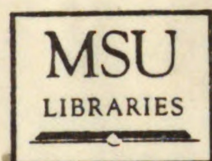


THE INTELLIGIBILITY OF
PHONETICALLY BALANCED LISTS OF
CNC WORDS IN WHITE NOISE
AND SPEECH BABBLE

Thesis for the Degree of M. A.
MICHIGAN STATE UNIVERSITY
Dianne R. Vertes
1968



RETURNING MATERIALS:

Place in book drop to
remove this checkout from
your record. FINES will
be charged if book is
returned after the date
stamped below.

--	--	--

ABSTRACT

THE INTELLIGIBILITY OF PHONETICALLY BALANCED LISTS OF CNC WORDS IN WHITE NOISE AND SPEECH BABBLE

By

Dianna R. Vertes

The major purpose of this study was to obtain normative data on the speech discrimination ability of young normal hearing adults in the presence of two types of background noise presented at two clinically useful hearing levels. Test-retest reliability, subject variability and effect of presentation level were also of interest.

Twenty-four normal hearing subjects were employed in this study. Monosyllabic words were presented in four speech conditions and two noise conditions during a listening session and to four levels of presentation.

The subjects were tested for speech discrimination in the presence of white noise and speech babble at 25 dB and 50 dB hearing level. The results showed that speech was more intelligible in white noise than in speech babble. All testing was conducted at a 0 dB signal-to-noise ratio.

A two-way analysis of variance was used to determine whether speech discrimination was affected by noise type and noise level and whether subjects performed differently on one another and whether subjects performed differently on one another.

across the conditions. In addition, correlations were obtained between performance in white noise and speech babble. The standard error of measurement was employed to measure absolute reliability.

ABSTRACT

THE INTELLIGIBILITY OF PHONETICALLY BALANCED LISTS OF CNC WORDS IN WHITE NOISE AND SPEECH BABBLE

By Dianne R. Vertes indicated that there was a significant difference between discrimination scores

The major purpose of this study was to obtain normative data on the speech discrimination ability of young normal hearing adults in the presence of two types of background noise presented at two clinically useful hearing levels. Test-retest reliability, subject variability and effect of presentation level were also of interest.

Twenty-four normal hearing subjects were employed in this study. Subjects were required to listen to four speech discrimination lists during the initial testing session and to four similar lists for the retest session.

The speech discrimination task consisted of listening to the NU Auditory Test No. 6 presented at 25 dB and 50 dB hearing level in the presence of white noise and speech babble. All testing was accomplished in a sound field, with speech and noise presented simultaneously through both speakers at a 0 dB signal-to-noise ratio.

A two-way analysis of variance was employed to determine whether speech discrimination scores differed from one another and whether subjects differed in their performance

across the conditions. In addition, correlations were obtained between performance in white noise and speech babble. The standard error of measurement was employed to measure absolute reliability.

This study provided normative data on the discrimination ability of normal hearing young adults in the presence of background noise. The results indicated that there was a significant difference between discrimination scores obtained at a 25 dB hearing level and those obtained at a 50 dB hearing level. There was a significant difference between discrimination scores obtained against a background of white noise and those obtained against a background of speech babble when both are presented at zero dB signal-to-noise ratio. There was a significant difference in discrimination scores among subjects.

In addition, two general trends were noted in the statistical analysis of data. The first was that of the two types of noise utilized as masking stimuli, speech babble had a more deleterious effect on speech discrimination than white noise, regardless of presentation level. Secondly, it was observed that speech discrimination scores were higher at 25 dB hearing level than at 50 dB hearing level.

THE INTELLIGIBILITY OF PHONETICALLY BALANCED LISTS
OF CNC WORDS IN WHITE NOISE AND SPEECH BABBLE

By

Accepted Dianne R. Vertes of the Department
of Audiology and Speech Sciences, College of
Communication Arts, Michigan State University,
in partial fulfillment of the requirements for
the Master of Arts degree.

