least to the greatest number of times on (1) initial voiced consonants, (2) medial voiced, (3) medial voiceless, (4) initial voiceless, (5) final voiced, and (6) final voiceless. Relative to the element of voice alone, errors occurred slightly more often on voiceless consonants than on voiced ones. In terms of consonant position only, finally placed consonants were missed most often, and initially and medially placed consonants were missed an equal number of times.
Part I

INTRODUCTION

As The Relationship between Speech and Hearing. The relationship between speech and hearing involves certain conditions which seem quite obvious, others which are somewhat generally assumed but definitely less obvious, and some which are quite unknown. Given the psychological assets, the intelligence, the neurological and anatomical structures, and the functional coordination requisite to the actual production of speech, its normal development seems to depend finally upon the ability to hear the speech of those around us and to make auditory check upon imitative reproductions. Three things, then, seem quite obvious: (1) an individual who is congenitally and completely deaf, or who is completely deafened before he has developed speech, will not only require special training to learn to speak at all, but he will never develop normal speech; (2) an individual who possesses normal hearing, in addition to the other requisites set forth above, will develop normal speech; (3) certain degrees and types of deafness should have corresponding, negative effects upon the development of speech.

The less obvious relationships between speech and hearing are the effects of given degrees and types of deafness upon the development of speech. Deficiencies in auditory acuity may be said to fall into two types: (1) reduced acuity, which includes (a) "fundamental range" deafness, (b) "resonance range" deafness and (c) "high frequency" deafness; (2) "tone" deafness. These types of hearing defects are so named to indicate loss of sensitivity to specific ranges, or bands, in the fre-
frequencies used in the sounds of speech. A third type, general deaf-
ness, may be added to indicate a composite of all the preceding types.

The average frequency range to which the human ear is sensitive is
from 20 to 20,000 cps. However, as the frequency approaches either of
these extremes, it is increasingly difficult of perception. Conse-
sequently, the sounds used in speech are limited by the natural law of
efficiency to a frequency range falling well inside the extremes of 20
and 20,000 cps. Approximate ranges of 100 to 8000 and 200 to 6000 cps.
have been indicated by West and Steinberg respectively. Fletcher
states that while the sibilants carry considerable energy at frequencies
up to 10,000 cps., those above 5000 are of little importance in under-
standing speech. Ansberry has concluded that the frequencies above
4000 cps. are of little importance in speech for those familiar with
English speech sounds. Watson and Knudsen, on the other hand, contend

1. Robert West, Lou Kennedy and Anna Carr, The Rehabilitation of
   Speech, (New York: Harper and Brothers, 1937), pp. 164-166. (Cited here-
   after as West et al., Rehabilitation).
2. Harvey Fletcher, Speech and Hearing, (New York: D. Van Nostrand
3. West et al., Rehabilitation, p. 125.
4. John C. Steinberg, "Effects of Distortion on the Recognition of
   Vol. 1, No. 1, pp. 121-137, October, 1929. (Cited hereafter as Stein-
   berg, "Effects of Distortion").
5. Harvey Fletcher, Letter to Robert N. Plumer, New York, Dec. 7,
   1939.
6. Earle Ansberry, "The Effect upon the Ability to Discriminate
   between Speech Sounds by the Elimination of Frequencies above 4,000
   Vol. XXIV, No. 3, p. 369, October, 1938. (In his article Ansberry re-
   ports over a dozen other "important ranges for speech," by some fifteen
   authors. These ranges are as limited as from 128 to 512 cps. and as
   wide as from 80 to 6000 cps., but by the very nature of their variety
   this study must place little significance in them).
that the consonants (s, s, f, v, δ) and (θ) have characteristic frequencies above 6000 oes, which are necessary for their sure recognition.

In terms of the types of deafness referred to earlier, the frequency range of speech has been divided into three bands; namely, the "fundamental," or low, frequencies, which arise at the vocal folds; the "resonance," or middle, frequencies, which are created in the resonance cavities around the speech mechanism; and the "friction," or high, frequencies, which arise at the narrow orifices created by the approximation of the organs used in speech during the utterance of certain sounds. Accordingly, West separates the sounds of speech into overlapping groups of (1) fundamental frequencies, with a range of from 100 to 400 oes; (2) resonance frequencies, with a range of from 400 to 2400 oes; and (3) friction frequencies, with a range of from 2400 to 8000 oes. In the fundamental group he places all semivowels, or voiced sounds; in the resonance group, all vowels, semi-vowels and the nasal consonants; and in the friction group, all stop, fricative and sibilant consonants. Steinberg states that the frequency region of importance for the vowels is from 200 to 5000, for the nasal consonants from 500 to 4000, for the stop consonants from 750 to 5000, and for the fricative consonants from


8. West et al., Rehabilitation, pp. 128-128, 176-177. (In a more recent publication West has been somewhat more specific in his indication of the frequencies involved in the sounds of speech. The only modification of even small significance, however, is his extension of the high frequency range to include 2000, rather than 2400, up to 8000 oes. See West, The Testing of Hearing Aids, College Typing Company, Madison, Wisconsin, 1949).
In such an overlapping classification of the frequencies said to be involved in the various sounds of speech, it may readily be seen that West's classification of the sounds in terms of fundamental, resonance and friction frequencies cannot mean that a given group of sounds involve only these characteristic frequency bands. For example, according to West, a voiced consonant contains fundamental frequencies, by virtue of its being voiced, and it contains high, or friction, frequencies by virtue of its being a consonant. His classification does indicate, however, that, according to his analysis, fundamental, resonance and friction frequencies form in major part the characteristics by which an individual recognises and discriminates between the sounds of speech. By his reasoning, for example, one can distinguish between two sounds, one voiced and the other voiceless, upon the basis of the presence of fundamental frequencies in one and their absence from the other. Similarly, one can distinguish between two vowels on the basis of differences in resonance frequencies, and between two voiced or two voiceless consonants upon the basis of a difference in friction frequencies.

In theory, then, according to West, fundamental frequency deafness refers to the inability to hear the frequencies from 100 to 4000 cps., and an inability to hear the fundamental tones of any sound of speech; resonance range deafness refers to the inability to hear the

10. West says that the factor of pressure pattern also forms a distinguishing characteristic between plosives and continuants. It is believed in this study, however, that this factor as employed in actual speech is so minimized as to be of little value in speech sound discrimination. As will be seen later, this belief is at least partially justified by the present findings with regard to the relative difficulty of discriminating between stop and fricative sounds.
frequencies from 400 to 2400 cps., and the inability to distinguish between the vowels, semi-vowels, diphthongs and nasal consonants; while friction, or high frequency, deafness refers to the inability to hear the frequencies from 2600 to 6000 cps., and the inability to distinguish between two voiced or two voiceless consonants. Tone deafness refers to the inability to distinguish between two closely related frequencies, or pitches, while a case of deafness which involves all of these special types is known as a case of general deafness.

The individual with articulatory speech defects is a common figure in the speech clinic. In many such cases there is no apparent anatomical or physiological cause for the defect. Some speech correctionists have believed that such a defect may be due to a special type of deafness. In accordance with this belief, which to date is largely assumption, that each of the four types of hearing difficulties bears a direct and special relationship to speech, it has been felt that the most efficient and expedient correction of articulatory defects due to deafness should proceed in accordance with the type of deafness present. It has been felt, therefore, that the correctionist must endeavor to ascertain the degree of hearing loss in a known case of deafness, or that he must endeavor to discover both the type and the degree of hearing loss in articulatory defects believed to be due to deafness which heretofore has not been discovered in the individual. In order to discover degrees and types of hearing difficulties, various auditory testing devices have been employed.


Wert et al., *Rehabilitation*, pp. 154-156.
Mechanical Hearing Tests. Many mechanical devices are used in testing hearing ability. Hearing loss is calculated upon the basis of sound to the watch tick, the coin click, tuning forks, Politzer's acometer and the human voice. Among many other testing devices are Galton's whistle, Struecken's monochord and, notably, a series of electrically operated audiometers. Several of these audiometers have been developed by Western Electric Company, while one, the Iowa pitch range audiometer, has been developed by the joint cooperation of several departments in the State University of Iowa.

There has been an attempt to standardize the watch tick test by exclusive use of the Ingersoll. This watch is normally heard at a distance of 40 feet. It is thought to be particularly suited to standardization because its parts are die pressed in manufacture, and each watch produces approximately the same sound. Generally, watches produce a frequency of about 2000 cps.

The coin click test consists of striking a coin on a hard surface. Its use is not standardized.

The acometer, as the watch and coin, produces one sound only, and also is essentially a test of high frequency. This device consists of a short steel bar set at right angles into an upright metal stand. Attached to the stand above the bar is a small metal hammer which, when released, falls and strikes the bar. The sound produced by the acometer

12. Fletcher, Speech and Hearing, p. 199. (The use of the unrecorded human voice is discussed in this section because the method of recording and interpreting the results of testing, in terms of distance or intensity ratios, is the same as that used for mechanical tests).
16. Fletcher, Speech and Hearing, pp. 207-208.
is similar to that of a loud watch tick. Its frequency is about 512 cycles and it is normally heard at a distance of 45 feet.\(^\text{17}\)

The procedure in testing with the watch, coin and acoumeter is to determine the greatest distance at which the sound of each is barely perceptible. This distance is then expressed in a ratio; for example, \(\frac{6}{40}\). The numerator is the distance a subject can hear the sound, while the denominator is the distance it can be heard by a person with normal hearing.

In using the human voice as a testing medium, a similar ratio is used to express the greatest distance—or least intensity—at which a subject can interpret words or sentences in loud and soft whisper, conversational and loud voices.\(^\text{18}\)

One model of the electrical audimeter, the WA, was developed by Western Electric Company to supplant the use of such tests as the watch tick, coin click and acoumeter. This audimeter produces a single, bussing sound which is made up of component frequencies scattered over the entire frequency range of speech.\(^\text{19}\)

Tuning forks are available for producing pure tones at intervals over the audible frequency range. The procedure in testing is to give a "standard" blow to the fork to set it vibrating, then to hold it very close, but not touching, to the ear. An individual's acuity is determined by recording the time elapsing between striking the fork and the moment at which a subject ceases to hear the sound. The time elapsing

\(^{17}\) Goldstein, Problems of Deaf, p. 191.
\(^{18}\) Fletcher, Speech and Hearing, pp. 202-206.
\(^{19}\) Being, Aspasia, p. 21.
is expressed in ratio to the length of time a person with normal acuity can hear the fork. By tables and formulas presented by Fletcher, ratios for all these hearing tests can be interpreted in terms of decibels, or sensation units. 20

Galton's Whistle and Struycken's monochord are utilized to test sensitivity to extremely high frequencies. Galton's whistle is constructed of a metal plunger, a cylindrical tube and a rubber bulb. The plunger is set into the cylinder and is adjustable to produce frequencies from 4000 to 25,000 cps. The rubber bulb, which is attached to the cylinder, is pressed to provide the source of energy. The monochord is composed of an adjustable steel wire strung on a flat, 60 cm. steel bar. Tension of the wire is accurately adjustable to produce the desired tones. Two models of this device are capable of producing, respectively, transverse vibrations from 387 to 6200 cps. and longitudinal vibrations from 6000 to 25,000 cps. Longitudinal vibrations are evoked by longitudinal strokes along the wire with an especially designed metal disc. Transverse vibrations are produced by striking the wire with a wedge-shaped metal hammer, or by drawing an especially constructed bow across the wire. In testing with the monochord and Galton's whistle, more sensitivity or insensitivity to the tones is recorded. 21

With the exception of the 2A model, all audiometers are constructed to produce approximately pure tones. The Iowa pitch range audiometer makes use of two generators, one for producing low and the other for

20. Fletcher, Speech and Hearing, pp. 196-221. (The term "decibel" is here used to indicate the least perceptible increase or decrease in the intensity of a sound).
producing high frequencies. The generators are driven by an electric
motor and are capable of generating frequencies from 30 to 14,500 cps.,
with 22 steps of intensity. The 2A Western Electric audiometer makes
use of five vacuum tubes, a copper-oxide modulator and an attenuator,
to produce and control the intensity of different frequencies from 64
to 8192 cps. 22 The 6B audiometer is the 1939, improved model of the
2A Western Electric audiometer. This device employs the same prin-
ciples of construction to produce continuous tones from zero to approxi-
mately 10,000 cps., with an intensity range of from minus 15 to plus 105
decibels. 23 In all audiometers, including the 2A model, the intensity
may be varied under accurate control.

Since this study concerns itself with certain devices used in an
effort to determine ability to hear speech, 24 those described above are
viewed in terms of their theoretical relationship to this interest.
They divide themselves, thus, into three groups: (1) those which are
believed to bear little or no relationship to speech; (2) those which
are inaccurate or only partially are tests of hearing for speech; and
(3) those which are presumed to be concerned directly with the hearing
of speech. Into the first group fall the watch tick and the coin tick,
the resonator and the 2A, buzzer type audiometer. The second group
includes tuning forks, the monochord and Galton’s whistle. Into the
third group fall the Iowa pitch range audiometer, the 2A and the 4A

24. The term “test for the hearing of speech” is used to indicate
a test which attempts to determine an individual’s ability to hear actual
speech as employed in the communication of ideas.
Western Electric audiometers and those tests which make use of the human voice. This division is based upon the assumption in this study, which in turn is based largely upon theory, that a test for the hearing of speech must involve either the human voice or rigid testing at close intervals over the entire frequency range said to be used in speech. If a test involves the frequencies said to be used in speech, a further requisite held by this study is that the intensity of the tones tested must be subject to controlled variability. Obviously, the watch tick, the coin click and the ascrometer are too limited in the frequencies they produce to give an indication of hearing for speech. The same may be said of the 3A audiometer in its production of a single sound. Tuning forks, the monochord and Galton's whistle are listed under the second category because (1) they are not constructed to produce all the frequencies used in speech, or (2) because of the impossibility of varying or controlling with any accuracy the intensity of the tones they produce. Both of these conditions apply to the monochord and Galton's whistle, while the second applies to tuning forks. Tuning forks are available for producing a series of tones, five frequency steps apart, from 32 to 30,720 cps. However, the most commonly used forks are those producing tones at octave intervals from 32 to 4096 cps.\textsuperscript{25} The use of these forks in a test for acuity to pure tones presents four difficulties: (1) it is difficult to calculate hearing distances; (2) it is difficult to control the intensity of the tone; (3) only a limited range of intensity may be assured; and (4) the use of eight or more tuning forks is a cumbersome and slow process, in that it is impossible to make even relatively rapid

changes in the intensity of the tone produced by each. 28

Among the testing devices listed in group three as presumed to be
directly related to hearing for speech—the human voice, the 2A, 4A and
the Iowa pitch range audiometers—the three audiometers are probably
the most efficient tests for acuity to the frequencies said to be im-
portant for speech. A test which employs the unrecorded voice is less
objective. The shortcoming of such a test is the uncertainty of the
control of intensity, as well as all other tonal elements. However,
the value of tests of this type cannot be entirely overlooked for the
simple reason that they use the human voice as the source of sound.
The virtue of the 4A audiometer lies in the fact that it uses the human
voice and at the same time controls the intensity. This test makes use
of recorded numbers. As the record is played, the intensity of the
voice is gradually diminished, and by noting the intensity of the last
correct number the subject was able to write down, his intensity, or
hearing, threshold is established. The value of these audiometers which
test acuity to pure tones lies in their ability to produce tones through-
out the entire frequency range said to be used in speech.

If the theory as above stated is true, namely, that the recognition
of and discrimination between certain groups of speech sounds depend
upon the acuity to fairly definite and corresponding frequency bands,
then it should follow that complete or partial deafness to a given fre-
quency band will affect one's ability to recognize and discriminate
between the speech sounds said to utilize that band. This is to say,

28. Deaf, Aphasia, pp. 23-26. (For a further discussion of the
audiometers, as well as a very thorough discussion of hearing in general,
that if an individual's acuity to tones of the high frequency band only is defective, it should follow that he has difficulty in recognizing and discriminating between only the so-called friction sounds, or, the stop, fricative and sibilant consonants. Similarly, if it is revealed that an individual has defective acuity only to the resonance frequencies, it should follow that he has difficulty in recognizing and discriminating only between the resonance sounds, or, the vowels, semi-vowels, and the nasal consonants.

That such a causal relationship exists between speech and hearing is somewhat in question, however. As stated earlier, the existence of this relationship is largely theoretical. In short, it lacks experimental verification. This is to say, that to date no complete and scientifically constructed tests have been devised for testing acuity to the individual groups of sounds said to depend upon corresponding frequencies for their recognition and discrimination; and having no such test, it has been impossible to check acuity to these individual groups of sounds against objective tests of acuity to these frequency bands. It seems probable that evidence as to the existence of this causal relationship, if it is to be found, lies in a comparative study of acuity to the various frequencies used in speech and the ability to recognize or discriminate between the actual sounds of speech which are said to be characterized by these frequencies. For testing acuity to the frequencies found in speech, the GR Western Electric audiometer is perhaps one of the most effective. In testing discrimination between specific sounds of speech a general test will not suffice. A test, for example, which requires interpretation of complete words or sentences
is not fine enough to reveal discriminative difficulties with specific sounds. Words and sentences containing single speech sounds which are difficult to perceive may be interpreted upon the basis of intellectual content or perceptible sound content, or both. In order to discover an individual's ability to recognize or discriminate between the speech sounds of a given frequency band, the sounds said to utilize this band must be presented in relatively isolated form, and not in intellectual context nor in a context with other sounds which may give pattern clues.

Though not for the purpose of a comparative study such as that stated above, several investigators have considered the value of general hearing tests for acuity to the single sounds of speech. Accordingly, several speech sound discrimination and recognition tests have been devised. These are described in the following section.

C. Speech Sound Discrimination and Recognition Tests. Dr. Harvey Fletcher devised a test, "The Standard Articulation Testing List," involving the sounds of speech. Each of the sounds used in the English language was incorporated in simple syllable forms, composed of consonant-vowel (pa, ba, etc.), vowel-consonant (ap, ab, etc.), and consonant-vowel-consonant (pab, tap, etc.) combinations. A subject listened to and indicated recognition of these syllables as they were called to him over a telephone system. Since, however, various distortions were introduced into the system as syllables were called, the test was devised, not for the purpose of determining the ability of an individual

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27. These investigators include Fletcher, Travis-Hassemer, Ansberry, Hall, Ewing and Hettem-Knudsen. References to and descriptions of their respective studies will be referred to in the following section.

to recognize normal speech sounds, but to determine the average person's ability to recognize distorted speech sounds. The ultimate purpose of the test was to discover the effects of distortion upon recognition of speech sounds, and thus to check upon the efficiency of transmission systems.

A test constructed by Travis and Rasmus, "The Travis-Rasmus Speech-Sound Discrimination Test," is based, as implied in the title, upon discrimination between the sounds of speech. It involves calling out pairs of speech sounds to an individual, who indicates whether the two sounds in a given pair are the same or different. The test makes use of twenty-four consonant and eleven vowel sounds. Each consonant is paired once with itself and once with every other consonant, and each vowel is paired once with itself and once with every other vowel. This test, however, in pairing voiceless consonant with voiced consonant and nasal sounds with both voiceless and voiced consonants, includes single pairs of sounds which, according to theory, may be discriminated upon the basis of as many as three sound elements. The three examples that follow illustrate this theory: (1) any pair composed of a voiced and a voiceless consonant (p-g, t-d, etc.) may be discriminated, or judged as different, upon the basis of both friction and fundamental frequencies. The latter is true because in the respective pairs one sound has fundamental vibrations, or is voiced, while the other sound has not, or is voiceless; and the former is true because, while both sounds in

such a pair have friction frequencies, the frequencies of one sound are
different from those of the other. (2) Any pair of sounds composed of
a voiced consonant and a nasal consonant (b-m, d-n, etc.) may be dis-
criminated upon the basis of both friction and resonance frequencies.
The latter is true because the nasal consonants are said to have reso-
nance frequencies that are not present in other consonant sounds; and
the former is true because the nasals are said to have no friction fre-
quencies, while the other consonants do. (3) Any pair of sounds made
up of a voiceless consonant and a nasal sound (p-m, t-n, etc.) may be
discriminated upon the basis of fundamental, resonance and friction
frequencies. This is true because the nasals are voiced and thus have
fundamental frequencies, while the other consonants involved in such
pairs are voiceless; the nasal consonants are characterized by resonance
frequencies and the other consonants are not, and the nasals are said
to have no friction frequencies, while the other consonants do.

Such pairs of sounds, whose members are said definitely to differ
in at least two frequency ranges, cannot be used to determine an in-
dividual's acuity to a given frequency band said to be characteristic
of a certain type of speech sound. Assuming, for example, that an in-
dividual is known to have impaired hearing in one of the two ranges,
he still can discriminate, or tell the difference between, the two
sounds in question upon the basis of the frequency characteristic in
which he has no impairment. Such test pairs would not show which fre-
quency range is abnormal, but they would indicate that at least one of
them is normal in acuity. In short, pairs of sounds which may be dis-
criminated upon the basis of more than one of the frequency character-
istics said to be involved in speech sounds, constitute a general test of the ability to hear speech, but not a test which is specifically diagnostic as to where the disabilities in discrimination lie.

The Travis-Rasmus test does include some pairs which differ, according to theory, within one frequency range only. For example, any two paired vowels are said to differ in the resonance frequencies, while two paired voiceless consonants or two paired voiced consonants are said to differ in the friction frequencies. And if an individual's discriminatory errors on such pairs are scored and studied apart from each other, they may reveal specifically where frequency range efficiencies and deficiencies lie. Failure, however, to score and study errors in vowel discrimination, in voiceless consonant discrimination and in voiced consonant discrimination as separate units, further marks the test as one of general hearing ability.

Margaret Hall, in a study at the State University of Iowa, constructed a "Complex Speech Sound Discrimination Test." It employs relatively short phrases, meaningful except for one word; for example, "My per'sen lent friends." The procedure in administering this test was to present such a phrase to a subject twice, orally. The phrase was then repeated six times, but only once correctly, or as it had been read originally. In each of the remaining five repetitions the nonsense word was altered slightly by changing one sound. The object was for the subject to recognize the one correct repetition and respond by recording the number of

30. Margaret E. Hall, "Auditory Factors in Functional Articulatory Speech Defects," Unpublished Doctor's dissertation, State University of Iowa, February, 1936, p. 13. (Cited hereafter as Hall, "Auditory Factors." The test referred to here is that form, of which there were two, which Hall used in testing adults).
its position in the series—1, 2, 3, 4, 5, or 6. The subject was required to listen to all six repetitions before recording his answer.

The nature of this test leads one to question its validity as purely a test of hearing. It may be also a test of memory. This possibility is strengthened by the fact that Bell found its coefficient of correlation with a 2A Audimeter test to be $r = .05 \pm .15$ for an experimental and $r = .18 \pm .15$ for a control group, and with the Travis-Ramus Speech-sound Discrimination Test, $r = .20 \pm .07$, and $r = .47 \pm .06$ for these two groups, respectively, whereas, the coefficient of its correlation with percentile ratings on a general ability, or intelligence, test was $r = .45 \pm .06$ and $r = .43 \pm .07$ for experimental and control groups, respectively.31

Ansberry instituted a procedure similar to Fletcher's, i.e., transmitting speech over a telephone system with certain frequencies eliminated.32 Instead of using nonsense syllables, Ansberry's test involved paired words which differed chiefly in one particular sound. The test made use of eleven vowels, each of which was paired with every other vowel, and twenty-one consonants, each of which was paired with every other consonant. Both the discussion relative to Fletcher's and that relative to the Travis-Ramus test apply to the test used by Ansberry. He was interested in determining the difficulty of discriminating and recognizing disturbed speech sounds and his test was one of general hearing in its use of complete words.

Watson and Knudsen devised a number of "articulation" lists, patterned after Fletcher's test, for a study concerning selective amplifi-

---

ocation in hearing aid. These lists made use of 69 words. Twenty of
them were one-syllable English words, each using a vowel between the
consonants (b) and (t) or (b) and (k). The remaining 49 were one-sylla-
ble English words, each made up of an initial consonant followed by (e)
or (al), or a final consonant preceded by the vowel (i).