Edward J. Hardick
Director of Thesis

Guided by: *Edward J. Hardick* Chairman

William F. Ritschman
Chairman

A THESIS

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

MASTER OF ARTS

Department of Audiology and Speech Sciences

1968

6-117812

TABLE OF CONTENTS

	Page
LIST OF TABLES	iv
Chapter Accepted by the faculty of the Department	
of Audiology and Speech Sciences, College of	1
Communication Arts, Michigan State University,	2
Definition of Terms	4
in partial fulfillment of the requirements for	5
I the Master of Arts degree.	7
Development of	7
Speech	7
Director of Thesis	7
Guidance Committee:	11
Chairman	17
III.	21
Leo V. Deal	22
IV.	22
Analysis of	24
Reliability	26
Discussion	27
Summary	29
V. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS	30
Summary	33
Conclusions	34
Recommendations for Further Research	37
	39
	45
	47
	48
	50
	51

Appendix

TABLE OF CONTENTS

A. DISCRIMINATION TEST SCORES FOR INDIVIDUAL SUBJECTS UNDER ALL EXPERIMENTAL CONDITIONS	Page 53
LIST OF TABLES	iv
Chapter	57
I. INTRODUCTION	1
Purpose of the Study	2
Definition of Terms	4
Limitations of the Study	5
II. REVIEW OF THE LITERATURE	7
Development of the NU Auditory Test No. 6	7
Speech Discrimination in the Presence of Noise	11
Summary	17
III. EXPERIMENTAL PROCEDURES	21
Subjects	22
Equipment	22
Test Environment	24
Test Materials	26
Screening Procedures	27
Test Procedures	29
Statistical Analysis	30
IV. RESULTS AND DISCUSSION	33
Analysis of Variance	34
Reliability	37
Discussion	39
Summary	45
V. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS	47
Summary	48
Conclusions	50
Recommendations for Further Research	51

BIBLIOGRAPHY	53
------------------------	----

Appendix

LIST OF TABLES

A. DISCRIMINATION TEST SCORES FOR INDIVIDUAL SUBJECTS UNDER ALL EXPERIMENTAL CONDITIONS	56
1. B. DISCRIMINATION RETEST SCORES FOR INDIVIDUAL SUBJECTS UNDER ALL EXPERIMENTAL CONDITIONS	57
2. Mean speech discrimination scores in white noise (M_{WN}) and speech babble (M_{SB}) and coefficients of correlation (r) between lists of NU Auditory Test No. 6 at a 24 dB hearing level	10
3. Mean speech discrimination scores in white noise (M_{WN}) and speech babble (M_{SB}) and coefficients of correlation (r) between lists of NU Auditory Test No. 6 at a 26 dB hearing level	11
4. Mean speech discrimination scores and standard deviations for three signal-to-noise ratios in speech babble and white noise	16
5. Coefficients of correlation (r) for sub-jects with complete counter-hearing loss	31
6. Coefficients of correlation (r) for sub-jects with partial counter-hearing loss	34
7. Coefficients of correlation (r) for sub-jects with normal hearing	35
8. Results of individual comparisons	36
9. Coefficients of correlation (Pearson r) between test and retest for two types of background noise at two hearing levels	37
10. Standard error of measurement (SE_m) for two conditions of noise at two hearing levels	38

LIST OF TABLES

Table	Page
1. Mean test (M_t) and retest (M_{ret}) speech discrimination scores, coefficients of correlation (r) and standard error of measurement (SE_m) between test and retest of NU Auditory Test No. 6 at a 24 dB sensation level	10
2. Mean speech discrimination scores in white noise (M_{WN}) and speech babble (M_{SB}) and coefficients of correlation (r) between lists of NU Auditory Test No. 6 at a 26 dB sensation level	11
3. Mean discrimination scores and standard deviations obtained at three signal-to-noise ratios in speech babble and white noise	16
4. Method of presentation of lists for subjects 1 through 8 (one complete counter-balanced set)	31
5. Mean speech discrimination scores and standard deviations as a function of presentation levels and type of background noise	34
6. Summary of two-way analysis of variance comparing differences of background noise, hearing level and subjects	35
7. Results of individual comparisons	36
8. Coefficients of correlation (Pearson r) between test and retest for two types of background noise at two hearing levels	37
9. Standard error of measurement (SE_m) for two conditions of noise at two hearing levels	38