These words were recorded. In actual testing, a record was played
and the subject was required merely to signal each time he heard a word.
At three-word intervals (bait, set, ret— but, rip, bom, etc.) the in-
tensity of the record was decreased until the subject no longer heard
any of the words. The intensity was then increased until all words were
again heard. A record of response or no-response was kept for each word.
From this record the percentage of correct responses, or the percentage
of articulation, was derived.

Watson and Knudsen's test is not a recognition test. The subject
was required only to indicate that he had heard a word, and not to
specify what the word was. For is the test one of discrimination, be-
cause it does not require indicating whether any two or more words are
the same or different. It is more nearly a general hearing test, in
that it requires merely a response to indicate that one has heard some-
thing, and in that the test is made up of complete words. It further
classifies itself as a general hearing test by its use of vowels, voiced
consonants and voiceless consonants in a single word; for example, the
words "bait," "rich," "whiz," etc. In short, this test would be no more
specifically diagnostic as to where disabilities in discrimination lie
than would the Travis-Fassnacht test.

Ewing, in a study of ten "congenitally" aphasic children, included tests of the ability to recognise and repeat vowels and consonants. These were presented, orally, in words and sentences which the subject attempted to repeat. Complete lists of such elements used do not appear in his report of the study, but the vowels were presented in poems and in such words as "two," "three," and "four." In Ewing's test the consonants were presented in such words as the following:

<table>
<thead>
<tr>
<th>word</th>
<th>confusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>drawer</td>
<td>(which same children confused with door)</td>
</tr>
<tr>
<td>candle</td>
<td>&quot;handle&quot;</td>
</tr>
<tr>
<td>hole</td>
<td>&quot;seal&quot;</td>
</tr>
<tr>
<td>candle</td>
<td>&quot;tunnel&quot;</td>
</tr>
<tr>
<td>glass</td>
<td>&quot;brass&quot;</td>
</tr>
<tr>
<td>train</td>
<td>&quot;sand&quot;</td>
</tr>
<tr>
<td>stamp</td>
<td>&quot;camel&quot;</td>
</tr>
<tr>
<td>bought</td>
<td>&quot;brought&quot;</td>
</tr>
<tr>
<td>summerhouse</td>
<td>&quot;summerhouse&quot;</td>
</tr>
<tr>
<td>spread</td>
<td>&quot;bread&quot;</td>
</tr>
<tr>
<td>tunnel</td>
<td>&quot;funnel&quot;</td>
</tr>
<tr>
<td>dashed</td>
<td>&quot;splashed&quot;</td>
</tr>
<tr>
<td>took</td>
<td>&quot;put&quot;</td>
</tr>
<tr>
<td>frog</td>
<td>&quot;fog&quot;</td>
</tr>
</tbody>
</table>

Ewing's study also included Western Electric 2A audiometer testings, and he concludes, upon the basis of high frequency deficiencies as revealed by the audiometer, that in six of the ten cases of "aphasia," consonant confusions such as those listed above were due to high, or friction frequency deafness. However, for reasons stated earlier in this discussion, the objection to Ewing's test is its lack of specificity as to the types of sounds tested.

It seems probable that the speech sound discrimination test best suited to the purpose of determining an individual's ability to recognise the difference between, or similarity in, two speech sounds when presented orally, would be a test made up of paired sounds which can be discriminated.

84. Ewing, Aphasia, Ch. IV.
upon the basis of the least possible number of elements, or distinguishing frequencies, involved in the sounds of speech.

In this speech sound discrimination test, then, vowels should never be paired with consonants, since two such sounds are said to be distinguishable from each other upon the basis of both resonance and friction frequencies. Likewise, voiceless consonants should never be paired with voiced ones, since they could be distinguished upon the basis of both fundamental and friction frequencies. Rather, vowels should be paired only with vowels, voiceless consonants only with voiceless consonants and voiced consonants only with voiced consonants. The distinguishing characteristic between any two vowels would then be, supposedly, the element of resonance frequency, while the distinguishing characteristic between any two voiceless or any two voiced consonants would be the element of friction frequency.

A further condition of the speech sound discrimination test is that it should involve only vowels or only consonants, or, if it involves both, an individual's vowel discrimination and his consonant discrimination ability should be reckoned separately and apart from each other; that is, if the test is to serve as a check of discriminatory ability on specific sounds against acuity to the specific frequencies said to be characteristic of those sounds. Deviation from either of these conditions marks the test as one of general hearing, rather than a test for locating hearing efficiencies on specific types of speech sounds, or in specific speech frequency ranges.

The speech sounds used in this test would probably best be incorporated in some context which would allow giving them as nearly as
possible their values as employed in normal speech. Presenting these sounds in isolated form would hardly be a test for the hearing of speech, because they do not occur in isolation in normal speech. Further, it would hardly do to present them in meaningful words, since these words could be discriminated upon the basis of meaningful context, and would not serve solely as a test of hearing. Obviously, then, these sounds should best be incorporated in nonsense syllables.

The method of sound pairing referred to above as probably the best, is used by West in paired words, such as "boat-goat," and "ball-bell." These words differ, respectively, by voiced consonants and by vowels. The use of words in a speech sound discrimination test, however, is believed, as stated above, to be undesirable. Both Fletcher and Travis-Rasmus have employed nonsense syllables in tests involving speech sounds, but it is believed, for reasons stated earlier, that these tests are too general to be of value in determining the nature of the loss in sound discrimination or in locating the loss of acuity in the hearing ranges.

Given a speech sound discrimination test which employs nonsense syllables, and which involves sounds paired in the manner described above, it would be desirable, in fact, necessary, to know as exactly as possible the value of this test, not only as a test of the ability to hear speech, but also as a test of hearing in general. It is probable that some type of speech sound discrimination test is used in most speech clinics, but the actual value of such tests is not known. As stated earlier in this study, they have been based upon the assumption that failure to discriminate between certain sounds indicated deafness to certain frequency bands; namely, the bands further assumed to charac-
terias the sounds tested. Just exactly what aspects of discrimination they actually test has never been definitely and experimentally determined. As also stated earlier, these tests have not been checked against objective tests of hearing. Ewing's study, referred to above, indicates that there is a direct relationship between consonant confusion and deficiencies in the high frequency ranges; and there has been an approach to an evaluation of the Travis-Rasmus discrimination test in the same light. This approach was made by Margaret E. Hall, at the State University of Iowa.

Hall, in the same study referred to earlier, administered the Travis-Rasmus test and the Western Electric 2A audiometer test to fifty people. One-half of these previously had been rated as defective in articulation and the other half as normal in this respect. Treating the normal and the defective groups as two separate units, Hall ran a correlation between their Travis-Rasmus discrimination test scores and their ratings for three frequencies on the 2A audiometer test. A correlation coefficient of .30 ± .14 was derived for the articulatory defective group and one of .18 ± .13 for the normal group. These correlations are definitely insignificant, but more significant ones could scarcely have been expected since the audiometric measure was only the average of the three middle frequencies, 512, 1024 and 2048.\textsuperscript{25} while the discrimination test, as already pointed out, included sounds in all the frequencies used in speech.\textsuperscript{26} The chief purpose of Hall's study, however, was to determine

\textsuperscript{25} Hall, "Auditory Factors," pp. 36-38.

\textsuperscript{26} This view is held despite the fact that the Western Electric Company states that the total percent hearing loss for speech is approximately equal to the average decibel reading at 512, 1024 and 2048, multiplied by .06. (Otto Carpenter, Western Electric Company, Letter to Robert E. Plummer, New York, January 26, 1940).
the relationship between general hearing and articulatory defects, and
not that existing between audiometer ratings and scores made on a speech
sound discrimination test.

**Be Statement of the Problem.** In view of the preceding background,
then, the problem of this study is as follows:

1. To construct a speech sound discrimination test for the
sixteen stop and fricative consonants in which friction frequen-
cies are commonly said to be characteristic.

2. To determine the retest reliability of, and the normal
range of scores for, this test.

3. To determine the relationship between scores made on this
discrimination test and hearing ability ratings as determined by
the Western Electric 68 Audiometer.

4. To determine whether there is a relationship between specific
errors in sound discrimination and specific losses in hearing at
certain frequencies.

**2. Subjects.** Students enrolled in Louisiana State University served
as the subjects in this study. In all, 505 students, chosen at random
from University speech classes, were given the speech sound discrimina-
tion test. Later, and by a process to be explained under Procedure, all
but 62 of the original 505 were eliminated from the study. This group
of 62 were given individual 68 audiometer tests.

For the original 505 subjects given the discrimination test no re-
quirements were set, and the only requirement for the 62 given audiometer
tests was that they should not be totally deaf. The factor of mental
ability was ignored. While it is generally acknowledged that radical
deficiencies in hearing ability may influence general educability, it
seems to be acknowledged that mental ability does not directly influence
hearing acuity. Specifically, it was found by Hall, that no significant
correlation existed between scores on the Travis-Rasmus Speech-sound
Discrimination Test and mental ability. Nor did she find a correlation
of any significance between mental ability and scores made on the Western
Electric Audiometer. Likewise, Travis-Rasmus found no relationship
existing between general intelligence and errors made on their discrimi-
nation tests. In the present study the factors of sex and age were also
ignored because no control group was used. This study is concerned pri-
marily with comparison of auditory acuity in certain frequency ranges and
speech sound discrimination ability in a single group of individuals, in
the hope that some light may be thrown on the question as to whether the
frequency regions known to be present in certain consonant sounds are
the sole or chief determining characteristics of these sounds.

37. Ibid., p. 36.
Part II

PROCEDURE

As The Speech Sound Discrimination Test. This test was devised especially for the present investigation. It is designed to test ability to discriminate among certain of the sounds used in English speech. Specifically, it is designed to determine ability (1) to distinguish any one of a certain group of eight voiceless consonants from the other seven, when presented orally; (2) to distinguish any one of a certain group of eight voiced consonants from the other seven; and (3) to recognize that the sound of any two of the sixteen sounds presented orally is a repetition of the first, and not a different sound. The group of voiceless consonants is composed of (p, t, k, f, s, th, θ, j) and the voiced group of (b, d, g, ð, v, z, ʒ) and (dʒ).

Pairings of one consonant with another, within each of these two groups, form the basis of the test. As the term "discrimination" implies, the subject is required to decide and indicate, as the sounds are called to him, whether any two paired consonants are the same or different. In order to reduce to a minimum the number of elements by which any pair of consonants may be distinguished, at least in theory, the test follows West's suggestion referred to earlier, in that a voiceless consonant is never paired with a voiced one. The pairings are always either voiceless with voiceless or voiced with voiced. This is to say, that no two consonants are so paired that they are distinguishable upon the basis

30. The phonetic symbols used are those of the International Phonetic Alphabet. Parentheses are used to indicate that the letters and signs enclosed are phonetic symbols representing speech sounds.
of the presence of fundamental frequencies in one and their absence from the other. This is to say, further, that according to West's classification of sounds, the element of fricative frequency affords the chief distinguishing characteristic between any pair of consonants in the test.

Each pairing in the test makes use of the vowel sound (a) or those of (u) and (o), to form, in every case, a pair of nonsense syllables. The sounds are incorporated into syllables rather than being used in isolated form because this is more nearly as they occur in actual speech. Nonsense syllables are used in order to prevent recognition of sounds by their appearance in familiar context. The test is made up of 312 pairs of such nonsense syllables. In 166 of these pairs, the consonants are different, while in 144 pairs they are the same. "Same" pairs were included in order to make the test one of actual discrimination, i.e., a subject had to recognize that two sounds were alike approximately the same number of times that he had to recognize that two were different. There is an unequal number of same and different pairs because it was impossible, due to the nature of the pairing, to equalize them and still have each consonant appear in the test an equal number of times. Proportionately, however, the difference of 24 is probably insignificant.

Each of the sixteen consonants appears in the test 37 times. Each voiceless consonant is paired with every other voiceless consonant, and each voiced with every other voiced, three times, i.e., the consonants are placed initially, medially and finally in nonsense syllables. Obviously, these positions were employed in the test because sounds occur
in all of them in normal speech. Each of the sixteen consonants appears, then, thirteen times initially, thirteen times finally and thirteen times medially in a nonsense syllable. The position of both consonants in a given pair of syllables is always the same, i.e., an initially placed consonant is always paired with another initially placed one, final with another final and medial with another medial. The consonants and the vowels (a) and (e) were used as follows in composing the 512 nonsense syllables:

1. A group of 52 nonsense syllables, with initially placed, voiceless consonants, including

   a. Twenty-eight "Different" pairs, which were formed by pairing each of the eight voiceless consonants, plus the vowel (a), with every other voiceless consonant, plus the vowel (a):

      D  pa-a
      t  pa-ta  ta-ta
      k  pa-ka  ta-ka
      f  pa-fa  ta-fa  ka-fa
      s  pa-sa  ta-sa  ha-sa  fa-sa
      0  pa-0a  ta-0a  ha-0a  fa-0a
      ʔ  pa-qa  ta-qa  ha-qa  fa-qa  a-qa  e-qa
      ŋ  pa-ŋa  ta-ŋa  ha-ŋa  fa-ŋa  a-ŋa  e-ŋa

   b. 24 "Same" pairs, which were formed by pairing each of the eight voiceless consonants, plus the vowel (a), with itself, plus the vowel (a), three times:

      pa-pa  ʔa-ʔa  e-ẹ
      ta-0a  ha-ha  fa-fa
      ka-ka  fa-fa
      sa-sa  e-ẹ
      θa-tha  e-ẹ
      ŋa-ŋa  e-ẹ
      fə-ŋə  fə-ŋə  fə-ŋə

2. A group of 52 nonsense syllables with initially placed, voiced consonants, including

   a. 28 "Different" pairs, which were formed by pairing each of the voiced consonants, plus the vowel (a), with every other voiced consonant, plus the vowel (a):
b. 34 "Same" pairs, which were formed by pairing each of the
eight voiced consonants, plus the vowel (a), with itself,
plus the vowel (a), three times:

\[
\begin{array}{ccc}
ba-ba & ba-ba & ba-ba \\
da-da & da-da & da-da \\
ge-ga & ge-ga & ge-ga \\
v-a-v & va-v & va-v \\
z-a-z & za-z & za-z \\
\delta-a & \delta-a & \delta-a \\
\tau-a & \tau-a & \tau-a \\
\delta-a & \delta-a & \delta-a \\
\end{array}
\]

c. A group of 52 nonsense syllables with finally placed, voiceless
consonants, including:

a. 29 "Different" pairs, which were formed by pairing each of
the eight voiceless consonants, preceded by the vowel (a),
with every other voiceless consonant, preceded by the
vowel (a):

\[
\begin{array}{cccc}
p & ap-at & at-ak & ak-af \\
k & ap-ak & at-ak & ak-as \\
f & ap-af & at-af & ak-as \\
s & ap-as & at-as & ak-as \\
b & ap-b & at-b & ak-b \\
r & ap-r & at-r & ak-r \\
s & ap-s & at-s & ak-s \\
t & ap-t & at-t & ak-t \\
\end{array}
\]

b. 34 "Same" pairs, which were formed by pairing each of the
eight voiceless consonants, preceded by the vowel (a), with
itself, preceded by the vowel (a), three times:

\[
\begin{array}{cccc}
\text{ap-ap} & \text{ap-ap} & \text{ap-ap} \\
\text{at-at} & \text{at-at} & \text{at-at} \\
\text{ak-ak} & \text{ak-ak} & \text{ak-ak} \\
\text{af-af} & \text{af-af} & \text{af-af} \\
\text{as-as} & \text{as-as} & \text{as-as} \\
\text{ae-ae} & \text{ae-ae} & \text{ae-ae} \\
\text{af-af} & \text{af-af} & \text{af-af} \\
\text{atf-atf} & \text{atf-atf} & \text{atf-atf} \\
\end{array}
\]
4. A group of 52 nonsense syllables with finally placed, voiced consonants, including

a. 22 "Different" pairs, which were formed by pairing each of the eight voiced consonants, preceded by the vowel (a), with every other voiced consonant, preceded by the vowel (a):

<table>
<thead>
<tr>
<th>Consonants</th>
</tr>
</thead>
<tbody>
<tr>
<td>d</td>
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<tr>
<td>g</td>
</tr>
<tr>
<td>z</td>
</tr>
<tr>
<td>s</td>
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<tr>
<td>n</td>
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</tbody>
</table>

b. 24 "Same" pairs, which were formed by pairing each of the eight voiced consonants, preceded by the vowel (a), preceded by the vowel (a), with itself: preceded by the vowel (a), three times:

<table>
<thead>
<tr>
<th>Consonants</th>
</tr>
</thead>
<tbody>
<tr>
<td>b</td>
</tr>
<tr>
<td>a</td>
</tr>
<tr>
<td>3</td>
</tr>
</tbody>
</table>

5. A group of 52 nonsense syllables with medially placed, voiceless consonants, including

a. 22 "Different" pairs, which were formed by pairing each of the eight voiceless consonants, preceded by (a) and followed by (a), with every other voiceless consonant, preceded by (a) and followed by (a):

<table>
<thead>
<tr>
<th>Consonants</th>
</tr>
</thead>
<tbody>
<tr>
<td>t</td>
</tr>
<tr>
<td>f</td>
</tr>
<tr>
<td>p</td>
</tr>
</tbody>
</table>

b. 24 "Same" pairs, which were formed by pairing each of the eight voiceless consonants, preceded by (a) and followed by (a), with itself, preceded by (a) and followed by (a), three times:
6. A group of 82 nonsense syllables with medially placed, voiced con-
sonants, including:

a. 28 "Different" pairs, which were formed by pairing each of the
eight voiced consonants, preceded by (a) and followed by (ε),
with every other voiced consonant, preceded by (a) and fol-
lowed by (ε):
b
d  a b e  a b e  a b e  a b e
s  a b e  a b e  a b e  a b e
v  a b e  a b e  a b e  a b e
t  a b e  a b e  a b e  a b e
z  a b e  a b e  a b e  a b e
d  a b e  a b e  a b e  a b e
f  a b e  a b e  a b e  a b e
h  a b e  a b e  a b e  a b e
j  a b e  a b e  a b e  a b e

b. 24 "Same" pairs, which were formed by pairing each of the eight
voiced consonants, preceded by (a) and followed by (ε), with
itself, preceded by (a) and followed by (ε), three times:
abe-abe  abe-abe  abe-abe
ade-ade  ade-ade  ade-ade
age-age  age-age  age-age
ave-ave  ave-ave  ave-ave
aze-aze  aze-aze  aze-aze
ade-adε  ade-adε  ade-adε
aze-aze  aze-aze  aze-aze

In order to exclude any possibility for the memorization of the order
in which "Same" and "Different" pairs were presented in the test, these
pairs were mixed within each of the six separate groups. Letting "S"
represent same and "D" different pairs, the order within each group was
thus:
The order of the six groups in the complete test is as they are listed in their description above, i.e., (1) voiceless consonants in an initial position; (2) voiced consonants in an initial position; (3) voiceless consonants in a final position; (4) voiced consonants in a final position; (5) voiceless consonants in a medial position; (6) voiced consonants in a medial position. In its final form the test is divided into four groups. The first three of these groups contain 80 pairs of nonsense syllables each, and the fourth and final group 72 pairs. This grouping was used to provide rest periods during testing. Figure A shows the test in its final form. The score on the test was the number of errors.

1. General Procedure in the Administration of the Discrimination Test. It was announced to the subjects that they were to be given a hearing test. Detailed instruction sheets were passed out and each subject was asked to follow his sheet as the experimenter read the instructions aloud very carefully. The instructions read as follows:

This is a test of hearing. You are to decide whether sound combinations, as they are called out to you in pairs, are the same or different. These sound combinations will be in the form of nonsense syllables, such as (ba-ga), (ad-ag), (ap-adk), etc. If the two syllables in a pair sound the same to you, you are to write the capital letter "S" in the appropriate square on the answer form. If the two syllables in a pair sound different, you are to write the capital letter "D" in the appropriate square. For example, the syllables in the pairs (ba-ga), (ad-ag), (ap-adk) are different and should be marked "D." On the other hand, the syllables in the pairs (ba-ga), (ad-adc) and (ak-adk) are the same and should be marked "S."
**SPEECH SOUND DISCRIMINATION TEST**

<table>
<thead>
<tr>
<th>Name</th>
<th>Male □</th>
<th>Female □</th>
<th>Freshman □</th>
<th>GROUP I</th>
<th>Age</th>
<th>Date</th>
</tr>
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**GROUP I**

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<tr>
<td>B</td>
<td>pa-tja ta-ka sa-sa sa-sa sa-sa sa-sa sa-sa sa-sa sa-sa sa-sa sa-sa</td>
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**GROUP II**

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**GROUP III**

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**GROUP IV**

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</table>

**Figure A**

*From here on, vowels are omitted from second syllables due to lack of space.*
The vowel sounds in a pair of syllables will always be the same. If the two syllables in a pair are different, the difference will always be in the consonants only. For example, in the pair (a-d-ag)—which would be marked as different—the vowel sounds are exactly alike in both syllables. Likewise, in a pair of syllables such as (a-de-ak-g) the vowels are alike. In pairs which are the same, all the sounds in one syllable will be exactly the same as the sounds in the other syllables; for example, (tu-ta), (fu-fu), (af-afo), etc.

Below is a sample of the form you will use to record your answers of "S" or "D" as the pairs of syllables are called out. We will call the sample below Line X. You are to proceed across the page, along the line, to the right. You are to place your answer for each pair in the appropriate square as the numbers 1, 2, 3, etc., are announced. For a period of practice before we begin the test proper, fill in Line X, below, as I now call out pairs of syllables to you. Unless an unavoidable distraction occurs, a pair of syllables will be pronounced only once. In order, therefore, that you may do your best, please be absolutely quiet and pay very close attention throughout the test. Now, let's begin on the practice line X.

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After the subjects had filled in the sample answer form included in the instructions, and after it had been ascertained, to the best of the experimenter's knowledge, that each subject definitely understood what was expected of him, the test was given. The examiner gave the test from a copy of Figure A. For recording his answers the subject used a blank copy of the same form as shown in Figure B.

As explained in the instructions, the order of the elements, or pairs of syllables, in the test was from right to left across the page, first along Line A, then B, etc., through Line K, and through groups I to IV. To insure each subject's recording his answers in the proper spaces, the first three elements in lines A and B of every group and the first element in all other lines were announced as "Line A, number 1."
# Speech Sound Discrimination Test

**Name**
- Male □  Female □  Freshman □
- Age ______  Date ______

## GROUP I

<table>
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## GROUP III

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</tbody>
</table>

*Figure B*
"line A, number 2," etc. In order, however, to reduce the time required in testing, elements 4-10 in lines A and B and elements 2-10 in all other lines were announced merely with a statement of the numeral, "four," "five," "six," etc., and "two," "three," "four," etc. Each group number, I, II, III and IV, was announced only once.

The rate at which the elements, or syllables, of the test were called out was as follows:

1. A quick, silent count of one was allowed between the two syllables of an element.

2. A silent count of three was allowed between elements, for marking answers.

3. A short rest count of five was allowed between lines.

4. A rest count of twenty-five was allowed between groups.

Each of the four groups required 7-8 minutes and the complete test, exclusive of the instruction period of about 10 minutes, required from 30-32 minutes.

In giving the test, an effort was made to pronounce with the greatest possible constancy of volume from syllable to syllable within each element, and from element to element during each testing. In the final test, given to small groups in a small quiet room, a fairly quiet, conversational voice was used. The volume used in large classrooms and with large groups was of necessity considerably louder. The point kept in mind throughout fifty administrations of the test, in large and small rooms, was that the volume should be sufficient, and not a great deal more, for the average person to understand clearly conversation carried on at the same level. The least possible inflection was used in calling syllables, and great care was taken not to overemphasize final consonants,
but to pronounce them as nearly as possible as they are used in ordinary conversation.

2. Conditions of Discrimination Testing. The first procedure in administering the speech sound discrimination test was the testing of 303 individuals. At this point 305 of them were eliminated. The remaining 88 were kept for a second testing and for use in a further eliminative process later in the experiment. This procedure divides the testing schedule into two series: First Testing Series, and Second Testing Series, and then a final selection of 52 subjects for audiometer testing. A schematic drawing of the testing schedule is shown in Figure C. The First Testing Series included (1) the retest reliability group of 70 members, who were tested twice in order to be used for determining the retest reliability of the speech sound discrimination test; (2) a general classroom group of 290 members; and (3) a general clinic room group of 35 members.