hearing population. The literature that is available is not as clinically useful as it might be. For example, many studies have employed speech stimuli which are no longer used in clinical procedures. Other investigations have presented the speech and noise at other than normal conversational level, which, again, are not practical in the routine.

CHAPTER I

INTRODUCTION

The audiologist is often confronted with the recurring problem of clients who experience difficulty hearing in the presence of noise. At times these are the same clients who perform satisfactorily when communicating with one person at a time in an environment in which there is little or no evident background noise.

An additional facet of the problem besets the audiologist who wishes to perform a hearing aid evaluation. He is fully aware of the limitations of commercially available hearing aids and realizes that frequently a hearing aid does not alleviate the problem of hearing in a background of noise. A hearing aid amplifies all auditory stimuli which reach its microphone and are within the frequency response range of the aid. Since this condition exists, the hearing aid may often compound rather than alleviate the problem of hearing speech in a noisy environment.

Clinical tests have often been employed which seek to quantify the degree to which this problem actually exists. It has been noted, however, that there is a dearth of normative data pertaining to this phenomenon among the normal

hearing population. The literature that is available is not as clinically useful as it might be. For example, many studies have employed speech stimuli which are no longer used in clinical procedures. Other investigations have presented the speech and noise stimuli at other than normal conversational level, which, again, are not practical in the routine of audiological testing.

For information regarding speech discrimination in noise to be applicable to the clinical setting, at least four important factors must be taken into account. These factors are (1) the speech discrimination tests currently available, (2) useful hearing levels at which tests might be accomplished, (3) types of noises most applicable in the testing procedure, and (4) signal-to-noise ratio. Application of the above factors in obtaining normative data for hearing in noise is the major concern of this research.

Purpose of the Study

The primary purpose of this study was to obtain normative data on the speech discrimination ability of young normal hearing adults in the presence of white noise and speech babble, with all signals presented at two clinically useful hearing levels. Specifically, the study was concerned with speech discrimination employing the Northwestern

University Auditory Test No. 6.¹ Hearing levels of 25 dB and 50 dB were employed.

Three aspects of speech discrimination were of considerable interest. One of these was test-retest reliability, a second was variability in discrimination performance among subjects, and the third was significant differences between scores as a function of presentation level.

In brief, then, the experiment consisted of obtaining speech discrimination scores for normal hearing subjects in the presence of two types of noise. All testing was accomplished in a sound field using two loud speakers, with both speech and noise presented simultaneously through both speakers. A 0 dB signal-to-noise ratio was retained throughout the study. Speech and noise stimuli were presented at two hearing levels (25 dB and 50 dB); thus, each subject obtained four speech discrimination scores. In addition, subjects were retested under similar conditions.

In order to answer the questions implied by the statements of purpose, the following null hypotheses were advanced:

1. There is no significant difference between speech discrimination scores obtained in noise at 25 dB and those obtained at 50 dB hearing level.

¹Tom W. Tillman and Raymond Carhart, "An Expanded Test for Speech Discrimination Utilizing CNC Monosyllabic Words (NU Auditory Test No. 6)," U. S. School of Aerospace Medicine - Technical Research, 66 - 55, June, 1966, pp. 1-12.

²Ibid., p. 36.

2. There is no significant difference between speech discrimination scores obtained against a background of white noise and those obtained against a background of speech babble when both noise and speech are presented as a 0 dB signal-to-noise ratio.
3. There are no significant differences among subjects in speech discrimination scores obtained in noise.

In addition, the question was proposed as to the reliability of the obtained data.