(1) The retest reliability group comprised five University speech classes of undergraduate level, chosen at random. The total of 70 members included 46 men, with an age range of from 18 to 27, and 24 women with an age range of from 17 to 26. This group was tested in a classroom, in sub-groups of 24, 21 and 25 members. All testing was done in the same room, each sub-group was tested twice, and each subject sat in the same, immovable seat for both testings. The seating arrangement was in the form of a semi-square, with a row of individuals across the front and one along each side toward the back of the room. While giving

40. Basis for the elimination of these subjects will be explained later in connection with selected group testing.
the test the experimenter sat in the center behind the group, as nearly equidistant as possible from all subjects. The experimenter occupied the same seat during all tests.

(2) The general classroom group of 290 members was composed of 12 University speech classes of undergraduate level, chosen at random. In the group there were 180 men, with an age range of from 17 to 36, and 110 women, with an age range of from 16 to 35. The subjects were tested in classrooms, in sub-groups of from 20 to 30 members. Two hundred and twenty-five of them, or 9 of the 12 classes, were tested in the same classroom, while the other 65 members, or 3 classes, were tested in three
different classrooms. For each testing, movable seats were placed in a semi-circle, with the experimenter sitting in the center behind the group, as nearly equidistant as possible from the subjects.

(3) The general clinic room group of 35 members included 15 men, age 17 to 25, and 15 women, age 17 to 22. These subjects were chosen at random from six University speech classes. Since it was planned eventually to test all subjects in a small, quiet room in the University speech clinic, it was believed expedient to take this relatively small group directly to the clinic room and thereby eliminate the classroom test. Testing was done in sub-groups of from three to five members.

The seating arrangement was in the form of a semi-circle such that the experimenter's position—back and center—was three feet from each subject.

The second testing series concerned itself with a second testing of 88 individuals selected from the original 335. The second testing originally was planned only for those subjects who had taken their first test in a classroom. The purpose was to determine their sound discriminatory ability under more favorable circumstances than were afforded by a classroom. It was decided, however, that the element of practice or added interest in a second testing might influence the results. This meant that in order to neutralize such existing elements, those individuals selected from the general clinic room group, which was originally tested in the clinic room, must be tested again. For convenience in later references and comparisons, then, these 88 subjects who were given a second test are divided into (1) Selected Classroom Group and
(2) Selected Clinic Room Group. This division is made upon the basis of the fact that the selected clinic group members were selected from a previous group which had its first test in the clinic room, and that the selected classroom members were chosen from previous groups which had their first test in a classroom.

(1) The selected classroom group of 70 included 48 men, age 17 to 28, and 22 women, age 17 to 28. Of this group 57 were selected from the retest reliability group and nine of the 12 classes in the general classroom group. With the exception of seven individuals with classroom scores between 25 and 9, these 57 were all the available people in the retest group and the 9 classes who had discrimination scores of 25 or more, or 9 or less. This selection was based upon the original plan to eliminate all but those of either superior or decidedly inferior discriminatory ability, in order to derive, thereby, a superior and an inferior group of hearing cases to be checked against each other in the audiometer testing.

However, when the 57 subjects in question, who were the first to be retested, were tested again, in the clinic room, they distributed themselves in such a manner that the gap between scores of 25 and 9 no longer existed. Under the more favorable conditions of the clinic room a large number of people with classroom scores of 25 or more distributed themselves in a much lower clinic room score range. As a result, there were relatively few subjects with very poor discriminatory scores.

From this condition it was evident that it would be difficult to match any sizeable number of superior discriminatory cases with a like number of inferior ones. In short, inferior discriminatory cases proved
to be scarce. Upon those grounds, the decision was made to conduct further testing with the view to finding as nearly as possible a normal distribution of scores from zero upward. This further testing was especially concerned with a search for poor discriminatory cases, since these were scarce at first.

The remaining 15 of this selected classroom group of 70 were taken from the three classes, numbering 65 in all, in the general classroom group which were tested in three different rooms. Ten of the 15 were the five poorest discriminatory cases from each of two of the three classes, and the other 5 were the poorest in the third class. The retest of the selected classroom group was conducted in sub-groups of from 1 to 5, in the same clinic room and with the same procedure used to test the general clinic room group in the First Testing Series.

(2) The selected clinic room group of 18 members included 11 men, age 19 to 21, and 7 women, age 17 to 22. They were selected from the general clinic room group in the First Testing Series. Nine of them were those with the poorest scores made in the group, and the remaining nine were chosen at random from the same group, chiefly upon the basis of a small number of errors.

From the 88 members of the selected classroom and the selected clinic room groups, 52 were chosen later to be given audiometer tests. The remaining 36 were eliminated at this point. The procedure in selecting the 52 members of the audiometer group will be explained in connection with audiometer testing.

B. The Western Electric 248 Audiometer. The Western Electric 248 audiometer is a familiar device for testing auditory acuity to pure
tions. The 63 audiometer used in this experiment is the newest form of the 2A audiometer. It was used because the audiometer long has been recognized as the most accurate and scientific means of testing auditory acuity at the frequency ranges involved in the sounds of speech.

The 63 audiometer is capable of producing a continuous series of pure tones from 125 to 9747 cps., at intensity ranges from minus 15 to plus 106 decibels. However, only those frequencies at quarter-octave intervals from 125 to 9747 cps. are indicated on the dial. Since it was desirable in this study to test at frequencies closer than quarter-octaves, an accessory dial was affixed. This accessory dial was marked to indicate the midpoints of all quarter-octave steps on the original audiometer frequency dial from 1536 cps. upward, through 9216. These midpoints approximate, then, eighth-octave intervals. Corresponding midpoints were marked off on the intensity dial of the audiometer for the normal intensity of those frequencies above 4096 cps. For the frequencies between 2048 and 4096, the intensity point for 2048 was used as the normal.

Since, further, it was not desired to test so intensively in the fundamental frequencies, only octave intervals from 125 to 1024 cps.

61. The frequency numbers assigned, in this study, to the eight steps within the octave markings on the audiometer dial are not true eighth, quarter, half, etc., octave steps. In setting new points on the audiometer dial, as indicated above, it would have been impossible to find exact eighth-octave intervals. Arbitrarily, then, the six frequency numbers within an octave were derived in straight calculation by dividing the octave into eight equal frequency steps. The differences between these straight calculations and the true octave fractions are considered insignificant in this study. These calculations are the equivalent to allowing approximately a 2 percent deviation above or below the true octave fraction. An exact eighth octave would be determined by taking a ratio of 1:2.8 or 1:1.09. One eighth octave above 2048, then, would be 2232.82 instead of 2304. This small difference of 71.82 cycles could not possibly make any significant difference in the determination of auditory acuity at this range.
were tested. The desire of this study was primarily to test more rigidly over the higher frequencies, and especially those said to characterize the consonants used in the discrimination test. The audiometer, then, was used to test each of the 52 subjects at 26 frequencies at octave intervals from 128 to 1024 cps., at approximately quarter-octave intervals between 1924 and 1536 cps., at approximately eighth-octave intervals from 1536 to 9216, and at 9747 cps. The complete frequency range with the approximate interval position of each frequency is as follows:

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<tr>
<th>Frequency</th>
<th>Interval</th>
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<tr>
<td>128</td>
<td>octave</td>
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<tr>
<td>256</td>
<td>octave</td>
</tr>
<tr>
<td>512</td>
<td>1/2</td>
</tr>
<tr>
<td>1024</td>
<td>1/4</td>
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<tr>
<td>2048</td>
<td>2/8</td>
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<td>4096</td>
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<tr>
<td>131072</td>
<td>1/256</td>
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<tr>
<td>262144</td>
<td>1/512</td>
</tr>
<tr>
<td>524288</td>
<td>1/1024</td>
</tr>
</tbody>
</table>

1. General Procedure in Administering the Audiometer Test. Audiometer tests were administered in a small, semi-sound proof room, with only the subject and the experimenter present. The subject was told that he was to be given another hearing test as a part of the experiment which he had previously agreed to participate in. He was seated in a chair facing away, and at a distance of three feet, from the experimenter's testing position. On the wall opposite the subject's position was a small mirror which reflected the signal light atop the audiometer. This mirror was so small and so placed that only the top of the audiometer and the signal light were visible to the subject. His position was such that his head and his left shoulder cut out all view of the audiometer dials and the experimenter's movements in operating them. This arrangement was made to prevent any distraction or suggestion which might result from the
subject's observation of the experimenter's manual procedure in administering the test.

Before seating the subject it was explained that this test involved listening to sounds through a receiver, and that he was to indicate the presence of sound by allowing the signal light to burn and the absence of sound by turning the light off. During this explanation the experimenter indicated the receiver, the light and the signal light button and its operation. The subject was then seated, handed the signal light button, told to listen for a sound and to indicate its presence or absence as instructed. He was asked to observe the reflection of the light in the mirror until he was sure there would be no confusion in his signals. A placard was hung on the wall beside the mirror which read, "When you do not hear a sound turn off the light. No light—no sound."

At this point a practice threshold was established for the tone at 1024 cps. While establishing this threshold any further necessary instructions were given the subject. In order that he might become acquainted immediately with the experience of hearing a sound in the receiver, the procedure in establishing all thresholds was to go from sound heard to sound not heard, by 5 db steps of intensity. When the point was reached at which a sound was no longer heard, decrements and increments of intensity were made within the last 5 db step to determine the exact threshold. Stimulus patterns in the interruptions of the sound were varied continuously in order to make certain that the subject definitely heard the sound and that his signals were consistently accurate. The lowest point of intensity at which a subject gave from three to five successively correct and ready responses was recorded as the threshold.
When the practice threshold had been established and it was ascertained that the subject understood the procedure, thresholds were established for all twenty-eight frequencies, including the practice tone, in the order and divisions described below.

In view of the possibility of the subject's "adaptation" to the audimeter tones if there were too gradual a change in successive test frequencies, an effort was made to maintain a definitely perceptible contrast between any two successive tones presented. In this effort the presentation order of the twenty-eight frequencies was such that any two were at least a half-octave apart. The exact order of presentation was as shown in Table I, below.

**TABLE I**

<p>| Frequencies at Which the Audimeter Group Was Tested |
|----------------------------------------|----------------|----------------|----------------|</p>
<table>
<thead>
<tr>
<th>Group I</th>
<th>Group II</th>
<th>Group III</th>
<th>Group IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1024 = practice tone)</td>
<td>1. 128</td>
<td>1. 1280</td>
<td>1. 1664</td>
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<tr>
<td>2. 256</td>
<td>2. 2560</td>
<td>2. 2560</td>
<td>2. 2560</td>
</tr>
<tr>
<td>3. 512</td>
<td>3. 5120</td>
<td>3. 5120</td>
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<td>4. 1024</td>
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<td>4. 10240</td>
<td>4. 10240</td>
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<td>5. 1536</td>
<td>5. 15360</td>
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<td>7. 2560</td>
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<td>8. 3072</td>
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<td>10. 4096</td>
<td>10. 40960</td>
<td>10. 40960</td>
<td>10. 40960</td>
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</table>

In order to decrease the factor of fatigue, two sittings were allowed for the complete testing. During the first sitting groups I and II were tested for first the right and then the left ear. Groups III and IV were tested in the second. For each subject the two sittings required from forty-five minutes to an hour and from twenty to thirty minutes, respectively. Short rest periods were allowed between groups.
2. Conditions of Audimeter Testing. Audimeter tests were administered individually to 52 people, including 34 men, with an age range of from 17 to 26, and 18 women, with an age range of from 16 to 21. This audimeter group was composed of 42 members from the Selected Classroom Group and 10 members from the Selected Clinic Room Group in the Second Testing Series. The remaining 28 in the Selected Classroom Group and the remaining 8 in the Selected Clinic Room Group were eliminated prior to audimeter testing because they either were not available for further use or it was felt that fewer subjects with the same scores would suffice for the experiment. The second test, or clinic room, scores of those given the audimeter test were as shown in Table II below.

**TABLE II**

<table>
<thead>
<tr>
<th>Score</th>
<th>Frequency</th>
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<th>Frequency</th>
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<td>2</td>
</tr>
<tr>
<td>2</td>
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<td>6</td>
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<td>7</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>122</td>
<td>1</td>
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</table>

Only the clinic room scores of these subjects are shown here because they served as the basis of selection. Classroom scores will be shown later.

All audimeter testing was done in a small, sound treated room, with only the experimenter and subject present. The latter sat with his back to the experimenter and the audimeter, as described under General Procedure. In every case both ears were tested, first the right and then the left, on alternate frequencies as also described under General Procedure. In order to control at least partially the element of fatigue, both ears were tested on 16 frequencies at one sitting and both on the remaining 12 frequencies at a second sitting.
Part III

RESULTS

A.
The Speech Sound Discrimination Testing

1. First Testing Series Groups.

(1) The retest reliability group. Table III presents the results of both testings for the 70 members of this group. Included here are individual rankings on each test by which the correlation for the retest reliability of the speech sound discrimination test was derived. The frequency with which each score appeared is shown in Table IV. On test I the range of scores is from 4 to 95, with a mean score of 17.86 and a SD of 11.61. Test II has a score range of 5 to 102, a mean score of 20.22 and a SD of 12.98.

The method used for all correlations in this study was the Spearman Rank-Difference method. A coefficient of .75 ±.03, as derived by this method and interpreted in terms of $r$, was obtained for the retest reliability of the speech sound discrimination test used in this study. While this does not represent a perfect correlation, it is considered relatively high for the reliability of the test, and especially so in view of the nature of the test and the testing procedure. The correlation of this test is better than Travis-Rasmussen were able to find for their speech sound discrimination test from two points of view. Whereas their correlation was .72 ±.07, and was based upon the best two out of

### TABLE III

**Discrimination Scores**

for both Classroom Tests of the 70 Members of the Retest Reliability Group

*(Test I [Classroom]: \( N = 17.48 \), \( SD = 11.51 \))

*(Test II [Clinic Room]: \( N = 20.22 \), \( SD = 12.66 \))

*(Correlation of I and II = .76±.09)*

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Scores I</th>
<th>Scores II</th>
<th>Ranks I</th>
<th>Ranks II</th>
<th>Case No.</th>
<th>Scores I</th>
<th>Scores II</th>
<th>Ranks I</th>
<th>Ranks II</th>
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<td>25</td>
<td>27</td>
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<td>60.5</td>
<td>68</td>
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<td>18</td>
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<td>59</td>
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<tr>
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TABLE IV

Distribution of Discrimination Scores
for Both Classroom Tests of the 70 Members of the Retest
Reliability Group

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Three scores of 52 individuals, the coefficient for reliability of the test used here is .75 ± .03, and was based upon only two testings of 70 people.

(2) General classroom group. The results of testing this group of 280 are presented in Table V. The range of scores is from 2 to 88, with a mean of 15.76 and a SD of 11.12. The Table shows only the frequency

distribution of scores, and not individual scores, because this testing was part of an eliminative process for selection of subjects. Individual scores of subjects from this group who served further in the experiment will be presented later.

**TABLE V.**

Distribution of Discrimination Scores for the 280 Members of the General Classroom Group (Classroom Tests: N = 15.76, SD = 11.12)

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(3) General clinic room group. The scores for the 33 members of this group are shown in Table VII. The range of scores for the testing is from 0 to 20, with a mean score of 7.72 and a SD of 4.56. Only the frequency distribution of scores is shown in the Table because this test also served as an instrument of elimination. Likewise, scores of those serving further in the experiment will be presented later.

2. **Second Testing Series Groups.**

(1) Selected classroom group. Table VII contains the results of the second testing for these 70 selected individuals. Column I of the Table shows the first scores of these individuals, made while members
TABLE VI
Distribution of Discrimination Scores for the 33 Members of the General Clinic Room Group
(Clinic Room Test: N = 7.72, SD = 4.56)

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TABLE VII
Distribution Scores for the 70 Members of the Selected Classroom Group
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(Test II [Clinic Room]: N = 15.46, SD = 24.28)

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<td></td>
</tr>
</tbody>
</table>
of either the retest reliability or the general classroom group in the First Testing Series. Column II contains the scores made on their second test, this time in the clinic room. The range of scores for the previous classroom testing of these 70 subjects is from 4 to 96, with a mean score of 55.12 and a SD of 19.74. The clinic room range of scores made in the present testing is from 2 to 122, with a mean of 13.44 and a SD of 24.98. Observation of the clinic room scores readily shows why this SD was so large. The distribution, while ranging from a score of 2 to one of 142, is skewed heavily toward the lower end, and the mean of 13.44 lies only 11.44 points from the lower end of the range.

(2) Selected clinic room group. The results of this testing are shown in Table VIII. The group was composed of 18 members selected from the general clinic room group in the First Testing Series. Column I contains the scores made in the previous clinic room test. The range of scores for this first test is from 0 to 20, with a mean of 9.00 and a SD of 5.28. Column II contains the scores made on this, the second, clinic room test. The range of these scores is from 1 to 15, with a mean of 5.94 and a SD of 4.39.

### Table VIII

Distribution of First and Second Discrimination Scores for the 18 Members of the Selected Clinic Room Group

| Test I | Test II |

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Scores I</th>
<th>Scores II</th>
<th>Case No.</th>
<th>Scores I</th>
<th>Scores II</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
<td>21</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>126</td>
<td>2</td>
<td>2</td>
<td>120</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>125</td>
<td>3</td>
<td>3</td>
<td>122</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>124</td>
<td>4</td>
<td>3</td>
<td>127</td>
<td>11</td>
<td>14</td>
</tr>
<tr>
<td>123</td>
<td>5</td>
<td>15</td>
<td>128</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>129</td>
<td>6</td>
<td>1</td>
<td>131</td>
<td>14</td>
<td>4</td>
</tr>
<tr>
<td>130</td>
<td>8</td>
<td>5</td>
<td>137</td>
<td>16</td>
<td>4</td>
</tr>
<tr>
<td>136</td>
<td>9</td>
<td>6</td>
<td>144</td>
<td>20</td>
<td>14</td>
</tr>
<tr>
<td>141</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
So Discussion of Results of Group Discrimination Testing. In deriving a total of 551 scores for the 393 subjects, the speech sound discrimination test used in this study was administered an even 50 times. The classroom groups required 19 testings and the clinic room groups 31. Quite necessarily, this means that conditions of testing must have varied considerably during the process of so many single administrations. Actually, a certain flexibility in conditions was permitted in administering the discrimination test. The greatest effort made to control conditions was that applied in the retest reliability groups. The reason for this is obvious.

If a test of any kind is to be made at least available for wide use, either, or both, of two conditions must exist: (1) it must be possible for any person to administer the test under rigidly controlled conditions, corresponding exactly with those prescribed by the authors of the test, or (2) the conditions under which the test was standardized must be flexible enough that any one may use it under somewhat varying conditions and still obtain fairly accurate results.

The chief objection to a hearing test which makes use of the unrecorded human voice is the variability of pitch, quality and intensity from person to person and from time to time with a given person. An objection to any hearing test in which the sound must transverse space, rather than being delivered directly to the ear by a contact receiver, is the variability of the acoustical conditions from one place of testing to another. Both of these objections are applicable to the speech sound discrimination test used in the present study. In the use of this test, then, condition (1), above, which requires rigid control of condi-

tions, is out of the question. Condition (2), which allows a certain flexibility without destroying reasonably accurate results, is the aim for the discrimination test used here.

Table IX contains a summary of the ranges of scores, the mean scores and the standard deviations for all groups tested. This Table shows these items listed according to groups within the two series. The Table also shows the place of testing and the number of times the discrimination test was administered to cover the members within each group.

TABLE IX
Summary of Discrimination Score Ranges, Mean Scores and SD's

<table>
<thead>
<tr>
<th>First Testing Series</th>
<th>No. of Score</th>
<th>Mean</th>
<th>SD Testing</th>
<th>Place of Required</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Scores</td>
<td>Range</td>
<td>Score</td>
<td>Testings</td>
</tr>
<tr>
<td>(1) Retest Reliability</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group, Test I</td>
<td>70</td>
<td>4-65</td>
<td>17.54</td>
<td>Classroom  5</td>
</tr>
<tr>
<td>Test II</td>
<td>70</td>
<td>5-102</td>
<td>20.52</td>
<td>&quot;</td>
</tr>
<tr>
<td>(2) General Classroom</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group</td>
<td>290</td>
<td>2-88</td>
<td>15.78</td>
<td>Classrooms  15</td>
</tr>
<tr>
<td>(3) General Clinic Room</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group</td>
<td>35</td>
<td>0-20</td>
<td>7.72</td>
<td>Clinic Room  7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Second Testing Series</th>
<th>Taken from</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Selected Classroom</td>
<td>Groups (1) and (2) above</td>
</tr>
<tr>
<td>Group, Test I</td>
<td>70</td>
</tr>
<tr>
<td>Test II</td>
<td>70</td>
</tr>
<tr>
<td>(2) Selected Clinic Room</td>
<td>Taken from</td>
</tr>
<tr>
<td>Group, Test I</td>
<td>18</td>
</tr>
<tr>
<td>Test II</td>
<td>18</td>
</tr>
</tbody>
</table>

The mean scores of 17.54 and 20.52 for tests I and II, respectively, in the retest reliability group yield an insignificant difference of 2.98. Both of these means, as well as the average of the two, 19.03, are higher than the mean of 15.78 for the general classroom group. The general classe-
room group of 260 members would be expected to have a smaller mean than the retest reliability group of 70 members. The greater the number of cases chosen at random, the greater the chances are that the ratio of good to bad hearing will be accurate. Actually, however, the difference of 3.35 between the average mean of the retest reliability group and that of the general classroom group is of little significance. The corresponding difference between standard deviations of 12.19 for the retest reliability group and 11.12 for the general classroom group, is 1.07.

The mean score of 7.72 for the general clinic room group is 11.51 less than the retest reliability group mean, and 8.56 less than the general classroom group. These differences in favor of the clinic room group are to be chiefly accounted for in the fact that testing conditions in the smaller, quieter clinic room were decidedly more favorable than those existing in testing large groups in large classrooms. The standard deviation of 6.56 for the general clinic room group is 6.56 less than that of the general classroom group, and 7.65 less than the average SD for the retest reliability group.

This decrease in the standard deviation in the clinic room group over the classroom groups would argue that many of the variables influencing the scores made in classrooms were absent in the clinic room situation. The variation that still exists in the clinic room scores is probably much more truly representative of a real variation in hearing ability among different individuals. It may be assumed that this one variable, i.e., basic hearing ability, did not change from class to clinic room situation. It is obvious then that much of the variation shown in the classroom groups as evidenced by the wide ranges and large SD's is due to
other factors arising from the test situation.

The means of the selected classroom and the selected clinic room groups, made on their second tests in the clinic room, are 13.66 and 5.94, respectively. The selected clinic room mean is 7.56 errors smaller than that of the selected classroom group. The reason for this is the fact that the poorest score of the selected clinic room group was 25 errors and a great majority of them were 5 or less; while the errors made by the selected classroom group ran as high as 142, and included practically all the poor discriminatory cases found in this study. There is a difference of 20.69 between the SD of 24.28 and 5.39 for the selected classroom and selected clinic room groups, respectively.

The mean scores for the first, classroom tests of these 70 subjects chosen to make up the selected classroom group was 25.22, against 13.66 for their second testing, this time in the clinic room. The difference of 11.56, or 46 percent, in favor of the second testing is probably largely due to the more favorable conditions of the clinic room. The SD of the first test scores is 19.74, against 24.28 for the second.

In an effort to determine more specifically the relationship between scores made in classrooms and in the clinic room, the scores of the 70 people given tests under both conditions were ranked, and a correlation was run. The coefficient of correlation was .54 ±.06. This relatively low correlation is probably accounted for chiefly by the fact that the classroom scores represent 16 different testing of groups numbering 20 to 30, and in five different classrooms. Although clinic room scores represent 16 testings, all were conducted in the same clinic room and on groups numbering one to five. In view of variations in acoustical conditions from room to room, the results of hearing tests
given in as many as five classrooms cannot escape wide fluctuations.
It seems safe to say, also, that noise, distractions and the spirit of
concentration in general will vary more widely among large groups than
among small groups of individuals. Finally, the coefficient of corre-
lation for the discrimination test, .75 ± .05, probably yielded some
influence in the clinic and class correlation.