Definition of Terms

The following definitions are used in this study:

Speech discrimination--speech discrimination is defined as the ability to verbally repeat speech presented as auditory stimuli. Discrimination is tested employing phonetically balanced lists of fifty monosyllabic words.

Hearing level--hearing level is defined as the intensity of a stimulus re: audiometric zero.¹

Broad-band white noise--broad-band white noise is defined as noise characterized by the presence of all the frequencies in the audible range presented randomly at the same amplitude or pressure.²

Speech babble--speech babble is defined as noise produced by the presentation of multiple, simultaneous speech

¹Ira J. Hirsh, The Measurement of Hearing (New York: McGraw-Hill Book Company, Inc., 1952), p. 342.

²Ibid., p. 36.

this stimuli obtained from 40 speakers. Frequency, intensity and rate occur at random. The outcome is a background of noise, recognizable as speech but unintelligible. Signal-to-noise ratio--signal-to-noise ratio is defined as the difference in decibels of the intensity of a speech signal to the intensity of the noise being employed.

Limitations of the Study

It was necessary to introduce boundaries in order to limit the scope of the present study. As stated earlier, there are at least four important variables which affect speech discrimination ability of normal hearing subjects in noise: testing materials, presentation levels, types of noise and signal-to-noise ratios.

It was realized that different choices in format such as different presentation levels, additional signal-to-noise ratios or additional lists of speech discrimination materials might have significantly altered the results of this study. However, the choices that were made were based on the premise of maximum clinical utility.

Another contingency is method of presentation. It cannot be inferred that results obtained by presenting speech stimuli and both types of noise through two speakers in a sound field would remain unchanged, if testing conditions were altered. That is, for example, the results of

this study cannot be used to make predictions about similar speech discrimination tasks under earphones.

In addition, since the normative data were obtained utilizing young adults, caution must be used in interpreting the results of this study for subjects in widely divergent age categories. That is, erroneous assumptions might be made if the results of this study were used to interpret scores obtained with pediatric or geriatric populations. and standardization of the NU Auditory Test No. 6 will be presented. The second major category will review pertinent investigations dealing with speech discrimination in the presence of noise. In the third section the research findings will be summarized and discussed relative to the purposes of this study.

Chapter II The NU Auditory

The NU Auditory Test No. 6 contains four lists of 50 monosyllabic words which were developed to represent the phonemic structure of English and to provide word lists which were developed in 1959 and revised in 1962.² It was their belief in developing the NU lists that an important variable in

¹I. Lehiata and G. E. Peterson, "Linguistic Considerations in the Study of Speech Intelligibility," Journal of the Acoustical Society of America, XXXI (1959), 280-286.

²G. E. Peterson and I. Lehiata, "Revised CNC Lists for Auditory Tests," Journal of Speech and Hearing Disorders, XXVII (1962), 62-70.

test word lists was uniformity.¹ That is, different lists used under variable listening conditions should produce comparable results.

CHAPTER II

REVIEW OF THE LITERATURE

This chapter will be divided into three main categories. First literature pertaining to the development and standardization of the NU Auditory Test No. 6 will be presented. The second major category will review pertinent investigations dealing with speech discrimination in the presence of noise. In the third section the research findings will be summarized and discussed relative to the purposes of this study.

Development of the NU Auditory Test No. 6

The NU Auditory Test No. 6 contains four lists of 50 monosyllabic words. These lists employ the phonemic structure of Lehiste and Peterson's¹ CNC word lists which were developed in 1959 and revised in 1962.² It was their belief in developing the CNC lists that an important variable in

¹I. Lehiste and G. E. Peterson, "Linguistic Considerations in the Study of Speech Intelligibility," Journal of the Acoustical Society of America, XXXI (1959), 280-286.

²G. E. Peterson and I. Lehiste, "Revised CNC Lists for Auditory Tests," Journal of Speech and Hearing Disorders, XXVII (1962), 62-70.

test word lists was uniformity.¹ That is, different lists used under variable listening conditions should produce comparable results.