These statements are evidenced by the results of three of the groups
tested in the general classroom group. The three groups in these three
testings totaled 65 members, and each group was tested in a different
classroom. The conditions under which the testing was done were most
unfavorable. Two of the groups were tested at periods when there was
an excessive amount of noise and other distractions present on a busy
thoroughfare just outside the windows of the testing room. The third
group was tested in a room adjacent to an auditorium where preparations
were being made for a performance. At the time appointed for testing
these three groups there were no other rooms available. It probably
would have been legitimate to exclude the results of these testings
from the study, but in tolerance of a flexibility of testing conditions
it was decided to include them.

Thirteen of the 65 subjects who were tested under very unfavorable
conditions were included in the group of 70 from which the correlation
of .56 ± .08 was derived. Considering the scores of these 13 subjects
alone, their classroom mean was 45.61, against their clinic room mean of
15.13. The difference of 30.48 errors between these two mean scores is
doubtless to be accounted at least in part by the unfavorable classroom
conditions of testing outlined above. In order to determine the influence
of the two scores of these 13 subjects on the correlation of .54 ± .06 between the total 70 classroom and clinic room scores, a second correlation was run, this time excluding these 13 subjects.

The coefficient of correlation between the first and second, or classroom and clinic room, scores of the remaining 57 subjects was .66 ± .06. In view of the fact that the conditions of testing for the thirteen subjects were so decidedly unfavorable and that the conditions under which the 57 subjects were tested were normally favorable, it was decided to use the correlation of .66 ± .06 as the relationship between classroom and clinic room scores. This still is not a high correlation, but in view of widely divergent conditions of testing it is probably of some significance. The classroom mean of the 57 scores was 20.91, with a SD of 19.00, while the clinic room mean was 18.06, with a SD of 21.45. The size of the latter SD is accounted for by wide gaps in the distribution of scores at the poor discriminatory end of the range, and by the fact that the mean is relatively so close to the zero end of the range.

The clinic room mean of these 57 individuals was 57 percent less than their classroom mean. Several reasons, at least, for this fact seem clear. The number of individuals per testing in classrooms was generally from five to six times larger than the number per testing in the clinic room. Larger groups are more subject to distractions. Further, the distance between subjects and experimenter was greater in the classroom, and the proper control of the intensity of the experimenter's voice was more uncertain. Of no little significance, too, is the fact that outside noises and inside acoustics were less favorable
in the classrooms. And, finally, a greater interest, and a consequent
effort to do well, on the second testing was manifest in nearly all
subjects.

The mean of the first clinic room scores of those making up the
Selected Clinic Room Group is 9.00, while the mean of their second
testing in the clinic room is 5.34. The respective standard deviations
were 5.26 and 4.59, the difference being .67. The difference of .66
fewer errors on the second testing is probably accounted for in the
element of practice in concentration or in the fact that some did not
understand the instructions at the first testing. Generally, there was
an added impetus in the efforts of all subjects during second testings,
because of increased interest when it was learned that they had been
selected to continue in the experiment. It is less likely that the
element of misunderstanding entered into this group's testing, since
there were no great differences between individual first and second
scores, but at various times throughout the experiment several subjects
indicated that they had misunderstood instructions at the first (class-
room) testing.

One thing seems certain. Because of increased sensitivity to dif-
fferences or similarities in a sound pair by means of practice, or because
of a desire to better the second scores, the procedure of this study re-
quires a second test to determine an individual's best score on the dis-
crimation test. This second test may be either a second clinic room
test, or a clinic room test preceded by a classroom test. The signi-
ficance of this point in the use of the discrimination test will be dis-
cussed in a later section.
The final step in the analysis of classroom and clinic room discrimination test scores was the determination of quartiles, means and SD's for over-all classroom and over-all clinic room scores. The total 380 classroom scores produced a mean of 16.26 and a SD of 10.59. The quartiles of these 380 scores were as follows:

a. Point of division of first and second quartiles (Q₁) = 10.39
b. " " " second " third " (Q₂) = 15.66
c. " " " third " fourth " (Q₃) = 19.12

The total 103 clinic room scores produced a mean of 11.61 and a SD of 20.52. As in the case of other relatively large SD's, this clinic room SD is large because of the skewness of the frequency distribution. It will be recalled that all clinic room groups included the poorest discriminatory cases available, and that there were wide gaps in the distribution between the scores of these cases and the scores of the majority of the other cases. The result, as stated earlier, is a very wide range of scores, the mean of which, however, lies well toward the zero end. The quartiles of the 103 clinic room scores were as follows:

   a. Point of division of first and second quartiles (Q₈) = 4.36
   b. " " " second " third " (Q₂) = 8.88
   c. " " " third " fourth " (Q₃) = 11.06

4. Summary Analysis of Speech Sound Discrimination Testing - The analysis of the results of speech sound discrimination testing provides answers to the following questions:

1. What is the retest reliability of the speech sound discrimination test presented in this study? Upon the basis of two testings for 70 Louisiana State University undergraduates, a correlation coefficient of .75 ±.08 was derived for the retest reliability of the discrimination test.

2. If this test is given under classroom conditions following
the procedure outlined in this study, how are the obtained scores to be interpreted? The classroom scores of 360 individuals produced a mean score of 18.28, and an SD of 10.83. The quartiles of these 360 scores were as follows:

a. Division of first and second quartiles (Q1) = 10.88
b. second = third = fourth (Q2) = 18.28
c. third = fourth (Q3) = 19.12

3. If this test is given to small groups and in a quiet room, approximating as nearly as possible the procedure as outlined in this study for clinic room testing, how are the obtained scores to be interpreted? The clinic room scores of 108 individuals tested in this study had a mean score of 11.61, and a SD of 20.92. The quartiles of these 108 scores were as follows:

a. Division of first and second quartiles (Q1) = 4.38
b. second = third = fourth (Q2) = 6.88
c. third = fourth (Q3) = 11.06

4. If this test is given as prescribed under classroom conditions, what predictions can be made as to the scores that would have been made under clinic room conditions? Using the scores of 57 individuals who had both a classroom and clinic room test, a correlation coefficient of .66 ±.04 was found between class and clinic room scores. The clinic room mean for these 57 individuals was 37 percent less than their classroom mean. Respectively, these means were 15.05 and 20.91.

5. What characteristic discrimination difficulties were shown by a representative number of individuals who took the speech sound discrimination test? This question is answered in detail under the heading, Analysis of Speech Sound Discrimination Errors.

The final question of importance in this study is,

6. What is the relationship of the speech sound discrimination scores to 62 Western Electric audiometer ratings? This question will be answered under a later section entitled, Analysis of 62 Individual Audiometer Ratings and Their Relationship to the Discrimination Errors Made by the Same 62 Individuals.
3. Analysis of Speech Sound Discrimination Errors. The analysis of the errors made on the speech sound discrimination test proposes to answer the following questions:

(1) What is the relationship between the difficulty in discriminating sound pairs made up of two different consonants and the difficulty in discriminating sound pairs in which the two consonants are the same?

(2) What is the relationship of consonant position and the elements of voicing and unvoicing to the difficulty in sound discrimination?

(3) What is the order of difficulty in discriminating the sixteen consonants used in the discrimination test, in terms of the frequency of their occurrence in sound pair errors?

(4) What is the relative difficulty in discriminating fricative-fricative, stop-stop and fricative-stop combinations?

In order to determine the nature of the errors made on the discrimination test, 86 papers were studied. These were the second test papers of the 86 individuals in the selected classroom and selected clinic room groups. The papers contained 1947 pair errors, or an average of 11.89 per person. The results of the study of these 86 clinic test papers is shown in Tables X to XIV. Table X shows the 188 "Different" pairs listed in columns numbered from 0 to 49, indicating the number of individuals who missed each pair. Table XI presents a summary of the pair errors shown in Table X.
<table>
<thead>
<tr>
<th>Subjects Missing Each Pair</th>
<th>Subjects Missing Each Pair</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. %</td>
<td>No. %</td>
</tr>
<tr>
<td>0 0</td>
<td>1 1 1</td>
</tr>
</tbody>
</table>

**Initial Voiceless**
- pa−ja  pa−sa  ta−fa  sa−ta  ta−ka
- fa−ja  pa−fa  ta−fa  fa−sa  pa−ta  sa−fa
- ga−tja  pa−tja  ka−ta  sa−ja  pa−ka
- ta−sa  ka−ga  fa−tja
- ta−ja  za−ta  ta−ga
- za−ja  ka−sa  ka−tja
- za−ta  ka−ja

**Initial Voiced**
- ba−d3a  ba−ga  ba−d3a  ba−va  ga−va
- da−3a  da−za  da−3a  da−ga  ga−3a
- sa−d3a  sa−ga  sa−d3a  za−3a  sa−ya
- va−za  va−d3a  za−3a  va−ga
- va−3a  ba−da  da−ga

**Final Voiceless**
- ap−af  ap−aj  ak−aj  ap−aq
- ap−atj  at−as  af−aj  af−at
- ak−af  at−as  as−aj  ak−aj
- ak−as  at−atj  as−atj  ak−atj
- as−atj  at−af

**Final Voiced**
- ab−d3a  ag−d3a  ad−av  ag−av  ad−aq
- ad−az  av−d3a  ab−az  ab−ag  ad−aq
- a5−d3a  ab−az  ab−ad  az−aq
- az−ad3  ag−az  ad−az

**Medial Voiceless**
- spe−ate  ate−ase  ase−atfe  afe−asae
- spe−ase  ake−aje  ake−ase  ape−ake
- spe−aje  ase−aje  ase−ake  ape−aje
- spe−atje  ase−atfe  ase−atje  ase−aje
- spe−aje  ase−afe  ase−ate  ase−aje

**Medial Voiced**
- abe−ade  abe−aze  aye−ad3e  aze−aye  aye−ade
- ade−az3e  abe−ad3e  ade−ad3e  aze−ade
- ade−ad3e  abe−age  age−ad3e
- age−ad3e  abe−aze  aye−ad3e
- age−ad3e  abe−aze  aye−ad3e
- age−ad3e  abe−aze  aye−ad3e
- age−ad3e  abe−aze  aye−ad3e
- age−ad3e  abe−aze  aye−ad3e
<table>
<thead>
<tr>
<th>TABLE I (cont'd)</th>
</tr>
</thead>
<tbody>
<tr>
<td>628 &quot;Different&quot; Pair Discrimination Errors</td>
</tr>
<tr>
<td>Made by 88 Subjects</td>
</tr>
<tr>
<td>on 168 Pairs of Consonants</td>
</tr>
<tr>
<td>No. %</td>
</tr>
<tr>
<td>5 5-6</td>
</tr>
<tr>
<td><strong>Initial Voiced</strong></td>
</tr>
<tr>
<td>pa-ða</td>
</tr>
<tr>
<td>ba-va</td>
</tr>
<tr>
<td><strong>Final Voiced</strong></td>
</tr>
<tr>
<td>a-pæ</td>
</tr>
<tr>
<td><strong>Final Voiced</strong></td>
</tr>
<tr>
<td>a-bav</td>
</tr>
<tr>
<td><strong>Medial Voiced</strong></td>
</tr>
<tr>
<td>afe-æø</td>
</tr>
<tr>
<td><strong>Medial Voiced</strong></td>
</tr>
<tr>
<td>ææ=æø</td>
</tr>
<tr>
<td>**No. %</td>
</tr>
<tr>
<td>11 11-5</td>
</tr>
<tr>
<td><strong>Initial Voiced</strong></td>
</tr>
<tr>
<td>3a-ð3a</td>
</tr>
<tr>
<td><strong>Final Voiced</strong></td>
</tr>
<tr>
<td>aæ=æø</td>
</tr>
<tr>
<td><strong>Medial Voiced</strong></td>
</tr>
<tr>
<td>aæ=æø</td>
</tr>
<tr>
<td>**No. %</td>
</tr>
<tr>
<td>34 34-5</td>
</tr>
<tr>
<td><strong>Initial Voiced</strong></td>
</tr>
<tr>
<td><strong>Final Voiced</strong></td>
</tr>
<tr>
<td><strong>Medial Voiced</strong></td>
</tr>
<tr>
<td>af=ø</td>
</tr>
</tbody>
</table>
Only twenty-three, or 3.6 percent of the 168 "Different" pairs, were not missed by any of the 36 individuals, while 42, or 6.7 percent, were missed by only one person. The eleven most frequently missed pairs, in order from least to greatest number of errors, are as follows:

<table>
<thead>
<tr>
<th>Sound Pair</th>
<th>Subjects Missing Each Sound Pair</th>
</tr>
</thead>
<tbody>
<tr>
<td>a f = a s</td>
<td>9</td>
</tr>
<tr>
<td>a d e = a δ e</td>
<td>9</td>
</tr>
<tr>
<td>a g = a δ</td>
<td>11</td>
</tr>
<tr>
<td>a v = a δ</td>
<td>16</td>
</tr>
<tr>
<td>a v = a δ e</td>
<td>17</td>
</tr>
<tr>
<td>a b e = a v e</td>
<td>17</td>
</tr>
<tr>
<td>τ a = a 3 a</td>
<td>18</td>
</tr>
<tr>
<td>a v = a δ</td>
<td>25</td>
</tr>
<tr>
<td>f a = a δ</td>
<td>34</td>
</tr>
<tr>
<td>a f = a θ</td>
<td>44</td>
</tr>
<tr>
<td>a f = a θ</td>
<td>49</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>10.2</td>
</tr>
<tr>
<td>9</td>
<td>10.2</td>
</tr>
<tr>
<td>11</td>
<td>12.5</td>
</tr>
<tr>
<td>16</td>
<td>15.1</td>
</tr>
<tr>
<td>17</td>
<td>19.3</td>
</tr>
<tr>
<td>17</td>
<td>19.3</td>
</tr>
<tr>
<td>18</td>
<td>20.4</td>
</tr>
<tr>
<td>25</td>
<td>29.5</td>
</tr>
<tr>
<td>34</td>
<td>38.6</td>
</tr>
<tr>
<td>44</td>
<td>50.0</td>
</tr>
<tr>
<td>49</td>
<td>55.6</td>
</tr>
</tbody>
</table>

Summary Table XII shows the total number and percentages of 1047 pair errors as distributed among voiced and voiceless, initially, medially and finally placed consonants. From least to greatest number, the errors fell as follows: (1) initial voiced, (2) medial voiced, (3) medial voiceless, (4) initial voiceless, (5) final voiced, and (6) final voiceless consonants.

With reference to errors on "Different" pairs, the lowest number, 81 or 8.1 percent, were contributed by initial voiced consonants, and the highest, 143, or 22.9 percent, were contributed by final voiceless consonants. In order from least to greatest number contributed, the errors fall as follows: (1) initial voiced consonants; (2) initial voiceless; (3) medial voiced; (4) medial voiceless; (5) final voiced; and (6) final voiceless. With reference to consonant position only, it is found as shown in
TABLE XI

Summary of the 623 "Different" Pair Errors
Made by 36 Subjects

| Found Pairs | No. 0 | No. 1 | No. 2 | No. 3 | No. 4 | No. 5 | No. 6 | No. 7 | No. 8 | No. 9 | No. 11 | No. 12 | No. 13 | No. 14 | No. 15 | No. 16 | No. 17 | No. 18 | No. 19 | No. 20 | No. 21 | No. 22 | No. 23 | No. 24 | No. 25 | No. 26 | No. 27 | No. 28 | No. 29 |
|-------------|------|------|------|------|------|------|------|------|------|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Initial     |      |      |      |      |      |      |      |      |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| Voiceless   | 8    | 8    | 8    | 8    | 8    | 1    | 0    | 1    | 0    | 0    | 0     | 0     | 0     | 0     | 0     | 0     | 1     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     |
| Voiced      | 6    | 2    | 2    | 2    | 2    | 0    | 0    | 0    | 0    | 0    | 1     | 0     | 1     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     |
| Final       |      |      |      |      |      |      |      |      |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| Voiceless   | 0    | 4    | 4    | 4    | 7    | 5    | 1    | 0    | 1    | 1    | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 1     | 143   | 22.9  |
| Voiced      | 5    | 5    | 5    | 5    | 5    | 0    | 1    | 2    | 1    | 0    | 1     | 0     | 0     | 0     | 1     | 0     | 0     | 0     | 0     | 0     | 1     | 0     | 110   | 17.6  |
| Medial      |      |      |      |      |      |      |      |      |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| Voiceless   | 5    | 6    | 5    | 7    | 1    | 1    | 1    | 1    | 1    | 0    | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 1     | 0     | 0     | 1     | 0     | 105   | 16.0  |
| Voiced      | 4    | 10   | 3    | 2    | 2    | 1    | 1    | 1    | 0    | 1    | 0     | 0     | 0     | 2     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 98    | 15.4  |
| Total Pairs | 23   | 42   | 28   | 23   | 18   | 9    | 9    | 4    | 4    | 2    | 1     | 1     | 2     | 1     | 1     | 1     | 1     | 1     | 1     | 1     | 1     | 1     | 1     | 1     | 1     | 1     | 1     | 1     |
| % of 168 "Different" Pairs | 13.8 | 25   | 15.4 | 16.6 | 10.7 | 5.3  | 1.7  | 2.5  | 2.5  | 1.1  | 0.8   | 0.8   | 0.6   | 0.6   | 0.6   | 0.6   | 0.6   | 0.6   | 0.6   | 0.6   | 0.6   | 0.6   | 0.6   | 0.6   | 0.6   | 0.6   | 0.6   | 0.6   | 0.6   | 0.6   |
| Total Errors | 0    | 42   | 52   | 28   | 72   | 45   | 18   | 26   | 28   | 16   | 11    | 16    | 24    | 16    | 22    | 25    | 22    | 23    | 24    | 44    | 40    | 17.6  |
| % of Errors | 0    | 6.7  | 8.3  | 15.4 | 11.5 | 7.2  | 2.9  | 4.4  | 5.1  | 2.9  | 1.8   | 2.5   | 5.5   | 2.9   | 4.1   | 5.8   | 7.8   | 10.1  |

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Table XII, that initial consonants represent 169, or 27.1 percent, of
the 622 "Different" pair errors; medial consonants 201, or 32.2 per-
cents; and final consonants 252 or 40.6 percent. In terms of the ele-
ments of voicing and unvoicing, it is found that voiceless sound pairs
accounted for 356, or 56 percent, and voiced pairs accounted for 267,
or 44 percent of the 622 "Different" pair errors. From this it is
evident that the position of the consonants is more important in dis-
rimination than the elements of voicing and unvoicing.

TABLE XII

Summary of 1047 Discrimination Errors
in Relationship to Consonant Position and Elements of
Voicing and Unvoicing

<table>
<thead>
<tr>
<th></th>
<th>622 &quot;Different&quot; Pair Errors</th>
<th>424 &quot;Same&quot; Pair Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
</tr>
<tr>
<td>Initial</td>
<td>86</td>
<td>16.1</td>
</tr>
<tr>
<td>Medial</td>
<td>105</td>
<td>16.8</td>
</tr>
<tr>
<td>Final</td>
<td>143</td>
<td>22.9</td>
</tr>
<tr>
<td></td>
<td>330</td>
<td>53.9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Grand Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
</tr>
<tr>
<td>Initial</td>
<td>168</td>
</tr>
<tr>
<td>Medial</td>
<td>166</td>
</tr>
<tr>
<td>Final</td>
<td>211</td>
</tr>
<tr>
<td></td>
<td>546</td>
</tr>
</tbody>
</table>

The errors made on "Same" pairs are shown in Table XIII. In all
there were 424 errors on these 144 pairs. Each of them was missed by at
least one of the 88 subjects, which was reasonable to expect, since each
pair occurred three times in the test. Approximately one-third, or 54 of the 164 "Same" pairs, accounted for 51.8 percent of the 424 errors, while the remaining 96 pairs, or approximately two-thirds, accounted for only 48.2 percent. The four "Same" pairs missed most frequently were, from least to greatest number, those involving the consonants (b, v, k and g). The four pairs missed the least frequently were, in the same order, (f, s, f and t). Table XII shows that the voiceless consonant pairs accounted for 208 errors and the voiced for 216 of the 424 "Same" pair errors. Of the voiceless pairs, those with initially placed consonants were missed the greatest number of times, finally placed consonants next greatest, and medially placed least. The same order held for the voiced pairs. Ranking the pairs according to the combined aspects of voice and consonant position, in the order from least to greatest number of errors, they fall as follows: (1) medial voiceless, (2) medial voiced, (3) final voiceless, (4) final voiced, (5) initial voiced, and (6) initial voiceless.

**TABLE XIII**

424 "Same" Pair Discrimination Errors
Made by 86 Subjects

<table>
<thead>
<tr>
<th>Initial Voiceless</th>
<th>Initial Voiced</th>
<th>Final Voiceless</th>
<th>Final Voiced</th>
<th>Medial Voiceless</th>
<th>Medial Voiced</th>
</tr>
</thead>
<tbody>
<tr>
<td>sa</td>
<td>4</td>
<td>43a</td>
<td>3</td>
<td>4</td>
<td>a</td>
</tr>
<tr>
<td>ja</td>
<td>4</td>
<td>a</td>
<td>43</td>
<td>a</td>
<td>a</td>
</tr>
<tr>
<td>sa</td>
<td>4</td>
<td>3a</td>
<td>3</td>
<td>4</td>
<td>a</td>
</tr>
<tr>
<td>ta</td>
<td>4</td>
<td>3a</td>
<td>3</td>
<td>4</td>
<td>a</td>
</tr>
<tr>
<td>fa</td>
<td>7</td>
<td>3a</td>
<td>3</td>
<td>4</td>
<td>a</td>
</tr>
<tr>
<td>pa</td>
<td>10</td>
<td>va</td>
<td>10</td>
<td>4</td>
<td>a</td>
</tr>
<tr>
<td>ka</td>
<td>15</td>
<td>3a</td>
<td>12</td>
<td>4</td>
<td>a</td>
</tr>
<tr>
<td>ga</td>
<td>22</td>
<td>3a</td>
<td>15</td>
<td>4</td>
<td>a</td>
</tr>
</tbody>
</table>
In determining single sound errors, the number of times a given
consonant occurred in sound pair errors was noted. Table XIV summarizes
this information. With respect to the 623 "Different" pair errors, the
voiceless consonants occurred 672 times in sound pair errors, while the
voiced occurred 574 times. In the order of least to greatest number of
times they entered into sound pair errors, the voiceless consonants fall
as follows: (p, t, t, k, s, f, s) and (θ). The voiced consonants in a
similar order are (s, z, d, v, b, 3, v) and (θ).

| TABLE XIV |
| Occurrence of the Sixteen Consonants in 1047 Discrimination Pair Errors |

<table>
<thead>
<tr>
<th>Sound</th>
<th>Occurrence in 424</th>
<th>Occurrence in 623</th>
<th>Occurrence in 1047</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&quot;Same&quot; Pair Errors</td>
<td>&quot;Different&quot; Pair Errors</td>
<td>Discrimination Pair Errors</td>
</tr>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
<td>R</td>
</tr>
<tr>
<td>Voiceless</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>p</td>
<td>25</td>
<td>6.1</td>
<td>9</td>
</tr>
<tr>
<td>t</td>
<td>25</td>
<td>6.1</td>
<td>9</td>
</tr>
<tr>
<td>k</td>
<td>37</td>
<td>5.7</td>
<td>15</td>
</tr>
<tr>
<td>f</td>
<td>16</td>
<td>3.7</td>
<td>3</td>
</tr>
<tr>
<td>s</td>
<td>15</td>
<td>3.6</td>
<td>2</td>
</tr>
<tr>
<td>θ</td>
<td>56</td>
<td>13.2</td>
<td>16</td>
</tr>
<tr>
<td>j</td>
<td>14</td>
<td>3.5</td>
<td>1</td>
</tr>
<tr>
<td>θj</td>
<td>19</td>
<td>4.2</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>208</td>
<td>69</td>
<td>672</td>
</tr>
<tr>
<td>Voiced</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b</td>
<td>27</td>
<td>6.3</td>
<td>11</td>
</tr>
<tr>
<td>d</td>
<td>20</td>
<td>4.7</td>
<td>9</td>
</tr>
<tr>
<td>g</td>
<td>22</td>
<td>6.1</td>
<td>9</td>
</tr>
<tr>
<td>v</td>
<td>53</td>
<td>8.8</td>
<td>14</td>
</tr>
<tr>
<td>s</td>
<td>25</td>
<td>5.8</td>
<td>7</td>
</tr>
<tr>
<td>θ</td>
<td>53</td>
<td>7.7</td>
<td>13</td>
</tr>
<tr>
<td>3</td>
<td>20</td>
<td>4.7</td>
<td>6</td>
</tr>
<tr>
<td>θ3</td>
<td>19</td>
<td>4.4</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td>215</td>
<td>51</td>
<td>574</td>
</tr>
</tbody>
</table>

44. (t and k) entered an equal number of times.
45. (d and g) entered an equal number of times.
In comparing the ranks of the single sounds involved in "Different" errors, it is found that in five of the eight combinations of voiceless sound and component voiced sound, the components rank the same. These component combinations which ranked the same are (t) and (d), (k) and (g), (s) and (v), (0) and (f), and (tj) and (dº). (u) and (s) are quite similar in their respective ranks of five and six, while (p) and (t), with respective ranks of one and five, and (a) and (a), with respective ranks of six and one, show the greatest differences. When voiced and voiceless sounds are ranked irrespective of these distinguishing elements, they rank from least to greatest number of errors as follows:

(a, p, t, d, s, z, g, 4, 5, t, k, 4, j, s, b, 3, v, d, f) and (0). The occurrence of single consonants among "Same" pair errors is identical with the occurrence of sound pairs, since a pair using the same sound in both syllables was counted as having only one single-sound error. The rank of single sounds, from least to greatest occurrence, among "Same" pair errors is thus: (s, k, f, t, d, s, 3, v) and equal rank for (g, t) and (p), then (b, d, z, v, k) and (0).