It was for this reason that Tillman and Carhart² employed the phonemic structure of the CNC word lists in their development of the Northwestern lists. The NU Auditory Test No. 6 ultimately consisted of four lists of phonetically balanced words. They were recorded and standardized at Northwestern University. Twelve normal hearing young adults were used as subjects.

The Northwestern word lists were standardized prior to the present study by Rintelmann and Jetty³ at Michigan State University following procedures outlined by Tillman and Carhart.⁴ The purpose of the Rintelmann and Jetty reliability study was to confirm the results obtained by Tillman and Carhart and to ascertain whether or not results were comparable when a different speaker was employed.

¹Ibid., p. 64.

²Tom W. Tillman and Raymond Carhart, "An Expanded Test for Speech Discrimination Utilizing CNC Monosyllabic Words (NU Auditory Test No. 6)," U. S. School of Aerospace Medicine - Technical Research, 66 - 55, June, 1966, pp. 1-12.

³William F. Rintelmann and Albert J. Jetty, "Reliability of Speech Discrimination Testing Using CNC Monosyllabic Words" (unpublished study, Michigan State University, 1968).

⁴Tillman and Carhart, op. cit.

Four lists of words, hereafter called Form A, making up the NU Auditory Test No. 6 were recorded on magnetic tape using an Ampex, model AG 350-2 tape recorder. A male speaker recorded the speech stimuli monitoring his output by means of a VU meter. Preceding each test word was the phrase, "You will say." The last word of the carrier phrase was monitored and the test word was said naturally.

Ten normal hearing young adults were employed as subjects. Lists were presented at six sensation levels (-4, 0, 8, 16, 24 and 32 dB). The articulation functions were found to be comparable to those obtained by Tillman and Carhart.

Mean speech discrimination scores obtained at a 24 dB sensation level will be presented in Table 1 since this level is closest to the 25 dB hearing level utilized in the present study. Mean test and retest scores and coefficients of correlation between test and retest for List I, II, III and IV and standard error of measurement (SE_m) are presented in Table 1.

It may be noted at this time that the correlations are not as high as one might expect or desire utilizing this type of speech material.

Four additional lists, hereafter referred to as Form B, were also recorded on magnetic tape. Form B of NU Auditory Test No. 6 was made from scramblings of the original lists.

Larry J. Lovering, "Reliability of Speech Discrimination Testing in Two Types of Background Noise Using CVC Monosyllabic Words" (unpublished study, Michigan State University, 1958).

Table 1. Mean test (M_t) and retest (M_{ret}) speech discrimination scores, coefficients of correlation (r) and standard error of measurement (SE_m) between test and retest of NU Auditory Test No. 6 at a 24 dB sensation level

	List I	List II	List III	List IV
(M_t)	92.2%	93.0%	87.4%	92.0%
(M_{ret})	93.4%	92.6%	90.4%	94.4%
(r)	.71	.75	.74	.73
(SE_m)	2.96	2.82	4.51	3.79

A two-way analysis of variance was also computed. Further standardization utilizing the NU Auditory Test No. 6 was accomplished at Michigan State University by Lovering.¹ His study involved speech discrimination in the presence of two types of background noise. Twenty-four normal hearing young adults were used as subjects. Form A, Lists I, II, III and IV of the NU Auditory Test No. 6 was utilized. Subjects listened to each list twice, once in the presence of white noise and once in speech babble noise. Both speech and noise were presented simultaneously, noise from one speaker and speech from another. A signal-to-noise ratio of 0 dB was used. Mean speech discrimination scores in speech babble and white noise and coefficients of correlation are presented in Table 2.

¹Larry J. Lovering, "Reliability of Speech Discrimination Testing in Two Types of Background Noise Using CNC Monosyllabic Words" (unpublished study, Michigan State University, 1968).