The six single sounds occurring most frequently among "Same" pair errors, from least to greatest occurrence were (b, d, z, v, k, 0). The six most frequently occurring among "Different" pair errors, in the same order, were (b, z, v, d, f, 0). Eight of these 12 sounds are common to "Same" and "Different" groups, and (b) and (0) occupy first and last places, respectively, in both. When these eight sounds are arranged together according to the number of times each was involved in the total

44. (t and k) entered an equal number of times.
45. (d and g) entered an equal number of times.
1047 "Same" and "Different" errors, they fall, from least to greatest number, in the order, (d, 3, b, k, 6, v, f, θ).

When all sixteen sounds used in this study are ranked from least to greatest occurrence in the 1047 "Same" and "Different" pair errors, they fall as follows: (a, t, j, d3, j, s, p, 3, t, d, 3, b, k, 6, v, f, θ). The place of least occurrence in the 1047 pair errors is shared by (tj) and (z). With regard to (s) and (z), two sounds which are generally agreed to be difficult to perceive and discriminate, this study is in agreement with Hall. She found that the two sounds occurred relatively few times in discrimination errors. 46 In the present study it is found that, in terms of the least number of errors, (z) shares first place with (tj), while (s) ranks fifth. This study is in agreement with Hall’s finding that (j) and (tj) occur in a relatively few and (3, θ) and (6) in a relatively great number of errors, but is in disagreement with her finding that (ds) occurs in a great number of errors. 47 In the present study (j) is found to rank the fourth least number of times among the sixteen consonants, (tj) 1-3, (6) sixth, and (d3) third. (θ) ranked last, or had the greatest number of errors.

Table IV shows the occurrence of errors on sound pairs which make use of fricative-fricative, stop-stop and fricative-stop combinations of the consonants. The 168 "Different" pairs included 24 fricative-fricative, 26 stop-stop and 32 fricative-stop combinations. 48 Half of these combinations were voiceless and half voiced. There were 285 errors

47. Ibid.
48. It will be recalled that each of these combinations appeared in the test three times, i.e., with consonants in initial, medial and final positions. Thus, multiplying 24, 26 and 32 by three accounts for the total 168 pairs.
### TABLE XV

**Relative Difficulty in Discriminating Sound Pairs**

**Composed of Plosive-Plosive, Stop-Stop, and Plosive-Stop Combinations**

<table>
<thead>
<tr>
<th>Plosive-Plosive Errors</th>
<th>Stop-Stop Errors</th>
<th>Plosive-Stop Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Voiceless</strong></td>
<td><strong>Voiced</strong></td>
<td><strong>R</strong></td>
</tr>
<tr>
<td>q-f</td>
<td>6</td>
<td>25.5</td>
</tr>
<tr>
<td>s-f</td>
<td>6</td>
<td>35</td>
</tr>
<tr>
<td>f-f</td>
<td>10</td>
<td>41</td>
</tr>
<tr>
<td>f-c</td>
<td>18</td>
<td>49</td>
</tr>
<tr>
<td>s-c</td>
<td>16</td>
<td>46</td>
</tr>
<tr>
<td>f-c</td>
<td>127</td>
<td>86</td>
</tr>
<tr>
<td>h-c</td>
<td>5</td>
<td>10.5</td>
</tr>
<tr>
<td>t-f-c</td>
<td>6</td>
<td>25.5</td>
</tr>
<tr>
<td>t-f-t</td>
<td>7</td>
<td>31</td>
</tr>
<tr>
<td>p-c</td>
<td>10</td>
<td>41</td>
</tr>
</tbody>
</table>

2
among the fricative-fricative combinations, 162 of which were on voiceless and 101 on voiced pairs. The fricative-fricative combinations accounted for 207 more errors than the stop-stop combinations. Forty-nine voiceless and 27 voiced pairs made up the 78 errors on stop-stop combinations. The fricative-stop combinations accounted for 266 errors, 105 of which were on voiceless and 156 on voiced pairs. This is the only case in which the voiced pairs accounted for more errors than the voiceless.

Since the ratio of occurrence of fricative-stop combinations was 8 to 3 against both the other combinations, the chance of error was 8 to 3 greater for fricative-stop combinations. Reducing this ratio to a percentage basis, fricative-stop pairs should account for 72.7 percent errors to 27.3 percent for either fricative-fricative or stop-stop pairs. Upon this basis it is found the fricative-stop pairs, in representing 77.8 percent of the total 540 fricative-stop and stop-stop pair errors, were missed 4.9 percent more often than stop-stop combinations. Upon the same basis, it is found that the fricative-fricative combinations, in representing 51.1 percent of the total fricative-fricative and fricative-stop errors, were missed only 28.9 percent more often than fricative-stop combinations. In these terms, or proportionately speaking, the least number of errors occurred in stop-stop combinations, second least in fricative-stop, and the greatest number in fricative-fricative combinations.

The only combination which was not missed by any of the 38 subjects is the stop-stop combination ($s$-$s$). The four combinations involved
most often in the "Different" errors were, in order from least to greatest, the two stop-fricative combinations (3-13) and (b-v) and the two fricative-fricative combinations (v-0) and (f-g). Hall found that of the sound pairs common to the Travis-Rasmus discrimination test and the test used in this study, these same four combinations were most frequently missed on the Travis-Rasmus test. Hall found, however, that the order of the four was, from least to greatest difficulty, (b-v, b-v, 8-f) and (d-3-7). Whereas she found (d-3-7) to give the greatest and (b-v) the least difficulty among these four pairs, it is found in this study that the combination of (f-g) gave the greatest and (d-3-7) the least. In a study involving their test Travis-Rasmus found that (8-f) and (b-v) combinations were the most difficult of all combinations to discriminate. Hall also found that these same two combinations were of the greatest difficulty for several of the individual groups of subjects which she used in her study referred to above.

In view of the decidedly different pressure pattern assigned to fricative and stop consonants, it is surprising that fricative-stop combination caused any appreciable difficulty in discrimination. It is especially surprising that they were actually missed 4.9 percent more often than stop-stop combinations and were missed only 26.9 percent less often than fricative-fricative combinations. Steinberg states that stop and fricative sounds are rarely confused, and West implies agreement.

49. The two affricates (d-3) and (t-1) are treated along with the stops since they are the only two which occur in the study.
50. Ibid., p. 37.
with this view in stating that sounds which are paired to test discrimination between frequencies would not be practical if their pressure patterns were different. He cites the fricative-stop combination (s-t) as an impractical pairing. The frequency of appearance of these combinations in discrimination errors in this study, however, is accounted for chiefly by seven voiced and three voiceless pairs. These ten accounted for 65 percent of the fricative-stop errors. In ascending order of difficulty, the seven voiced pairs were (b-β, d-v, g-v, d-β, g-β, b-v) and (d3-β). The probable reason for their difficulty is that the element of voicing minimizes the clarity of their pressure patterns. It will be noted that either (β) or (v) occur in all of these combinations excepting that of (d3-β). These two voiced sounds, (β) and (v), and their voiceless components, (β) and (f), it will be recalled, were the four highest ranking single sounds in terms of occurrence in discrimination errors. The pair (d3-β) may have been increasingly difficult because of the final fricative element in the affricate (d3).

The element of voicing cannot account, however, for the errors made on the three most frequently missed voiceless fricative-stop combinations, (t-θ, p-θ and tʃ-ʃ). The greatest number of errors on (tʃ-ʃ), may have been due, as in the voiced pair (d-i), to the final fricative element in the affricate (tʃ). The only reason that can be given for the numerous errors on (t-θ) and (p-θ) is simply that the two sounds in each are strikingly similar.


(1) Relationship between difficulty in discriminating "Same" and "Different" consonant pairs;

a. It is approximately one-third more difficult to discriminate between two sounds which are different, than it is to determine that two sounds are the same. This statement is based upon the fact that of the 1047 total discrimination errors made by 36 subjects, 623 were "Different" pair errors, while 424 were "Same" pair errors.

b. A relatively small number of pairs caused a large percentage of difficulty in discrimination. Fifty-one and one-tenth percent of the 424 "Same" pair errors were accounted for by 54, or approximately one-third, of the "Same" pairs. The six sounds involved in these 54 pairs are, in order from least to greatest difficulty, (h, d, f, v, k) and (e).

c. Even fewer pairs accounted for a great percentage of the difficulty in discriminating "Different" pairs. Eleven pairs, or approximately 6 percent, accounted for 40 percent of the 623 errors, while the remaining 157 pairs, or 94 percent, accounted for 60 percent of the errors. From least to greatest difficulty, the eleven pairs which accounted for 40 percent of the errors were 

\( \{(a, u, e, 56, a, d, a, 56, a, g, a, 56, a, v, a, 56, a, b, a, 57, a, b, a, 57, a, d, a, 57, a, d, a, 57, a, e, a, 57, a, e, a, 57, a, e, a, 57, a, e, a\} \) and \( \{(a, e, a)\} \).

(2) Relationship of consonant position and the elements of voicing and unvoicing to the difficulty of speech sound discrimination:

a. Voiceless pairs of sounds were of slightly greater difficulty in discrimination than voiced. Voiceless pairs accounted

66. It will be recalled that in making up "Same" pairs, each consonant was used in three different combinations and each combination was used three times in the test, making a total of 9 pairs for each consonant.

66. These two pairs were of equal difficulty.

67. These two pairs were of equal difficulty.
for 54%, or 62 percent, of the 1047 errors, while voiced pairs accounted for 30%, or 48 percent.

b. With reference to consonant position the greatest difficulty in discrimination occurred among finally placed consonants, while medially and initially placed were of almost identical difficulty. Of the 1047 errors, final consonants accounted for 394, medial consonants for 327 and initial consonants for 326.

c. With reference to the combined elements of consonant position and voicing and unvoicing, final voiceless consonants were of greatest difficulty in discrimination, while initial voiced were of the least. Final voiceless consonants accounted for 211 of the total 1047 errors and initial voiced consonants for 168. Final voiced consonants were of second greatest difficulty, with 183 errors; initial voiceless of third greatest, with 168 errors; medial voiceless of fourth greatest, with 165 errors; and medial voiced consonants were of fifth greatest difficulty, with 182 errors. Initial voiced accounted for 158 errors.

(3) Frequency of occurrence of single sounds among consonant pair errors:

a. Of the sixteen consonants used in this study, (a) occurred least often among 625 “Different” pair errors and (j) occurred least often among 424 “Same” pair errors. (g) occurred most often among both “Same” and “Different” pairs.

b. The six sounds occurring most often among “Different” pair errors were, in order from least to greatest frequency, (b, 3, v, δ, f) and (g); while among the “Same” pairs they were (b, d, δ, v, k)
and (c).

(a) The order of frequency of occurrence of the sixteen sounds among the total 1067 "Same" and "Different" errors in the order from least to greatest was as follows: (s, tʃ, dʒ, j, z, p, s, t, dʒ, b, k, ɹ, v, f) and (θ).

(4) Relative difficulty in discriminating fricative-fricative, stop-stop and fricative-stop sound combinations:

(a) In proportion to their number of occurrences in the discrimination test, stop-stop combinations accounted for the least errors, fricative-stop for the second least and fricative-fricative for the greatest number of errors. In terms of the 2 to 3 ratio for the number of fricative-stop pairs used in the test against both other combinations, fricative-fricative combinations were missed 28.9 percent more often than fricative-stop combinations, and 53.6 percent more often than stop-stop combinations. Fricative-stop combinations were missed 4.9 percent more often than stop-stop combinations. The predominance of errors among fricative-fricative pairs is in accordance with West's statement that the fricative sounds are distinguished from each other with considerable difficulty.58

58. West et al., Rehabilitation, pp. 148-149.
RESULTS

3

39 Western Electric Audimeter Testing

This section proposes an attempt to answer the following questions:

1. What is the general relationship between audimeter ratings and discrimination test scores made in the clinic room?

2. What is the specific relationship between individual audimeter ratings and individual discrimination test scores made in the clinic room?

3. What is the general relationship between audimeter ratings and discrimination test scores made in the classroom?

4. What is the specific relationship between individual audimeter ratings and individual discrimination test scores made in the classroom?

5. What is the general relationship between the discrimination test scores made in the clinic room and those made in the classroom?

6. What is the specific relationship between individual discrimination test scores made in the clinic room and those made in the classroom?

7. What is the relationship between specific losses of hearing acuity as determined by the audimeter and specific errors in speech sound discrimination?

1 Relationship between Audimeter Ratings and Clinic Room Discrimination Test Scores. The first and second speech sound discrimination test scores of the 52 subjects given the audimeter test are shown in
Table XVI. The table also shows for each individual the algebraic sum of the plus and minus audiometer ratings on 26 frequencies for the better ear. Using the ranks shown for audiometer ratings and discrimination test II, the clinic room test, a correlation was run and a coefficient of .73 ±.04 was derived. Recalling that the discrimination scores used in this correlation were drawn from those of 18 different testings, and considering that 52 is a relatively small number of cases, this coefficient may be considered fairly significant. This indication of a fairly high relationship between speech sound discrimination ability and acuity to the pure tones of the audiometer is contrary to the findings of Hall in her experiment referred to earlier in this study. For a normal and a defective articulatory group of college freshmen, respectively, she found a correlation of .10 ±.14 and .18 ±.15 between audiometer ratings and scores made on the Travis-Raamus speech sound discrimination test.

It will be recalled, however, that the audiometer measure which Hall used in her correlation was the average of only the three middle frequencies, 512, 1924 and 2048 cps. The audiometer ratings used in the present study to derive the correlation coefficient of .73 ±.04 included 26 frequencies, from 128 to 9747 cps. Hall might have found a higher correlation had she used a comparable number of frequencies.

Figures 1 to 52 (pages 128–179) present the results of audiometer testing for both ears of each of the 52 subjects. The figure numbers of these double curve audiographs correspond to individual case numbers.

69. The term better ear refers to the ear, whether right or left, which has the highest rating on a given frequency, poor ear to the contrary.

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<th>A_R</th>
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Case numbers were assigned on the basis of the clinic room discrimination test scores. The subject with the least errors on the test was numbered one and the remaining subjects were numbered in order from low to high. Within a group of subjects having identical discrimination scores, or errors, the least case number indicates that that subject had the highest audiometer rating. For the sake of clarity, however, the rank of each subject on both the audiometer and the discrimination test are found on the audiograph.

Figures 53 to 104 (pages 180-231) are single curve audiographs, which are based upon the subjects' decibel ratings for the better ear on each of the 20 frequencies tested. West says that the rating for the poor ear has something near a 10 percent negative influence on an individual's hearing for speech. He says, further, that one normal ear is sufficient for the development of normal speech.61 In agreement with these views, and assuming that an individual can make adjustments in most situations to utilize the better ear, the discussion in this section is based upon the single curve audiographs. Whatever the loss of hearing effected by the poor ear, it will be approximately uniform in each of the cases used.

The single curve audiographs are arranged into four divisions. In the order named, these four divisions contain (1) twenty-five subjects, or 48 percent of the 52, whose audiometer ratings are considered superior (Figures 85 to 77, pages 180-204); (2) fifteen, or 28.8 percent of the 52, whose ratings are considered normal (Figures 78 to 92, pages 205-219); (3) nine subjects, or 17.3 percent of the 52, whose audiographs show high

61. West et al, Rehabilitation, pp. 507, 152.
frequency losses (Figures 93 to 101, pages 220-228); (4) three subjects, or 8.9 percent of the 52, whose audiographs show a general hearing loss (Figures 102 to 104, pages 229-231). These four divisions are made arbitrarily and for the sake of convenience in discussion. They are based purely upon the similarity in appearance of individual audiographs. Within each division, however, the arrangement of rank numbers from least to greatest shows the relative standing with the other members of the division.

Table XVII shows these divisions with discrimination scores, audiometer ratings and the ranks of each case on both. It will be noted that even in these arbitrary divisions, solely upon the basis of similarity in the appearance of their audiographs, the 25 highest ranking cases in terms of plus and minus audiometer ratings fall in the superior group. Of the next highest ranking 17, only Cases 46 and 41, ranking 36 and 41, do not fall in the normal group. Of the third highest ranking eight, all but Case 50, with a rank of 49, fall into the high frequency loss group; and all but one of the remaining three lowest ranking cases, Case 47 with a rank of 50, fall into the general hearing loss group.

Examination of their audiographs will reveal that those members of the superior group (Figures 53 to 77, pages 160-206) without question are rightfully assigned. Assignment of four of the normal group cases may be questioned. Assignment of Case 13 (Figure 89) may be questioned on the grounds that it deviates below normal at 17 of the 28 frequencies. Only two of these deviations, however, fall as much as eight decibels below normal, and 12 of the 17 fall within the five decibel range below.

In spite of the fact that this case is fairly consistently below the

62. For reference to audiographs, figure numbers are shown in the Table.
## Table XVII

Clinic Room Discrimination Test Scores and Audimeter Ratings for 52 Cases

**Correlation: +0.73 ± 0.09**

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<th>Figure</th>
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### High Frequency Loss

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<th>Figure</th>
<th>Score</th>
<th>R</th>
<th>No.</th>
<th>%</th>
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### General Loss

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<th>%</th>
<th>Case</th>
<th>Figure</th>
<th>Score</th>
<th>R</th>
<th>No.</th>
<th>%</th>
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<td>50</td>
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<td>57</td>
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<td>78</td>
<td>+387</td>
<td>51</td>
<td>58</td>
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<td></td>
<td></td>
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<td>104</td>
<td>122</td>
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<td></td>
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</table>
zero, or absolute normal, line, it is consistently within what this study assumes to be the normal range, or, the range which indicates hearing sufficient for the hearing and development of normal speech. Hall states that a hearing loss probably must exceed ten or fifteen decibels before affecting hearing for speech, 63 and Steinberg and Gardner indicate that an average loss of 25 decibels over the speech frequency range will impair hearing for church or theatre, but than an average loss of about 45 decibels is necessary before hearing impairment for conversational speech is affected. 64 The reasons for assigning Case 15 to the normal group apply as well to Cases 19, 29 and 44 (Figures 91, 90 and 92). Case 29 drops five decibels below the "normal range" at 256 ops. and three below at 9216, but such slight drops at these frequencies are considered insignificant in view of the ratings on the other 25 frequencies. In the group showing high frequency losses (Figures 93 to 101, pages 220-223) assignment of Cases 41 and 54 (Figures 94 and 95) may be questioned. In all probability, their hearing is sufficient for normal hearing of speech. They were assigned to this group in view of slight but decided, and almost identical, sub-normal deviations at several high frequencies. The reasons for assigning the three Cases 50, 51 and 52 (Figures 102 to 104, pages 222-251) to the general loss group is obvious.

Summary Table XVIII shows the score ranges of the clinic room discrimination test, the number of cases within each range and their assignment to the four audiograph groups. Thirty-two, or 61.5 percent of the 52 cases, had a score range of from one to nine errors. Of these thirty-two, 65.

TABLE XVIII
The Relationship between Classroom Discrimination Test Scores and Audiometer Ratings for 52 Cases

<table>
<thead>
<tr>
<th>Prediction</th>
<th>Clinic Discrim. Test Scores</th>
<th>Superior % with Same</th>
<th>Normal % with Same</th>
<th>N. Freq. Loss % with Same</th>
<th>General Loss % with Same</th>
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<td>% of 52</td>
<td>Score</td>
<td>Range</td>
<td>No. of Cases</td>
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<td>61.5</td>
<td>1-9</td>
<td>&lt;300 to &gt;78</td>
<td>23</td>
</tr>
<tr>
<td>8 to 5</td>
<td>13</td>
<td>25</td>
<td>10-16</td>
<td>&gt;240 to 428</td>
<td>2</td>
</tr>
<tr>
<td>100% Defective</td>
<td>7</td>
<td>13.4</td>
<td>16-22</td>
<td>&gt;27 to 1079</td>
<td>0</td>
</tr>
<tr>
<td>Total No.</td>
<td>25</td>
<td>15</td>
<td>9</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Total % of 52</td>
<td>48</td>
<td>23.5</td>
<td>17.4</td>
<td>5.9</td>
<td></td>
</tr>
</tbody>
</table>
23 or 71.8 percent, fell into the superior group, while nine or 28.2 percent fell into the normal group on the audiometer test. Thirteen of the 52 cases, or 25 percent, had a discrimination score range of from ten to fourteen errors. Two of the thirteen, or 15.3 percent, fell into the superior group; six, or 46.1 percent, into the normal; and five, or 38.5 percent, into the high-frequency loss group on the audiometer test. None of the thirteen cases with 10 to 14 errors fell into the general loss group. Seven of the 52 cases, or 13.4 percent, had a score range of from 16 to 122 errors. Four of the seven, or 57.1 percent, are found in the high-frequency loss group; and the remaining three, or 42.9 percent, fall into the general loss group. None of the seven cases in the score range 16 to 122 fell into either the superior or the normal group.

A study of the audiographs in the high-frequency loss group (Figures 93 to 101, pages 220-223) reveals that out of five cases in the score range 10 to 14, only two show a serious and decided loss while of the four in the score range 16 upward, three have decidedly serious losses and one a mildly serious loss. In terms of clinic room score ranges and superior, normal, and below normal hearing, the preceding findings may be summarized as follows: (1) of 52 subjects with clinic room scores from one to nine, 100 percent had superior or normal audiometer ratings. Twenty-three, or 71.8 percent, were superior, and nine, or 28.2 percent, were normal. (2) Of thirteen cases with scores from ten to fourteen, eight, or 61.5 percent, were normal or better, and five, or 38.5 percent, were below normal. Two, or 15.3 percent of the thirteen cases,
had superior hearing; six, or 48.1 percent, had normal hearing; and five, or 33.3 percent, had appreciable losses in the high frequencies. (3) Of seven subjects with scores from 15 to 122, 100 percent had definitely serious hearing losses. Four, or 57.1 percent of the seven, had serious high frequency losses, and three, or 42.9 percent, had serious general losses.

These findings may be set down in terms of chance prediction as follows: (1) the chances are 100 percent that an individual making a clinic room score of nine or less will have superior or normal hearing; (2) the chances are eight to five that an individual making a clinic score of 10 to 14 will have superior or normal hearing; (3) the chances are 100 percent that a clinic score of 15 errors or more will indicate defective hearing. These chance predictions are shown in Table XVIII.

In anticipation of a question as to why the audiometer group contained relatively few cases with low discrimination scores and audiometer ratings, it should be said that such subjects are difficult to find. Sub-normal cases of hearing are relatively scarce among a university population. This is evidenced by the fact that the 12 such cases used in this study were the results of a thorough sifting of 593 subjects. Without question, and as will be evident later, the findings of this study could have been more satisfactory in some respects had more defective cases been available.