Table 2. Mean speech discrimination scores in white noise (M_{WN}) and speech babble (M_{SB}) and coefficients of correlation (r) between lists of NU Auditory Test No. 6 at a 26 dB sensation level

	List I	List II	List III	List IV
(M_{WN})	57.08	64.58	58.66	65.91
(M_{SB})	57.66	66.58	60.25	60.87
(r)	0.36	0.33	0.04	0.19
Grand Mean	57.36	65.88	59.46	63.39

A two-way analysis of variance was also computed. List I was found to differ significantly from List II (across noise conditions) at the 0.01 level of confidence. No other significant difference between lists was observed. In addition, no significant difference was found to exist between speech babble and white noise conditions.

Speech Discrimination in the Presence of Noise

According to Miller¹ in 1947, there are three major characteristics to be considered relative to the masking sound: (1) intensity relative to intensity of speech, (2) acoustic spectrum and (3) temporal continuity. In Miller's study, speech was heard binaurally under phones at a constant

¹George A. Miller and J. C. E. Licklider, "The Intelligibility of Interrupted Speech," Journal of the Acoustical Society of America, XXII, No. 2 (March, 1950), 167-171.

²George A. Miller, "The Masking of Speech," Psychological Bulletin, XLIV, No. 2 (1947), 105-129.

intensity of 95 dB re: 0.0002 dynes/cm². Articulation curves were plotted. None of the eight narrow bands nor speech babble noises used to mask speech were any more effective than white noise. Miller concluded, therefore, that uninterrupted noise with its major emphasis in the spectrum ranging from 100-5000 Hz produces the most deleterious effect on the perception of speech.

Again, in 1950, Miller and Licklider¹ investigated the effect of interrupted noise on the perception of speech. Phonetically balanced words published by Egan were used as discrimination materials. With the speech and white noise presented at a zero dB signal-to-noise ratio, listeners heard 50 percent of masked words. The level at which the lists were presented was not specified.

Utilizing continuous discourse presented monaurally, Hawkins and Stevens² plotted thresholds of detectability and thresholds of intelligibility. Measurements were made in quiet and in white noise at eight sensation levels from 10 to 90 dB. Results indicate that speech thresholds are affected most by high intensity levels and are hardly affected by low intensity levels of noise. "At noise levels above threshold of 50 dB and greater, the threshold of

¹George A. Miller and J. C. R. Licklider, "The Intelligibility of Interrupted Speech," Journal of the Acoustical Society of America, XXII, No. 2 (March, 1950), 167-173.

²J. E. Hawkins and S. S. Stevens, "The Masking of Pure Tones and of Speech by White Noise," Journal of the Acoustical Society of America, XXII (1950), 6-13.

intelligibility is reached at a signal-to-noise ratio of -8 dB. Speech is detectable as low as -17 dB signal-to-noise ratio." Intensity level of 95 dB re: absolute zero as a

masking Using Harvard PB lists, Simonton and Hedgecock¹ determined discrimination performance of normal hearing subjects in the presence of a simulated noise somewhat similar to that heard in a cockpit of an airplane. The noise was a mixture of white noise, 60 Hz harmonics and 112 Hz tones; it was presented at a constant intensity of 98.5 dB. The signal intensity was an estimation of most comfortable loudness level. Each subject adjusted the intensity to his own preference. Intensity levels varied from 102-108 dB or +3.5 to +9.5 dB signal-to-noise ratio. Although reference level was not specified, these intensities are probably relative to 0.0002 dynes/cm². Discrimination scores varied from 78 percent to 88 percent; the average was 83 percent.

Abrams,² also using airplane noise, obtained scores ranging from 19 percent at a -10 dB signal-to-noise ratio to 94 percent at a +15 dB signal-to-noise ratio. The level of noise was held constant at 115 dB SPL.

¹Kinsey M. Simonton and LeRoy D. Hedgecock, "A Laboratory Assessment of Hearing Acuity for Voice Signals Against a Background of Noise," Annals of Otolaryngology, Rhinology and Laryngology, LXII (1953), 735-747.

²M. H. Abrams et al., "Speech In Noise; A Study of the Factors Determining Its Intelligibility," Psycho-Acoustic Lab., Harvard University, OSRD Report 4023, September 1, 1944.