2. Relationship Between Audiometer Ratings and Classroom Discrimination Test Scores. In order to determine the general relationship between classroom discrimination test scores and audiometer ratings, the respective scores and ratings of 42 subjects were used. These were the 52
members of the audimeter group, minus the ten cases who had both first and second tests in the clinic room. A correlation was run between the audimeter ratings and the classroom test scores of the 42 cases. As in all instances where audimeter ratings were used, the audimeter measure was the algebraic sum of plus and minus ratings for the better ear. The test scores and audimeter ratings, and the ranks of each subject on both, are shown in Table XIX. A correlation coefficient of .60 ±.06 was derived as the general relationship between classroom discrimination test scores and audimeter ratings.

This is not a high correlation. It must be remembered, however, that the discrimination test scores used in the correlation were drawn from scores made in fifteen separate testings, conducted in five different classrooms. In such a series of testings it is impossible to keep conditions even reasonably constant from one testing to another. When these things are noted along with the fact that 42 is a relatively small number of cases, the correlation of .60 ±.06, though not high, is probably of considerable significance. The difference between this coefficient and that of .78 ±.04 for clinic room scores and audimeter ratings is in all probability due to the uniformity in the clinic room testing, despite the fact that the latter represents eighteen different testings.

It is reasonable to expect that had all classroom tests been administered in the same classroom, the relationship between the scores and audimeter ratings would have been considerably higher. With that, it is possible to deduce a reasonable, positive interrelationship between clinic room scores, classroom scores, and audimeter ratings. Finally, the correlation of .78 ±.04 between clinic room scores and audimeter
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<th>Figure</th>
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<th>Above Normal</th>
<th>Total No.</th>
<th>Case</th>
<th>Figure</th>
<th>Score</th>
<th>Normal</th>
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<td>19.5</td>
<td>52</td>
<td>104</td>
<td>88</td>
<td>+1079</td>
<td>41</td>
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**TABLE XIX**

Scores, Audiometer Ratings and Ranks for 42 Cases
Who Had First Discrimination Test in Classroom
(Correlation: .80 5.06)

<table>
<thead>
<tr>
<th>Case</th>
<th>Figure</th>
<th>Score</th>
<th>Above Normal</th>
<th>Total No.</th>
<th>Case</th>
<th>Figure</th>
<th>Score</th>
<th>Normal</th>
<th>Total No.</th>
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<td>22</td>
<td>54</td>
<td>7</td>
<td>-216 5.5</td>
<td>21</td>
<td>51</td>
<td>103</td>
<td>95</td>
<td>+667</td>
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<tr>
<td>52</td>
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<td>3</td>
<td>7</td>
<td>3</td>
<td>3</td>
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ratings reveals that as conditions become more satisfactory, the relationship between abilities on the two measures becomes more direct. In view of this it is not inconceivable that if the discrimination test were administered individually, or, under conditions comparable to those under which the audiometer test was given, i.e., individually and in an approximately sound-proof room, the correlation would be extremely high. This study, shows, in short, that upon the basis of its findings, the discrimination test it uses is a reliable test of hearing if administered under the conditions described.

In seeking the specific relationship between individual classroom discrimination test scores and individual audiometer ratings, the same procedure was used as that in connection with clinic room scores. Table IX shows the classroom scores and audiometer ratings of the 42 cases, divided, according to similarity in appearance of audiographs, into groups containing (1) twenty-two cases of superior hearing, representing 54 percent of the 42; (2) nine cases with normal hearing, or 21 percent; (3) eight cases with high frequency losses, 19 percent; and (4) three cases with general hearing loss, or 7 percent of the 42 cases. In observing these arbitrary divisions of audiographs, made purely upon similarities in appearance, it may be noted that the 22 highest ranking cases, in terms of plus and minus audiometer ratings, fall into the superior group. Of the eleven second highest ranking cases, only Cases 48 and 41 fail to appear in the normal group. Of the seven third highest ranking cases, only Case 50 fails to appear in the high frequency group, and of the three highest ranking cases, all but Case 47 fall into the general loss group.
Summary Table II presents the classroom score ranges of the 42 subjects, the number of cases in each range, and their assignment to the four audiograph groups—superior, normal, high frequency loss and general loss. Examination of the Table shows that of 18 cases, with a score range of from 4 to 9, 88.5 percent fall into the superior group. The remaining 16.4 percent fall into the normal group. The score range of 12 to 25 contains eight, or 19.2 percent, of the total 42 cases. Of these eight cases, 37.5 percent fall into the superior, 37.5 percent into the normal, and 25 percent into the high frequency loss group. Ten cases, 23.8 percent of the 42, had scores in the range 25 to 50. Thirty percent of the 10 cases had superior hearing, 20 percent normal, and 50 percent had high frequency losses. Six of the 42 cases, or 14.6 percent, had scores of from 50 upward. One case, or 16.7 percent of the six, had superior hearing, one was normal, one had a high frequency loss and three of the six, or 50 percent, had general hearing losses.

In terms of classroom score ranges and superior, normal and below normal hearing, as determined by the audiometer, these findings may be summarized as follows: (1) one hundred percent of the eighteen cases in the score range four to nine had normal, or better, hearing. Fifteen of the eighteen cases, or 83.3 percent, were superior, while three, or 16.6 percent, were normal. These eighteen cases represent 43 percent of the total 42. (2) Of eight cases within the 12 to 25 score range, three each, or 37.5 percent, fell into the superior and normal groups; while two, or 25 percent of the eight, fell into the high frequency loss group. These eight cases represent 19.2 percent of the total 42. (3) Of ten cases with a score range of 26 to 50, three, or 30 percent, are found in
<table>
<thead>
<tr>
<th>Prediction</th>
<th>Classroom Noise Test Score</th>
<th>Superior % with Same Score</th>
<th>Normal % with Same Score</th>
<th>H. Freq. Loss % with Same Score</th>
<th>General Loss % with Same Score</th>
<th>No. of Cases</th>
<th>Range</th>
<th>No.</th>
<th>Range</th>
<th>No.</th>
<th>Range</th>
<th>No.</th>
<th>Range</th>
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</thead>
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<tr>
<td>100% normal or above</td>
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<td>45</td>
<td>-350 to +45</td>
<td>15</td>
<td>S3.6</td>
<td>3</td>
<td>16.4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3 to 1 &quot;   &quot;</td>
<td>8</td>
<td>19.2</td>
<td>12-25</td>
<td>-262 to +66</td>
<td>3</td>
<td>57.5</td>
<td>3</td>
<td>57.5</td>
<td>2</td>
<td>25</td>
<td>0</td>
<td>0</td>
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</tr>
<tr>
<td>1 to 1 defective</td>
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<td>25.3</td>
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<td>5</td>
<td>50</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>2 to 1 &quot;   &quot;</td>
<td>6</td>
<td>16.1</td>
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<td>16.7</td>
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<td>16.7</td>
<td>3</td>
<td>50</td>
<td>50</td>
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</table>

Total No. 22 9 9 3
Total % of 42 62.4 21.9 19.1 7.1
the superior group; two, or 20 percent, in the normal; and five, or 50 percent, in the high frequency loss group. These ten cases represent 23.5 percent of the 42. (4) Six cases, or 14.4 percent of the 42, distribute themselves one each, or 16.7 percent of the six, into the superior, normal and high frequency loss group; while three, or 50 percent of the six, are found in the general loss group.

Summarising further, it may be said that, upon the basis of the findings of this study, if the discrimination test is administered under the classroom conditions described, the chances are (1) 100 percent that a case falling in the score range of 9 or less will have superior or normal hearing; (2) three to one that the score range 12 to 25 will indicate superior or normal hearing; (3) the chances are equal that the range 26 to 50 will indicate either normal or better hearing, or defective hearing; and (4) two to one that the score range 51 upward will indicate seriously defective hearing. These chance predictions are recorded in Table II.

3. Relationship between Classroom and Clinic Room Discrimination Test Scores. It was desirable as the next step in this study to determine the relationship between discrimination test scores made in the clinic room and those made in the classroom. Since it has been found that the clinic room scores bear a more direct relationship to audiograms, the proper method of determining the relationship between class and clinic room scores was concluded to be in determining the classroom scores of the cases which, upon a second testing, fell into the respective clinic room score ranges, 1 to 9, 10 to 14 and 15 upward. The classroom test scores which fell into these three clinic score ranges are shown in Table XXX. These are the classroom scores of the 42 subjects
### TABLE XII

Matching of Classroom and Clinic Room Discrimination Test Scores with Audiometer Ratings for 42 Cases

<table>
<thead>
<tr>
<th>Classroom Score Range</th>
<th>Total No.</th>
<th>In This Range</th>
<th>Classroom Scores Range</th>
<th>No.</th>
<th>%</th>
<th>No.</th>
<th>Score</th>
<th>Sup.</th>
<th>Mar.</th>
<th>H. Fr.</th>
<th>Loss</th>
<th>Gen. Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 to 9</td>
<td>18</td>
<td>18</td>
<td>100</td>
<td>1</td>
<td></td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>12 to 25</td>
<td>9</td>
<td>2</td>
<td>25</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25 to 50</td>
<td>10</td>
<td>3</td>
<td>30</td>
<td>1</td>
<td>6</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>51</td>
<td>8</td>
<td>2</td>
<td>33-3</td>
<td>4</td>
<td>7</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 to 9</td>
<td>13</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>12</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 to 25</td>
<td>6</td>
<td>6</td>
<td>75</td>
<td>1</td>
<td>18</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25 to 50</td>
<td>10</td>
<td>4</td>
<td>40</td>
<td>1</td>
<td>21</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>51</td>
<td>8</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>22</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 to 9</td>
<td>13</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>29</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td>12 to 25</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>35</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25 to 50</td>
<td>10</td>
<td>3</td>
<td>30</td>
<td>1</td>
<td>45</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>51</td>
<td>8</td>
<td>4</td>
<td>66-6</td>
<td>1</td>
<td>61</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 to 9</td>
<td>13</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>57</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 to 25</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>86</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25 to 50</td>
<td>10</td>
<td>3</td>
<td>30</td>
<td>1</td>
<td>95</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>51</td>
<td>8</td>
<td>4</td>
<td>66-6</td>
<td>1</td>
<td>100</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total No. | 23
% of 42 cases | 59.5
who had clinic and classroom discrimination tests and an audiometer test.

Of 42 classroom scores, 26, or 62.5 percent, fell into the clinic room range of from one to nine; ten, or 23.8 percent, fell into the clinic range of from ten to fourteen; and seven, or 16.6 percent, fell into the clinic range of from sixteen upward. Eighteen of the 42 cases made classroom scores of nine or less, and without exception these eighteen made scores of nine or less in the clinic room. Of eight cases making scores of from 12 to 25 in the classroom, 25 percent made clinic scores of nine or less, and 75 percent made clinic scores of 10 to 14. Of ten cases with classroom scores of from 26 to 50, 30 percent made clinic scores of nine or less; 40 percent made clinic scores of from 10 to 14; and 30 percent made clinic scores of 15 or more. Of six cases with classroom scores of 51 or more, 36 percent made clinic scores of nine or less; and 65.6 percent made clinic scores of 15 or more.

In terms of chances, and as based upon the findings of this study, the following statements are evident: (1) the chances are 100 percent that those subjects making discrimination test scores, or errors, of nine or less under conditions described for classroom testing, would make from one to nine errors under the conditions described for clinic room testing; (2) the chances are only two in eight that those making classroom scores of from 12 to 25 would make clinic room scores of from one to nine; six in eight that they would make clinic room scores of ten to fourteen; and zero chances in eight that they would make clinic room scores of sixteen or above; (3) the chances are only three in ten that those making classroom scores of from 26 to 50 would make clinic room scores of from one to nine; four in ten they would make clinic scores of from ten to fourteen, and three in ten they would make clinic scores of sixteen or more; (4) the
chances are one in three that an individual with a classroom score of 51 or more will make a clinic score of from one to nine; and two chances in three that he will make clinic scores of sixteen or more.

6. Discussion of Discrimination Test Scores and Audiometer Ratings.

As a test of hearing the speech sound discrimination test used in this study seems to have two fairly distinct values. It has one value as a classroom test for large groups and another for use in testing smaller groups in a relatively quiet room. In all probability the size of the room is insignificant provided the subjects are no more than three feet, the distance used in this study, from the tester. As shown by the previous discussion, if the test is given to small groups in a quiet room, the results are much more directly related to the results of audiometer testing. Whereas the classroom scores required division into four uncertain ranges, 4-9, 12-25, 26-50 and 51 upward, in order to show their relationship to audiometer results, clinic room scores fell readily into three clearly defined ranges, 1-9, 10-14 and 15 upward. Two of the three clinic room score ranges had no exceptions as to the hearing abilities they indicated. The range 1-9 indicated, without exception, superior or normal hearing. The middle range, 10-14, was definitely the borderline range since it divided itself almost equally among superior or normal cases, and cases with both mild and serious high frequency losses. The midpoint of this range, or 12 errors, is less than one point removed from the lower end of the third quartile, Q₃ 11.05, for 108 clinic scores. The range from 15 upward contained none but cases of high frequency and general hearing losses.

The classroom score ranges are less definite in their indication
of hearing ability. The only range without exception in its indications
was that of scores nine or less. Cases within this range were superior
or normal, without exception. The second range of 12 to 25, while made
up chiefly of superior and normal cases, had two, Cases 41 and 54, which
showed rather mild but definite losses in the high frequencies. The
third range of 26 to 30, with five cases superior or normal and five
cases defective, show itself as definitely the classroom borderline
as did the clinic borderline range of 10-14. The last classroom range
of from 31 upward is very indefinite in its prediction of hearing ability.
One subject (Case 31) in this range, with a score of 61, proved to have
normal hearing and one (Case 30) with a score of 76, proved to have
superior hearing. It might be possible to explain away these two cases.
It is possible that these subjects did not understand directions at the
first testing. It is possible that they set farthest from the experi-
menter during testing, or that they were very near noisy windows or
other of the various sources of distraction. The fact remains, however,
that in some cases classroom scores which from all appearances should
have indicated defective hearing, did not rightfully do so. Such "false"
indications not only occurred among high test scores, but among scores as
low as twelve. Case 41, with 12 errors, would reasonably have been ex-
pected to have at least normal hearing, and his clinic score would have
been expected to drop something near 40 to 50 percent lower; but his
clinic room score was also 12, and he proved to have a rather severe
high frequency loss. Such cases as this might be explained away on the
grounds that the subject probably sat very near the experimenter during
the classroom testing, or that he happened to be one of those farthest
removed from noisy windows or other sources of distraction which hampered many of the subjects. Such a procedure would be unsound, however. It is safer to agree that the test has its limitations. Had there been a more representative number of poor discriminatory cases, such exceptions as the scores 76 and 61 might have been overshadowed by a large number of similar scores which were not exceptions. More poor discriminatory cases were unavailable, however, and the result is that as the scores on this test increase above nine, the prediction of hearing ability becomes correspondingly less certain.

It appears that the discrimination test as a large group, classroom measure of hearing has its value, not as a means of discovering defective hearing, but rather as a means of eliminating cases with normal or superior hearing. This observation is based upon the fact that without exception, those cases making classroom scores of nine or less proved superior or normal on their audiometer ratings. However, the test can be of considerable value in mass hearing testing even if it is used only to eliminate those with good hearing. A vast majority of any group of individuals picked at random will have normal or better hearing. This test, in its ability to discover a great number of these at a first testing, can save time consuming administering of tests which require testing one individual at a time. In the present study, for example, it was possible to eliminate 90 of the 383 subjects, on the basis of scores of nine or less, at a first testing. At forty-five minutes per testing in groups of 25 or 30, the elimination of these 90 normal or better cases required approximately 12 hours of testing; which is exceedingly reasonable for that number of people. To say nothing of the time
that would have been required to test the whole group of 393 subjects, the time required for individual audiometer testing of the 90 subjects eliminated in 12 hours would have been approximately 40 to 45 hours. A thorough audiometer test for both ears over the eight frequencies usually tested, requires 20 to 30 minutes.

If it is desirable to discover only the seriously defective cases, that is, to eliminate along with the normal or superior cases, those with only mild loss, all subjects with classroom scores of from 12 to 25 also may be eliminated at the first testing. This observation is based upon the fact that in terms of the findings of this study, the chances are three to one that cases falling in the range 12 to 25 will have normal or better hearing, seven to one they will not have a high frequency loss, and the chances are 100 percent that they will not have serious, general losses. Upon this basis it would have been possible to eliminate 353 of the 393 subjects in the first test, in twelve hours of testing. The midpoint of the range 12 to 25, or 18.5, corresponds roughly with the lower end of the third quartile, 20, for 350 scores. Further time may be saved by this test in the search for seriously defective cases by testing those with classroom scores of 26 or above under conditions described for clinical room testing, and basing further elimination upon the derived clinical score predictions. Only relatively small groups can be tested under these conditions, but even then considerable time can be saved over that required for individual audiometer testing.

From the standpoint of economy of time, the only accurate and standardized device for mass hearing testing which seems to approach the discrimination test used in this study is the 6A Western Electric Audiometer.
Large groups can be tested by this device, but its cost is prohibitive in many places where there is a definite need for a mass testing device. It is probable that the Travis-Sachs speech sound discrimination test could be used for such a purpose, but it has not been thoroughly checked against an objective test. Whether the discrimination test used in this study may be used, either in classroom or under conditions prescribed for clinic room testing, to discover general or specific types of range deafness or both, will be discussed later.

5. Relationship between Acuity to Specific Frequency Ranges and Specific Errors in Discrimination. The determination of the relationship between acuity to the frequency ranges involved in the sounds of speech and specific errors in speech sound discrimination must be based upon three things: (1) consideration of individual audiograph curves with reference to their normality and their deviations above or below normal at the 25 frequencies; (2) consideration of the discrimination errors made by individuals whose audiograph curves deviated below normal at various of the 25 frequencies; and (3) considerations of the single sound errors, specific frequency losses and the frequencies said to be important in recognition of the single sounds.

Deferring for the present any reference to the frequency ranges, or bands, said to be characteristic of the sixteen consonants used in this study, an examination was made of the sound errors and the single audiograph curves of the 52 cases in the audiometer group. A comparative study was made of the number of single sound and pair errors made by the superior, the normal, the high frequency loss and the general loss groups. The figures derived are shown in Table XXII.
TABLE XXII

Single Sound and Sound Pair Discrimination
Errors Made by the Audiometer Group of 62

<table>
<thead>
<tr>
<th></th>
<th>Superior (28)</th>
<th>Normal (15)</th>
<th>High Freq. Loss (9)</th>
<th>General Loss (6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>S</td>
<td>M</td>
<td>S</td>
<td>M</td>
</tr>
<tr>
<td>Single Sound Errors</td>
<td>182</td>
<td>17.6</td>
<td>7.2</td>
<td>302</td>
</tr>
<tr>
<td></td>
<td>12.5</td>
<td>18.4</td>
<td>209</td>
<td>20.2</td>
</tr>
<tr>
<td></td>
<td>25.2</td>
<td>441</td>
<td>42.6</td>
<td>147</td>
</tr>
<tr>
<td>Pair Errors</td>
<td>118</td>
<td>18.2</td>
<td>4.7</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>8</td>
<td>129</td>
<td>20.2</td>
</tr>
<tr>
<td></td>
<td>14.2</td>
<td>266</td>
<td>42</td>
<td>88.6</td>
</tr>
</tbody>
</table>

The distribution of 1086 single sound errors among the four divisions were: superior group 182, or 17.6 percent, with a mean of 7.2; normal group 302, or 18.5 percent, with a mean of 13.4; high frequency loss group 209, or 20.2 percent, with a mean of 23.2; and general loss group 441, or 42.6 percent, with a mean of 147. The distribution of 652 sound pair errors were: superior group 118, or 18.2 percent, with a mean of 4.7; normal group 120, or 19 percent, with a mean of 8; high frequency loss group 129, or 20.2 percent, with a mean of 14.2; and general loss group 266, or 42 percent, with a mean of 88.6.

As has been the case in every instance where these groups have been studied individually, single sound and pair errors of each steadily increased from the superior through the general loss group. These findings further strengthen the indications that in terms of total errors, and within the bounds and limitations set forth in discussing the relationship of discrimination score ranges and audiometer rating, the speech sound discrimination test is a reliable test of hearing. This conclusion is based upon total discrimination errors and applies to general hearing ability. The next desirable step is to determine whether specific sound errors indicate hearing losses at any specific frequency range used in speech.
Again from the point of view of the four audiograph divisions, the specific single sound errors are presented in Table XXIII. This Table shows the errors each audiometer division made on the eight stop consonants, (p, t, k, g, b, d, j, d), and the eight fricative consonants, (f, v, s, z, f, s, z, j). In order to ascertain the average relative difficulty of these two groups of sounds, the number of errors made on each by the 52 subjects was tabulated. It was found that out of the total 1034 errors, 625, or 60.6 percent, were fricative and 389, or 37.6 percent, were stop consonant errors. In order to check upon this ratio, the same procedure was instituted on the single sound errors of the 36 cases used earlier to determine general errors in discrimination. It was found that out of 1670 errors, 1045, or 62.5 percent, were fricative and 625, or 37.5 percent, were stop consonant errors. It will be noted that the respective percentages were practically identical in the group of 52 and that of 36.

TABLE XXIII

<table>
<thead>
<tr>
<th></th>
<th>Superior Errors</th>
<th>Normal Errors</th>
<th>E. Resp. Loss Errors</th>
<th>General Loss Errors</th>
<th>Total Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. %</td>
<td>No. %</td>
<td>No. %</td>
<td>No. %</td>
<td>No. %</td>
</tr>
<tr>
<td>Fricatives</td>
<td>142 70</td>
<td>125 67</td>
<td>166 70</td>
<td>221 50</td>
<td>640 62</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>34</td>
<td>40</td>
<td>0</td>
<td>26</td>
</tr>
<tr>
<td>Steps</td>
<td>61 30</td>
<td>66 35</td>
<td>62 30</td>
<td>220 50</td>
<td>389 36</td>
</tr>
<tr>
<td>Totals</td>
<td>103</td>
<td>211</td>
<td>228</td>
<td>441</td>
<td></td>
</tr>
</tbody>
</table>

The difference of 25 percent between these respective percentages was assumed to indicate the average added difficulty of discriminating fricative consonants. It was assumed, further, that if a given frequency
range were of most importance for recognition or discrimination of either of these groups of sounds, that is, the fricatives and stops, a number of individuals with hearing losses at a given frequency should show a corresponding increase of errors in the sounds employing it. This should mean that discrimination errors made by a group with normal or better hearing would consist of approximately 25 percent more fricative than stop consonant errors. It is possible only to hazard a guess as to the number of fricative and stop errors the general loss group would make. Assuming, however, that the lower frequencies are as important for the stops as the higher frequencies are for the fricatives, these subjects with a general loss in both high and low frequencies but who still had hearing sufficient for reasonably good speech, also should make approximately 25 percent more errors on fricative sounds.

Observation of Table III reveals that these assumptions were not borne out by the findings of this study. The superior group made 40 percent and the normal 36 percent more fricative errors. The normal group's deviation of 9 percent above the 25 percent average added difficulty for fricatives might be considered insignificant, but the same hardly can be said of the 15 percent deviation of the superior group. Neither do the previous assumptions hold in the general hearing loss group. In distributing themselves equally among fricative and stop sounds, the errors show a 25 percent deviation below the average added difficulty of the fricatives.

As stated at the beginning of this study, Steinberg has pointed out

65. It will be recalled that according to Steinberg the range of greatest importance for the stops is 750 to 5000 cps, and for the fricatives above 2000 cps. (Steinberg, "Effect of Distortion," pp. 8, 12).
that the frequency region of from 750 to 5000 cps. is of greatest imp- 
portance for the stop consonants and that from 1000 to 8000 for the fri-
ctives.66 Fletcher states that the elimination of high frequencies by 
a low pass filter, which is equivalent to an individual's deafness to 
high frequencies, seriously affects the fricative sounds.67

Accepting these views, it should be expected that the sound errors 
of the high frequency loss group should show a considerable increase 
above the 25 percent difficulty for the fricative consonants. Here is 
found the only correspondence to the assumptions that given frequency 
losses should result in an increased number of errors in those sounds 
employing that frequency range. Table XXIII shows that the high frequency 
loss group had 40 percent more difficulty with the fricatives than with 
the stop consonants. This increase of 15 percent above the average of 
25 percent, however, loses its significance when it is recalled that the 
superior hearing group had exactly the same difficulty and the normal 
group only seven percent less difficulty with the fricatives.

A possible explanation of the unexpected deviations of these per-
centages is, first, that the keen auditory acuity of the superior group 
made less difficult their discrimination of stop consonants, and, second, 
the reduced acuity of the high frequency group made more difficult the 
discrimination of the fricatives. Third, it may be that the reverse ratio 
of errors in the general loss group, which made 25 percent fewer errors 
than expected on the fricatives, is due to increased difficulty in dis- 
criminating stop consonants by virtue of low frequency losses. This would 
involve an assumption that a loss in the high frequencies is of less

67. Fletcher, Speech and Hearing, p. 288.
importance in discriminating fricatives than a comparable low frequency
loss is in discrimination of the stop consonants. This is contrary to
West's statement that a loss from 2048 c/s upward has twice the negative
effect on hearing than does a comparable loss in the lower frequencies.68
It would appear that a hearing loss in the lower ranges is twice as
serious, at least for the stop consonants, than a loss in the higher
ranges, at least for the fricatives.

None of these explanations, however, accounts for the fact that
the fricative sounds were 40 percent more difficult for the normal group,
when they might have been expected to be only 25 percent more so. What-
ever explanations are offered here, it appears that the significance
attached to the higher frequencies for the recognition of the fricative
and stop consonants as separate groups of sounds is unwarranted. This
conclusion must stand as tentative, however, in view of the small number
of defective hearing cases, 12, and the large number of normal or better
cases, 60, upon which it is based.

In seeking the relationship between specific hearing losses and
specific errors in discrimination, the superior and normal groups are
automatically eliminated, since they had no appreciable hearing losses.
Cases 34, 35, 41 and 65 (Figures 93 to 96) in the high frequency loss
group, were also eliminated because their losses were not considered
serious enough to compare with the others. Accordingly, the single curve
audiographs of five cases in the high frequency loss group (Figures 97 to
101) and the three cases in the general loss group (Figures 102 to 104)
were studied. The study was based upon the sound errors of each case,

68. West et al., Rehabilitation, p. 307.
which are shown on the audiograph, and the errors that might have been predicted for him because of the importance of the frequencies at which he had losses. The most complete body of information at present concerning the frequencies of importance for the individual consonant sounds is probably that offered by Fletcher. 68 By the use of electrical by-pass filters he was able to eliminate certain frequencies from the various speech sounds as they were transmitted over a telephone system. The object was to determine the percentage of recognition of the sounds when given frequencies were absent from them. Table XXXIV shows a summary of the percentages of recognition when, by means of low pass filters, 70 the indicated frequencies were eliminated from the consonants.

The difficulty in using these percentages is that they are based, not upon mere reduced auditory acuity to the frequencies indicated, but upon complete elimination of the frequencies from a given point upward.

None of the cases used in this study had complete loss of hearing at any range of frequencies. 71 The use of Fletcher's percentages is especially uncertain in the three general loss cases, because the percentages are based also upon the assumption that all frequencies below a given point are present; or, they are based upon the assumption that an individual has at least normal hearing below the point in the frequency range where the loss begins. However, it may be possible to use the recognition per-

68. Fletcher, Speech and Hearing, pp. 270-289. (Irving B. Grindall also gives interesting information regarding the frequencies found in the consonants, but Fletcher's report is more suited to use in this study. For Grindall's report see "The Sounds of Speech," The Bell System Technical Journal, Vol. IV, pp. 586-626, October, 1925).

69. Low pass filters allow only certain low frequencies to be transmitted, or, they eliminate the passage of high frequencies; high pass filters to the contrary.

70. Steinberg and Gardner say that complete hearing loss for speech requires losses of from 65 to 85 decibels for the frequencies 125 to 512 c.p.s., from 85 to 95 decibels for the frequencies 512 to 4096, and from 65 to 85 for the frequencies 4096 to 8192. (John C. Steinberg and Mark B. Gardner, op. cit., p. 273).
TABLE XXIV
Percentage of Recognition* of the Consonants with the Indicated Frequencies Eliminated

<table>
<thead>
<tr>
<th>Frequencies Eliminated</th>
<th>Percent Recognition</th>
<th>Frequencies Eliminated</th>
<th>Percent Recognition</th>
<th>Frequencies Eliminated</th>
<th>Percent Recognition</th>
<th>Frequencies Eliminated</th>
<th>Percent Recognition</th>
</tr>
</thead>
<tbody>
<tr>
<td>(p)</td>
<td></td>
<td>(b)</td>
<td></td>
<td>(c)</td>
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</table>

*Fletcher, Speech and Hearing, pp. 175-289.
sentiages in making some calculations as to whether the eight cases in question made more or fewer errors than would have been expected con-
sidering their hearing losses.

The first procedure in this calculation was to determine a point on
each audiograph at which the most serious losses began. Determining this
point was simple on the five high frequency loss audiographs. The points
for these were as follows:

<table>
<thead>
<tr>
<th>Case</th>
<th>Figure</th>
<th>Loss Begins</th>
</tr>
</thead>
<tbody>
<tr>
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<td>4096</td>
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<tr>
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</table>

Determination of the proper points on the three general loss audiographs
was not so simple. However, they were set arbitrarily as follows:

<table>
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<th>Figure</th>
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<tr>
<td>52</td>
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</table>

The next part in the procedure involved two steps, (a) the assump-
tion that each case had a complete loss from the determined point upward,
and determination of the percentage of discrimination expected upon the
basis of Fletcher's recognition Table, XXIV; (b) determination of the
actual percentage of discrimination for each subject upon the basis of
39 occurrences for each consonant in the discrimination test, except for
(δ) and (ζ). This information on (δ) and (ζ), as given by Fletcher, was
not complete enough to allow their use here. The results of steps (a)
and (b) are recorded in Table XXIV.
### TABLE XXV

**Predicted Percentages of Discrimination**

Compared with Actual Discrimination Percentages

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<th>No. Other Losses</th>
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**Legend:**
- C: Cases
- N: Case No.
- F: Figure No.
- P: Predicted percentage of discrimination
- A: Actual

**Note:** The vertical percentage totals at the extreme right vary one to two percent from the bottom horizontal line totals because decimals were not carried. This variance was considered insignificant and vertical totals were used.
Despite the fact that the prediction percentages in Table XXIV are based upon complete absence of, or an individual’s complete insensitivity to, the frequencies from a given point upward, there is a striking similarity between the composite prediction percentage and the actual discrimination percentage made by the eight cases in this comparative study. It would have been expected, since each case had some hearing at all frequencies, that the group’s actual discrimination percentage would have been considerably higher than the predicted recognition percentage. The difference of 7 percent, however, between the predicted percentage of 82 and the actual discrimination of 69 percent, is comparatively small.

Considering the high frequency loss and the general loss groups as separate units, the respective predicted recognition and actual discrimination percentages were 68 against 96 percent and 70 against 77 percent. The difference here of 8 and 7 percent are likewise smaller than would have been expected.

Generally speaking, the same is true of individual case percentages. Among the five high frequency loss cases, four had differences of only 1 percent, all in favor of actual discrimination, and one (Case 49) had a difference of 2 percent in favor of the predicted percentage. Two of the general loss cases had differences of 4 and 6 percent, both in favor of the predicted percentage. Only the third general loss case (Case 52) had anything near the difference that would have been expected. His predicted recognition percentage was 45 percent, while his actual discrimination was 75 percent.

In finding so little general difference between Fletcher’s predicted percentages for an individual made completely insensitive to given frequencies, and the actual discrimination ability of one who has some hearing
at all frequencies, it might be argued that Fletcher's figures are too high, or that the two sets of percentages compared were based upon two different abilities. The more logical argument seems to be that Fletcher's cases, in being able to hear the frequencies below the point at which the higher frequencies were eliminated, suffered no added handicap in discriminating the consonants; and that the higher frequency loss group used in the present study, in suffering no acuity losses below the point at which their serious loss began, experienced no added difficulty. This argues, finally, that the higher frequencies are of little consequence in discrimination of the consonants, because approximately the same percentage of errors were made by both Fletcher's group and the high frequency loss group in this study.

Further, since the three general loss cases in this study made progressively smaller percentages of correct discrimination, depending upon the extension and the severity of their hearing losses into the lower frequencies, it appears that discrimination ability depends upon the distance to which the loss extends into the lower frequencies. Whatever the cause, the fact remains that there is considerable general similarity in the predicted sound recognition percentages based upon Fletcher's figures and the actual general discrimination percentages made individually and collectively by the eight cases used for the comparison in this study.

When the total individual sound percentages in Table XXV are studied the general similarity still exists. The greatest differences are found to be in the percentages for (s) and (z). The discrimination percentages of both were considerably higher than the predicted percentage for every case. This further confirms the earlier conclusion that the higher
frequencies are of less importance in (e) and (g) than has been assumed. While (e) and (f) were missed relatively often on the discrimination test, the percentage of correct discrimination for them was reasonably high. All but one of the eight cases made a much higher discrimination percentage than predicted on (e) and (f), and the collective correct discrimination on these sounds was 88 percent. This figure was 20 percent higher than the prediction of 68 percent. This seems to warrant the statement that (f) and (e) depend relatively little upon the higher frequencies for their distinguishing characteristics, but they are relatively difficult to discriminate generally. The percentage of individual errors on (v) was approximately the same as those on (e).

Of the five cases whose high frequency loss began as low as 3500, none made a significant number of errors on the sounds (p, t, k, tʃ, b, g) and (dʒ). All made 100 percent correct discrimination on (ʃ) and only one failed to make 100 percent on (d). The individual discrimination percentages on the fourteen sounds for the five cases with losses beginning at 3500 cps were 90, 96, 96, 96, and 80 percent. The three general loss cases made considerably more errors on the 14 sounds. These cannot be discussed in terms of high frequency losses, however, because such a discussion based upon Fletcher's percentage predictions assumes that hearing at the frequencies below a certain point is normal.

It would have been interesting had it been found in this study that specific frequency losses could be predicted on the basis of an individual's specific sound errors in discrimination. After a careful examination of the findings in Table XIV, it is seen that no such relationship exists. The most that can be said is that the lower the point along the
frequency range at which the loss occurs, the more numerous will be the
general, not the specific, errors in speech sound discrimination. The
discrimination test stands as a general hearing test, and not as a test
by which may be determined acuity to certain specific frequencies. The
most that can be said in this connection, as explained earlier in the
study, is that an extremely high number of discrimination errors is more
likely to indicate a general loss along the entire frequency range, the
middle range of small group scores, 10 to 14, may indicate superior,
normal or slightly deficient hearing, and the small group scores 16 to
21 may indicate either slight or serious losses from in the neighborhood
of 3000 cps. upward. It cannot be said on the basis of this study that
a given frequency loss, say at 4036 cps., can be indicated by excessive
errors on any one or more sounds used in the discrimination test; or
that any hearing loss, in a limited range, i.e., 4500-6000, etc., makes
any particular difference in the specific sounds missed on the discrimi-
nation test. Stating it still another way, it does not appear that
special types of hearing losses account for specific sound errors. It
can be said only that any type of deafness will account for general
errors in discrimination, the number depending upon the severity of the
deaflness.

A further conclusion of this section is that in terms of the per-
centage of correct discrimination made by the members of the high fre-
quency loss group in this experiment, the importance of the high fre-
quencies for the 16 sounds involved seems generally to be over-emphasized.
While it is true that the high frequency loss group made more errors than
these cases with no losses, the increase was extremely small in terms of
the possible number of errors on the discrimination test. It is of course possible that if these cases had had comparable losses in the lower frequencies and no losses in the higher frequencies, their discrimination errors might have remained the same, but this study yields no information on this point. There is no justification for concluding that the lower frequencies are entirely responsible for discrimination of the so-called high frequency sounds, but it can be said that the higher frequencies are not essential to their discrimination, and that a pure case of high frequency deafness can no longer be held of great significance in hearing for speech. Witnesses to this conclusion are Cases 34, 35, 41, 42, 45, 49, 47, 48 and 49 (Figures 93 to 101). These cases ranged from very mild to very severe cases of high frequency deafness, yet the highest number of discrimination errors out of a possible 512, was 21, or 6.7 percent. One of the most severe cases of high frequency deafness, Case 47 (Figure 101), missed only 5 percent of the 512.

On the other hand, the three cases showing more general losses show a different picture. If we set, somewhat arbitrarily, a loss of 20 or more decibels as the line of demarcation between a relatively mild hearing loss and a severe one, Case 50 (Figure 102) has mild losses at the frequencies 1024, 1536, 1792, 2048 to 3584 inclusively, and at 6656 and 8886. At all other frequencies his loss is 20 decibels or greater. His hearing is not normal at any frequencies, although it is nearly so at 2560 and 3072. This case was in error 23.4 percent of the time on the discrimination test. On the same basis Case 51 (Figure 103) has slightly better than normal hearing at 128 and 512, mild losses at 256 and 1024 to 1664 inclusively. All other frequencies show severe drops. This subject
was in error 22.9 percent of the time on the discrimination test. Case 52 (Figure 166), on the other hand, has losses that exceed 20 decibels at every frequency. He was in error 49 percent of the time on the discrimination test. On the basis of these three cases it would appear that:

1. A more general loss of hearing is required to produce any considerable percentage of error on the discrimination test. This is witnessed by the fact that the three cases with general hearing loss, Cases 50, 51 and 52 made errors of 71, 73 and 122; while the highest number of errors among the entire high frequency loss group was only 21.

2. The failure of discrimination is chiefly influenced by the amount of loss of hearing and the extent of the loss on the speech hearing range, particularly the extension of the loss toward the fundamental frequencies; witness Cases 50 and 51 as against Case 52.

3. Hearing losses that are comparable on the average yet quite different in general pattern may show about the same degree of failure in discrimination; witness Case 50 as against Case 61. It is regrettable that more cases showing severe general losses could not be found so that these tentative conclusions could be further substantiated.

A final conclusion of this section is that there probably is little need in the speech clinic for speech sound discrimination tests and other devices which are meant to discover certain types of range deafness, in the belief that they alone are responsible for failure to hear and develop normal speech. That is to say, a general discrimination test covering all sounds might be just as useful in discovering losses in hearing. This, however, is yet to be established.
6. Summary Analysis of Audimeter Testing. The findings of this section fall under the following headings:

1. General relationship between audimeter ratings and discrimination test scores made in the clinic room:

   a. Using the clinic room test scores of 52 cases, and the algebraic sum of their plus and minus audimeter ratings for the better ear on 20 frequencies, a correlation coefficient of .73 ±.06 was derived.

2. Specific relationship between individual audimeter ratings and individual discrimination test scores made in the clinic room:

   a. If the discrimination test used in this study is administered as described under clinic room conditions, the following predictions may be made upon the basis of present findings:

      (1) The chances are 100 percent that an individual making a clinic room score of from one to nine will have superior or normal hearing. Of 52 cases in this score range, 71.8 percent had superior hearing and 28.2 percent had normal hearing.

      (2) The chances are eight to five in favor of superior or normal hearing if an individual makes a clinic room score of from ten to fourteen errors. Of thirteen cases with scores within this range, 15.3 percent had superior, 46.1 percent and 38.5 percent defective hearing.

      (3) The chances are 100 percent that an individual
making a score of over sixteen errors will have defective
hearing. Of seven cases with scores of sixteen or more,
57.8 percent had serious high frequency losses and 42.2 per-
cent had serious general losses.

3. General relationship between audiometer ratings and dis-
 crimination test scores made in the classroom:

a. Using the classroom scores of 42 cases, and the algebraic
sum of their plus and minus ratings for the better ear on 28
frequencies, a correlation coefficient of .60 ± .06 was derived.

4. Specific relationship between individual audiometer ratings
and individual discrimination test scores made in the classroom:

a. If the discrimination test used in this study is adminis-
tered as described under classroom conditions, the following
predictions may be made upon the basis of the present findings:

(1) The chances are 100 percent that an individual making
a classroom score of nine or less errors will have superior
or normal hearing. Of eighteen cases with scores of nine
or less, 66.6 percent had superior hearing and 16.6 percent
had normal hearing.

(2) The chances are three to one in favor of superior or
normal hearing if an individual makes a classroom score of
from twelve to twenty-five. Of eight cases making scores
within this range, 57.6 percent had superior hearing, 37.5
percent had normal and 25 percent had definite but rather
mild high frequency losses.
(3) The chances are equal that an individual who makes a classroom score within the range 26 to 50 will have normal or better hearing, or that he will have defective hearing. Of ten cases in this range, 20 percent had superior hearing, 20 percent normal, and 50 percent had high frequency losses.

(4) The chances are two to one that an individual making a score of 51 or more will have seriously defective hearing. Of six cases with classroom scores of 51 or more, 16.7 percent had superior hearing, 16.7 percent had normal, 16.7 percent had a serious high frequency loss and 50 percent had serious general losses.

5. General relationship between discrimination test scores made in the clinic room and those made in the classroom

a. Using the classroom and clinic room discrimination test scores of the 57 subjects who had tests in both places, a correlation coefficient of .66 ± .04 was derived as the general relationship between classroom and clinic room scores. (See page 57 of this study.)

b. The classroom mean of 380 classroom scores was 29 percent more than that of the mean for 103 clinic room scores. (See page 59 of this study.)

6. Specific relationship between individual discrimination test scores made in the clinic room and individual scores made in the classroom

a. If the discrimination test is administered under the procedure described for classroom testing, the following
predictions, based upon the findings of this study, may be made:

(1) The chances are 100 percent that an individual making a classroom test score of nine or less would also make a clinic room score of nine or less. Every individual who made a score of nine or less in the classroom, made a score of nine or less in the clinic room.

(2) The chances are only two in eight that an individual making a score of from 12 to 25 in the classroom will make a score of nine or less in the clinic room, and the chances are three in four that he will make a score of 10 to 14 in the clinic room. Of eight cases making scores of 12 to 25 in the classroom, 25 percent made clinic scores of nine or less, and 75 percent made clinic scores of 10 to 14.

(3) The chances are only three in ten that an individual making a classroom score of 26 to 50 will make a clinic score of nine or less; four in ten that he will make a clinic score of from 10 to 14; and three in ten that he will make a clinic score of 16 errors or more. Of ten subjects with classroom scores of from 26 to 50, 30 percent made clinic scores of nine or less; 40 percent made clinic scores of from 10 to 14; and 30 percent made clinic scores of 16 or more errors.

(4) The chances are only one in two that an individual with a classroom score of 51 or more will make a clinic score of nine or less; zero that he will make a clinic score of 10 to 14; and three to two that he will make a clinic score of
10 errors or more. Of six cases with classroom scores of 51 or more, 50.3 percent made clinic scores of nine or less; and 68.6 percent made clinic scores of 16 or more.

7. The relationship between specific losses of hearing acuity as determined by the audiometer and specific errors in speech sound discrimination:

a. Further evidence is added to the earlier statement that the speech sound discrimination test is closely related to hearing ability. Of the total single sound errors made by the 82 members of the audiometer group, the superior division made 17.6 percent, the normal 19.6 percent, the high frequency loss division 20.2 percent, and the general loss division 42.6 percent. Of the total sound pair errors, the superior division made 18.6 percent, the normal 19 percent, the high frequency loss division 20.2 percent and the general loss division 42 percent.

b. There seems to be no direct relationship between errors on the stop and fricative consonants as two separate units and acuity to the respective frequency bands said to be most important for their recognition. A group of cases with superior hearing throughout the speech frequency range made the same percentage of errors on stop consonants and on fricative consonants, respectively, as did a group of cases with high frequency deafness.

c. Neither mild nor severe cases of high frequency deafness can account for any very great deficiency in discriminating the sixteen consonants said to depend largely upon the
frequencies 2000, or thereabout, upward, for their recognition. In nine cases with high frequency losses, ranging from mild to very severe, the highest number of discrimination errors was 21, or 6.7 percent, out of a possible 312. In other words, this case discriminated correctly 93 percent of the time. The most severe case of high frequency deafness used in this study made only 17 errors, or 5 percent, out of a possible 312. His discrimination was 95 percent correct.
Part IV
SUMMARY AND CONCLUSIONS

As conclusions reasonably well substantiated by the findings of this study:

1. The general relationship between clinic and classroom discrimination test scores is represented by a correlation coefficient of .62 \( \pm .06 \). However, all individuals making scores of nine or less in classroom made scores of nine or less in the clinic room.

2. It is approximately one-third more difficult to discriminate between two sounds which are different, than it is to determine that two sounds are the same.

3. The six sounds occurring most often in "Same" pair errors accounted for over fifty percent of the "Same" errors. These six sounds in the order of least to greatest number of occurrences were \( (b, d, f, v, k) \) and \( (\theta) \).

4. The eleven most often missed "Different" pairs accounted for forty percent of the "Different" errors. These eleven pairs, in the order of least to greatest number of errors are as follows: \( (af=as) \), \( e=\bar{e} \), \( a\bar{e}=\bar{a} \), \( a=\bar{a} \), \( av=\bar{a} \), \( \theta=\bar{\theta} \), \( af=\theta \), \( \theta=\bar{\theta} \), \( af=\bar{a} \) and \( (af=\theta) \).

5. In both "Same" and "Different" sound pairs the difficulty of the sixteen segments, in terms of least to greatest number of occurrences in errors was as follows: \( (s, t, f, d, j, s, a, p, e, t, d, 3, b, k, \delta, v, f) \) and \( (\theta) \).

72. Of equal difficulty.
73. Of equal difficulty.
6. With reference to the combined elements of consonant position and voice, least to greatest number of errors fell as follows: (1) initial voiced consonants, (2) medial voiced, (3) medial voiceless, (4) initial voiceless, (5) final voiced, and (6) final voiceless. With reference to the element of voicing alone, the voiceless consonants were missed only slightly more often than voiced. In terms of consonant position alone, those sound pairs with finally placed consonants were missed most often, while those with initially and medially placed consonants were missed an almost identical number of times.

7. Contrary to former opinion, combinations made up of stop-fricative sounds are relatively difficult to discriminate. Considering the proportionate number of times each occurred in the test, fricative-fricative combinations were missed only 29 percent more often than stop-fricatives, and the latter were missed 6 percent more often than stop-stop combinations.

8. There is a reasonably high degree of correlation between scores made on the speech sound discrimination test constructed for this study and ratings made on a 68 Western Electric audiometer. The coefficient of correlation between audiometer ratings and clinic room discrimination scores was .73 ± .04.

9. As a mass hearing testing device the discrimination test is reliable and economical of time in determining a large percentage of those whose hearing is normal or above. One hundred percent of the cases in this study who made classroom scores of nine or less in the classroom, also made scores of nine or less in the clinic room; and 100 percent of the 32 cases making clinic room scores of
nine or less had either superior or normal audiometer ratings. Out of eight cases with classroom scores of 12 to 25, 75 percent had normal or superior hearing and 25 percent had very mild cases of high frequency losses.

10. There seems to be no direct relationship between hearing losses at specific frequencies of the speech range and difficulty in discriminating specifically any one or more of the sixteen consonants used in this study. The most that can be said is that the more extensive the hearing loss along the frequency range, the greater the percentage of errors among all the sounds.

11. Neither mild nor severe losses in the frequencies 3000 c.p.s. upward, alone, account for any appreciable difficulty in discriminating these sixteen consonants. Difficulty in discriminating these sounds seems to depend, not upon a given segment of the range at which there are losses, but the length of the range at which an individual has rather severe losses. The farther a general loss in hearing extends into the lower frequencies, the more difficult discrimination will become. The lowest correct discrimination among the high frequency loss group used in this study was 93 percent. The most severe case of high frequency deafness discriminated correctly 95 percent of the time. This conclusion is further borne out by the close similarity in the percentage of errors made by Fletcher's group when certain frequencies were filtered out of the consonants, and the percentage made by the group in this study who had deafness at the same frequencies.
Conclusions To Be Drawn Tentatively. Pending Further Investigation:

1. Clinic room discrimination test scores falling within the range of sixteen errors or above indicate defective hearing. One hundred percent of seven cases whose scores were sixteen or above had defective hearing as determined by the audiometer. Seven cases, however, are a relatively small number upon which to derive conclusive evidence.

2. The chances are two to one that an individual with a classroom discrimination score of 51 or above will have defective hearing. This conclusion is based upon the relatively small number of six cases.

3. Normal or above hearing ability and defective hearing ability seem to bear no direct relationship to the ability to discriminate fricative and stop consonants as two separate units. In view of the small number of 12 cases with hearing losses against the number of 40 cases with normal or better hearing, this conclusion must be tentative.

The speech sound discrimination test constructed for this study can be of value for mass hearing testing if administered under the procedure prescribed. It has its value, however, not as a direct means of discovering cases of defective hearing, but as a means of eliminating from any group a great majority of the individuals whose hearing is normal or better. This observation is reasonable in view of the fact that all individuals making discrimination errors of nine or less, had normal or better hearing as determined by the 65 audiometer. Certain other score,
or error, ranges above mine may be of limited value as described in the
summary analysis of audiometer testing.

The test can serve as a general hearing test, only. It cannot be
used as a means of determining acuity losses in any specific sound
frequency range. While the sixteen sounds used in the test are com-
monly designated as "high frequency" sounds, there seems to be no justifi-
cation for such a reference. Contrary to rather common opinion, the
findings here indicate that either mild or severe high frequency hearing
losses do little, if anything, to impair hearing for these sounds. It
seems altogether reasonable to say that, merely because the consonants
are known to employ some of the higher frequencies, some writers have
been led to place, without experimental evidence, too much emphasis
upon their importance as distinguishing characteristics of these con-
sonants.

Impairment of the ability to discriminate these sounds seems to
depend, not upon losses at a given segment of the frequency range, but
upon the length of the range at which an individual has rather severe
losses. General hearing losses must penetrate the lower frequencies
before severe impairment appears. It would have been desirable to have
had subjects with losses in the lower frequency range, only. It then
would have been possible to determine whether lower frequencies alone
had more impairing effects in discrimination than high frequency losses.
No such cases were available for this experiment, however, as were cases
with pure high frequency losses. No statement can be made, therefore, as
to the independent value of the low frequencies in discrimination; but
it can be said rather conclusively that there is little or no clinical value in the practice of devising consonant discrimination tests for the purpose of discovering cases of high frequency deafness.
Audiometer Rating: -550  R: 1  Case 20
Discrimination Errors: 6  R: 20.5

Sound Errors
p -  b -
t -  d -
k -  g -
f -  v - 2
s -  z - 1
θ -  ρ -
ʃ -  dʒ -

Right ear — Intensity Steps in Decibels
Left ear ——— Figure 1
Audiometer Rating: -340

Discrimination Errors: 2

Case 2

Right ear — Intensity Steps in Decibels
Left ear —

Figure 2
Audiometer Rating: -333  R: 5
Discrimination Errors: 8  R: 10

Case 7

Sound Errors:

Right ear Intensity Steps in Decibels
Left ear

Figure 3
Audiometer Rating: -328  R: 4
Discrimination Errors: 2  R: 4

Right ear——— Intensity Steps in Decibels
Left ear———  Figure 4

Sound Errors
p -  b -
t -  d - l
g -  v -
f -  s -
0 -  t -

Audiometer Rating: -309  R: 5.5  
Discrimination Errors: -5 R: 10

Case 8

Figure 5
Frequency Range

Right ear
Intensity Steps in Decibels

Left ear

Figure 6
Audiometer Rating: -305
Discrimination Errors: 2

Case 4

Right ear —— Intensity Steps in Decibels
Left ear ——

Figure 7
Audiometer Rating: -285  R: 9
Discrimination Errors: 4  R: 16.5

Sound Errors
p - b - 1
t - d - 1
k - e -
f - 2  v - 1
s - z -
0 - 2
f -

Right ear——— Intensity Steps in Decibels
Left ear—-—

Figure 9
Audiometer Rating: -283  R: 10
Discrimination Errors: 6  R: 24.5  Case 22

Sound Errors
- p - b -
- t - d - 1
- k - g -
- f - 2  v - 2
- s - z -
- c - 2  j - 4
- t/ -  d -

Right ear—— Intensity Steps in Decibels
Left ear——

Figure 10
Figure 11

Sound Errors

Right ear — Intensity Steps in Decibels
Left ear —

Right ear
Left ear

Audiometer Rating: -282
Discrimination Errors: 5
R: 11
R: 20.5
Case 21
Audiometer Rating: -281  R: 12
Discrimination Errors: 2  R: 4

Case 5

Figure 12
Audiometer Rating: -280  R: 13
Case 28

Discrimination Errors:
R: 13
R: 28.5

Sound Errors

Right ear  Intensity Steps in Decibels
Left ear  ---

Figure 13
Audiometer Rating: -278
Discrimination Errors: 4
R: 14
R: 16.5

Case 16

Right ear — Intensity Steps in Decibels
Left ear —

Figure 14
Audiometer Rating: -274  R: 15
Discrimination Errors: 4  R: 16.5

Case 17

Right ear ——— Intensity Steps in Decibels
Left ear ———

Figure 15
Audiometer Rating: -265  R: 16
Discrimination Errors 4  R: 16.5

Case 18

Right ear ————  Intensity Steps in Decibels
Left ear ————  Figure 16
Audiometer Rating: -282  R: 17
Discrimination Errors: 6  R: 24.5
Case 23

Figures 17

Right ear  Intensity Steps in Decibels
Left ear  

Sound Errors
p - l  b -
t - d -
k - l  g -
f - 3  v -
s - z - 1
0 - 4  j -
1/ - z -
R: 24.5
Frequency Range

Audiometer Rating: -255  R: 18
Discrimination Errors 9  R: 31
Case 30

Sound Errors

\[
\begin{align*}
\text{p} & \quad \text{b} \\
\text{t} & \quad \text{d} - 1 \\
\text{k} & \quad \text{g} \\
\text{f} & \quad \text{v} - 2 \\
\text{s} & \quad \text{z} \\
\text{z} & \quad \text{z} - 2 \\
\text{f} & \quad \text{z} - 1 \\
\text{t} & \quad \text{d} = -1
\end{align*}
\]

Figure 18
Audiometer Rating: -247

Discrimination Errors: 12

Right ear: Intensity Steps in Decibels

Left ear: --

Figure 19
Audiometer Rating: -242  R: 20
Discrimination Errors: 11  R: 36.5

Sound Errors

p - b - 2
p - d -
k - 1  e -
f - 3  v - 3
s - 2  z - 3
0 - 5  θ - 1
θ - 1  θ -
θ - 1
θ -

Right ear ---  Intensity Steps in Decibels
Left ear ---

Figure 20
Frequency Range

Audiometer Rating: -238  R: 21
Discrimination Errors: 3  R: 10

Case 10

Right ear  Intensity Steps in Decibels
Left ear

Figure 21
Frequency Range

Audiometer Rating: -222 R: 22.5
Discrimination Errors: 6
R: 24.5
Case 24

Right ear — Intensity Steps in Decibels
Left ear —

Figure 23
Audiometer Rating: -215  
R: 24  
Discrimination Errors: 6  
R: 24.5  
Case 25

Right ear  Intensity Steps in Decibels  
Left ear

Figure 24
Audiometer Rating: -211  R: 25
Discrimination Errors: 2  R: 4

Case 6

Right ear - - - Intensity Steps in Decibels
Left ear - - -

Figure 25
Audiometer Rating: -201
Discrimination Errors: 9
Case 31

Sound Errors
- p
- t 1
- k
- f 3
- s
- 0 3
- s 2
- t 3
d2 - 1

Right ear  Intensity Steps in Decibels
Left ear  

Figure 26
Audiometer Rating: -187  
Discrimination Errors: 11  
Case 37

Right ear  ---  Intensity Steps in Decibels  
Left ear  -----  

Figure 28
Audiometer Rating: -183  R: 28.5
Discrimination Errors:

Case 1

Right ear ---  Intensity Steps in Decibels
Left ear ---

Figure 28
Audiometer Rating: -183
Discrimination Errors: 28.5

Right ear ___ Intensity Steps in Decibels
Left ear ______

Figure 29
Right ear: Intensity Steps in Decibels
Left ear: Figure 30

Frequency Range

<p>| | | | | | | | | | | | | |</p>
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Sound Errors

- p - 1
- t - 2
- k - 1
- f - 1
- s -
- 0 - 1
- / -
- dz - 1

Audiometer Rating: -168
Discrimination Errors: 10
R: 30
R: 34
Case 33

Figure 30
Audiograph Rating: -165  R: 31
Discrimination Errors: 6  R: 24.5

Sound Errors
p - 1  b -
t - 1  d -
k -  g -
f - 2  v - 2
s -  z -
0 - 3  3 - 2
f -  dz -

Right ear  Intensity Steps in Decibels
Left ear  

Figure 31
Audiometer Rating: -155  R: 32  Discrimination Errors: 6  R: 24.5  Case 27

Right ear  Intensity Steps in Decibels
Left ear  Figure 32
Audiometer Rating: -150 R: 33
Discrimination Errors: 12 R: 40 Case 39

Right ear Intensity Steps in Decibels
Left ear

Figure 33
Audiometer Rating: -137  R: 34
Discrimination Errors: 3  R: 10

Case 12

Right ear --- Intensity Steps in Decibels
Left ear ---

Figure 34
Audiograph Rating: -106  R: 35
Discrimination Errors: 13  R: 43

Case 43

Sound Errors
p - 1  b - 1
t - 1  d - 3
k - 1  g -
f - 3  v - 3
s - 3  z - 1
O - 3  j' - 4
/ - 1  z - 2
\ - 1  d - 2

Right ear  ---  Intensity Steps in Decibels
Left ear  ---

Figure 35
Frequency Range

Audiometer Rating: -78 R: 36
Discrimination Errors: 12 R: 40

Case 40

Right ear—— Intensity Steps in Decibels
Left ear——

Figure 36
Audiometer Rating: +30

Discrimination Errors: 3

Case 13

Right ear ——— Intensity Steps in Decibels
Left ear ———

Figure 37
Audiometer Rating: +45
R: 40
Discrimination Errors: 7
R: 28.5
Case 29

Right ear —— Intensity Steps in Decibels
Left ear ——

Figure 38
Figure 41
Audiometer Rating: 466
Discrimination Errors: 12
Case 41

Right ear
Intensity Steps in Decibels
Left ear

Figure 42
Frequency Range

Audiometer Rating: +110  R: 44
Discrimination Errors: -10  R: 34

Case 35

Right ear ——— Intensity Steps in Decibels
Left ear ——— Figure 44
Audiometer Rating: +266  R: 45
Discrimination Errors: 12  R: 40
Case 42

Sound Errors
p -  b - 2
k - 1  g -
f - 4  v - 5
s -  z - 1
O - 3  j - 5
c -  g -
t / - 1  dz -

Right ear  Intensity Steps in Decibels
Left ear  Figure 45
Frequency Range

Audiometer Rating: +387

Discrimination Errors: 21

Sound Errors

- p -
- t - 3
- k - 2
- f - 4
- s - 4
- o - 4
- j - 6
- z - 3
- t - 2
- dz - 1

Right ear ——— Intensity Steps in Decibels
Left ear ——— Figure 46
Audiometer Rating: 426
Discrimination Errors: 14

Right ear Intensity Steps in Decibels
Left ear

Figure 47
Frequency Range

[Graph showing frequency range with specific values for Right ear and Left ear intensity steps in Decibels]

Right ear ——— Intensity Steps in Decibels

Left ear ———

Figure 49

Case 47
Audiometer Rating: 616 R: 49
Discrimination Errors: 71 R: 50

Case 50

Sound Errors

p - 5 b - 13
t - 5 d - 7
k - 10 g - 11
f - 3 v - 12
s - 3 z - 4
  10 y - 10
  4 z - 3
t - 2 dz - 2

Right ear _____ Intensity Steps in Decibels
Left ear _____

Figure 50
Audiometer Rating: +857  R: 51
Discrimination Errors: 73  R: 51

Sound Errors

R = 8  b = 5
T = 8  d = 5
K = 9  g = 8
F = 8  v = 8
S = 8  z = 7
O = 11  j = 12
E = 10  z = 8
Y = 8  dz = 5

Right ear___  Intensity Steps in Decibels
Left ear_____

Figure 51
Audiometer Rating: 1079  R: 52
Discrimination Errors: 222  R: 52

Case 52

Sound Errors

p - 15  b - 14
a - 17  c - 13
k - 15  g - 14
f - 14  v - 14
s - 10  z - 10
o - 15  - 13
j - 8  - 16
t - 12  dz - 9

Intensity Steps in Decibels

Right ear --- Left ear ----

Figure 52
Audiometer Rating: -340  R: 2
Discrimination Errors 2  R: 4

Case 2

Sound Errors

Right ear  Intensity Steps in Decibels
Left ear  Better ear *

Figure 54
Frequency Range

Audiometer Rating: -328
Discrimination Errors: 2

Right ear

Left ear

Better ear *

Intensity Steps in Decibels

Sound Errors

Figure 56
Right ear  ---  Intensity Steps in Decibels
Left ear  - - - - - - Figure 57
Better ear *
Audiometer Rating: -309  R: 5.5
Discrimination Errors: $  R: 10  Case 9

Right ear  Intensity Steps in Decibels
Left ear
Better ear *  Figure 58
Audiometer Rating: -305
Discrimination Errors: 2
Right ear: Intensity Steps in Decibels
Left ear: Figure 59
Figure 60

Right ear

Intensity Steps in Decibels

Left ear

Better ear *

Audiometer Rating: -289

Discrimination Errors 4

R: 8

R: 16.5

Case 14
Audiometer Rating: -285 Rs 9
Discrimination Errors: 4 Rs 16.5
Case 15

Sound Errors
p - b - 1
t - d - 1
k - g -
f - 2 v - 1
s - z -
O - 2 \( \ddot{e} \) -
\( t/ \) - dz -

Right ear - - - Intensity Steps in Decibels
Left ear - - -
Better ear * Figure 61
Audiometer Rating: -285 R: 10
Discrimination Errors: 6 R: 24.5 Case 22

Sound Errors
p - b -
t - d - 1
k - g -
f - 2 v - 2
s - z -
o - 2 q - 4
I - dz -

Right ear.
Left ear.
Better ear *

Figure 62
AUDIOMETER RATING: -282

DISCRIMINATION ERRORS: S
R: 11
R: 20.5

Case 21

Sound Errors
p - b -
t - d -
k - 2 e -
f - 2 v -
s - 1 z -
o - 1 c -
t - 2 d -

Right ear — Intensity Steps in Decibels
Left ear —
Better ear *

Figure 63
Audiometer Rating: -280  R: 13
Discrimination Errors: 7  R: 28.5
Case 28

Sound Errors
p -  b -
t - 1  d -
K -  e -
f - 2  v - 1
s -  z -
O - 3  ã - 1
حرف -  ã -
f/ -  ã - 1

tight ear ___ j & f
tight ear ___
In ten sity Steps in Decibels

Figure 65
Audiometer Rating: -274  R: 15
Discrimination Errors: 4  R: 16.5
Case 17

Sound Errors:

Right ear —  Intensity Steps in Decibels
Left ear —
Better ear *

Figure 67
Audiometer Rating: -265  R: 16
Discrimination Errors: 4  R: 16.5

Right ear ——— Intensity Steps in Decibels
Left ear ——— Figure 68
Better ear *

Sound Errors
p — b —
t — d —
k — g —
f — 1 —
s — 3 —
q — z —
[t] — d2 —
Audiometer Rating: -262  R: 17
Discrimination Errors 6  R: 24.5

Case 23

Sound Errors
p - l   b -
t - d -
k - l   g -
f - 3   v -
s - z - 1
O - 4   S -
\( \text{fr} \) - dz -

Right ear _____  Intensity Steps in Decibels
Left ear  ____  Better ear *

Figure 69
Audiometer Rating: -255

Discrimination Errors: 

R: 18  
R: 31  

Case 30

Sound Errors

p -  b -
t -  d - 1
k - 1  e -
f - 1  v - 2
s -  z -
ß -  z - 2
ß -  z - 1
t - 1  ß -  1

Right ear  Intensity Steps in Decibels
Left ear
Better ear *

Figure 70
Audiometer Rating: -247  R: 19  Discrimination Errors 12  R: 40  Case 38

Frequency Range

Sound Errors
- p - 2
- t - 1
- k - 1
- f - 2
- s - 1
- 0 - 2
- f - 1
- d - 1

Right ear ——— Intensity Steps in Decibels
Left ear ——— Figure 71
Better ear *

Figure 71
Audiometer Rating: -238  R: 21
Discrimination Errors: 3  R: 10

Case 10

Sound Errors
p - b -
t - d -
k - g - 1
f - v - 1
s - z -
q -
ʃ - 1
z -
tʃ - dʒ -

Right ear ——— Intensity Steps in Decibels
Left ear ———
Better ear *

Figure 73
Frequency Range

Audiometer Rating: -222  R: 22.5
Discrimination Errors: 6  R: 24.5

Sound Errors

Right ear —— Intensity Stops in Decibels
Left ear ——*
Better ear *

Figure 75
Audiometer Rating: -215  R: 24
Discrimination Errors 6  R: 24.5

Frequency Range

Right ear — Intensity Stairs in Decibels
Left ear —
Better ear *

Sound Errors
p — b —
t — d — 1
k — g — 1
f — 3 — v — 1
s — z —
0 — 3 — z — 1
s — dz —

Figure 76
Audiometer Rating: \(-211\)  R: 25

Discrimination Errors: \(\hat{2}\)  R: 4

Case 6

Frequency Range

Right ear —— Intensity Steps in Decibels
Left ear —— Better ear *

Sound Errors

- \(p\) - \(b\)
- \(t\) - \(d\)
- \(k\) - \(g\)
- \(f\) - \(v\)
- \(s\) - \(z\)
- \(\mathfrak{f}\) - \(\mathfrak{g}\)
- \(\mathfrak{t}\) - \(\mathfrak{d}\)

Figure 77
Frequency Range

Audiometer Rating: -187  R: 27

Discrimination Errors: 11  R: 36.5

Right ear  -  Intensity Steps in Decibels
Left ear  -  Figure 79
Better ear *
Audiometer Rating: -183  R: 28.5
Discrimination Errors: 1  R: 1

Case 1

Figure 80
Audiometer Rating: -183  R: 28.5
Discrimination Errors: 9  R: 31  Case 32

Sound Errors
p -  b - 1
pt -  d - 1
k -  e - 1
f -  v - 1
s -  z -
\theta -  \theta - 1
\iota -  \iota - 1

case

Right ear  Intensity Steps in Decibels
Left ear  ---
Better ear *  Figure 81
Audiometer Rating: -168  R: 30
Discrimination Errors 10  R: 34
Case 33

Sound Errors
p - 1  b -
t - 2  d -
k - 1  e -
f - 1  v - 1
s -  z - 2
O - 1  j - 1
f/ -  s -

Right ear --- Intensity Steps in Decibels
Left ear ----
Better ear *
Figure 82
Audiometer Rating: -165 R: 31
Discrimination Errors: 6 R: 24.5

Case 26

Right ear --- Intensity Steps in Decibels
Left ear ------- Figure 83
Better ear *
Audiometer Rating: -155  R: 32
Discrimination Errors: 6  R: 24.5

Case 27

Sound Errors
p  b
|    |
| t  d
| k  e
| f  v
| s  z
| o  æ
|  æ
| tʃ  ð

Right ear    Intensity Steps in Decibels
Left ear     Figure 84
Better ear   211
AUDIOPHOTOGRAPH

Audiometer Rating: -150  R: 33
Discrimination Errors: -12  R: 40
Case 39

Sound Errors
p -  b -
t -  d -
k - 1  g - 4
f - 3  v - 4
s -  z -
ø - 3  å - 5
t -  dz - 1

Right ear — Intensity Steps in Decibels
Left ear —— —— Figure 85
Better ear *
Audiometer Rating: -137  R: 34
Discrimination Errors: 3  R: 10

Case 12

Figure 86
Audiometer Rating: +30 R: 39

Discrimination Errors: 3 R: 10 Case 13

Right ear—— Intensity Steps in Decibels
Left ear ———— Figure 89
Better ear *
Audiometer Rating: 443  R: 40
Discrimination Errors 7  R: 28.5
Case 29

Sound Errors
- p - 1  b - 1
- t -  d -
- k -  e -
- f -  v - 1
- s -  z - 1
- 0 - 3  j -
- f - 1  t -
- f - 1  d3 -

Right ear —— Intensity Steps in Decibels
Left ear —— Figure 90
Better ear *
Audiometer Rating: 473  R: 42
Discrimination Errors: 4  R: 16.5

Case 19

Sound Errors
- p - b -
- t - d - 1
- k - g - 1
- f - 2 v - 1
- s - z -
- θ - 2 θ - 1
- s' - θ - db -

Right ear
Intensity Steps in Decibels
Left ear
Better ear *

Figure 91
Audiometer Rating: -32 R: 37
Discrimination Errors: 14 R: 44.5

Sound Errors
- p - 1
- t - 1 d - 2
- k - 1 s - 2
- f - 3 q - 3
- s - 3

Right ear — Intensity Steps in Decibels

Left ear — Figure 92
Better ear *
Figure 94

Audiometer Rating: +66  R: 41
Discrimination Errors: 12  R: 40  Case 41

Sound Errors

- Intensity Steps in Decibels

Right ear ———
Left ear ———
Better ear *

Frequency Range
Audiometer Rating: +88  R: 43
Discrimination Errors: 10  R: 34
Case 34

Sound Errors
- p - 2  b -
- t - 2  d -
- k - 2  g - 2
- f - 2  v - 1
- s -  z -
- o - 3  s - 1
- z - 2
- t -  d -

Right ear ——— Intensity Steps in Decibels
Left ear ———
Better ear  *

Figure 95
**Frequency Range**

Audiometer Rating: +110
Discrimination Errors: 10
R: 44
R: 34

**Case 35**

**Sound Errors**

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Right ear ----- Intensity Steps in Decibels
Left ear -------
Better ear * Figure 96
Figure 98
Audiometer Rating: 4426
Discrimination Errors: 14

Right ear — Intensity Steps in Decibels
Left ear —
Better ear *

Figure 99
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Right ear ___ Intensity Steps in Decibels
Left ear _____ Figure 100
Better ear *
Audiometer Rating: +659  R: 50
Discrimination Errors: 16  R: 46.5
Case 47

Sound Errors

Right ear
Intensity Steps in Decibels

Left ear

Better ear *

Figure 101
Frequency Range

Audiometer Rating: 486
Discrimination Errors: 71 R: 50

Case 50

Sound Errors

Right ear:  Intensity Steps in Decibels
Left ear:   Better ear *

Figure 102
AUDIOMETER RATING: +857
R: 51
DISCRIMINATION ERRORS: 73
R: 51
Case 51

In ten sity Steps in Decibels

Sound Errors
p - 8  b - 5
t - 8  d - 5
k - 9  g - 8
f - 8  v - 8
s - 8  z - 7
0 -11  j -12
f -10  z - 8
t -8  d - 5

Right ear
Left ear
Better ear

Figure 103
Frequency Range

Audiometer Rating: +1079 R: 52
Discrimination Errors 122 R: 52

Case 52

Right ear    Intensity Steps in Decibels
Left ear  
Better ear *

Figure 104
BIBLIOGRAPHY

Books


Letters


Periodical Articles


Periodical Articles (Cont'd)


Unpublished Paper

BIOGRAPHY

Robert Newcomb Flummer was born in Joplin, Missouri, June 28, 1906. He was graduated from the Lincoln, Nebraska High School in 1925 and from Oklahoma Agricultural and Mechanical College, with a B.S. Degree, in 1928. After receiving the Master's Degree from George Peabody College for Teachers in 1936, he spent the academic year 1936-37 teaching at Linsly Institute, a private military school in Wheeling, West Virginia. The following summer, of 1937, was spent in attendance in the School of Speech at Northwestern University, and at the beginning of the academic year of 1937-38 he entered the Department of Speech at Louisiana State University as a teaching fellow. With the exception of the summer session of 1939, which he spent in the Medical School of the University of Wisconsin, he has continued his work at Louisiana State University as a candidate for the Degree of Doctor of Philosophy.
EXAMINATION AND THESIS REPORT

Candidate: Robert Newcomb Plummer

Major Field: Speech

Title of Thesis: Comparison of Auditory Acuity to Pure Tones and the Ability To Discriminate Between Sixteen English Consonants

Approved:

Claude E. Kantner
Major Professor and Chairman

Dean of the Graduate School

EXAMINING COMMITTEE:

Date of Examination:

May 7, 1940