Conflicting results were obtained by Palva¹ in a study quite similar to those just mentioned. He used white noise at an intensity level of 95 dB re: absolute zero as a masking source. Speech was presented at 105 dB SPL (+10 dB signal-to-noise ratio). With normal hearing subjects, he obtained discrimination scores from 90-100 percent. Although the author used a signal-to-noise ratio similar to, and in one case lower than Simonton and Hedgecock² and Abrams,³ higher percent discrimination was obtained in the Palva study. Ross et al.⁴ used the CID Auditory Test W-22 presented 40 dB above obtained speech reception thresholds. Noise was presented 2.5 dB SPL less than the speech stimuli. Tests were accomplished monaurally. Normal hearing subjects obtained scores of 75.6 percent (right ear) and 76.4 percent (left ear). Standard deviations were 7.7 percent and 7.9 percent for the right and left ears, respectively.

¹Tuano Palva, "Studies of Hearing for Pure Tones and Speech in Noise," Acta-Oto-Laryngologica, XLV (1955), 231-243.

²Simonton and Hedgecock, op. cit., p. 740.

³Abrams, op. cit.

⁴M. Ross, D. Huntington, H. Newby and R. Dixon, "Speech Discrimination of Hearing-Impaired Individuals in Noise," Journal of Auditory Research, V (1965), 47-72.

⁵Gordon L. Cluff, "A Comparison of the Effects of Speech Noise and White Noise on the Discrimination of Speech," Dissertation Abstracts, 1967, 27 (9-11), 3144-3145 (Southern Illinois University).

Sambataro and Pestalozza¹ plotted articulation curves for normal hearing subjects using logatomes as speech materials. Testing was accomplished in a sound field. White noise was presented at 20, 40, 60 and 80 dB above normal threshold. They concluded that for low intensities of noise, threshold shift was much lower than at high intensities of noise. At a 20 dB level, a 7 dB rise in threshold of perception was noted; at a 40 dB level there was a 21 dB shift.

Cluff² compared the effects of speech noise and white noise on the discrimination of speech. Twenty-four normal hearing subjects were tested using half-lists of the CID W-22 word lists. Signal-to-noise ratios of -10, -5, 0, +5 and +10 were used; the speech levels were 20 dB, 40 dB, 60 dB and 80 dB relative to speech audiometric zero. When discrimination ability in white noise and speech babble was compared, generally lower scores were obtained in speech noise below the zero dB signal-to-noise ratio. At positive signal-to-noise ratios, lower scores were obtained in white noise. The lowest discrimination scores were obtained at the 20 dB level for all signal-to-noise ratios; highest

¹Carlo Sambataro, M. D. and Guilio Pestalozza, M. D., "Masking and Fatigue Effect of White Noise in Connection with Speech Tests," Laryngoscope, LXII (1952), 1197-1204.

²Gordon L. Cluff, "A Comparison of the Effects of Speech Noise and White Noise on the Discrimination of Speech," Dissertation Abstracts, 1967, 27 (9-A), 3144-3145 (Southern Illinois University).

scores were obtained at the 60 dB level for all signal-to-noise ratios. Test-retest reliability was low.

Higgins¹ also used speech babble and white noise as variables affecting speech discrimination. Speech stimuli were presented at 55 dB, 60 dB and 65 dB and noises were presented at 60 dB re: speech audiometric zero, thus resulting in signal-to-noise ratios of -5, 0 and +5 dB. Testing was accomplished in a sound field using the CID W-22 lists.

Mean scores in speech babble and in white noise at -5, 0 and +5 dB signal-to-noise ratios together with their respective standard deviations are presented in Table 3.

Table 3. Mean discrimination scores and standard deviations obtained at three signal-to-noise ratios in speech babble and white noise

S/N Ratio	Speech Babble	(Standard Deviation)	White Noise	(Standard Deviation)
-5 dB	30.80	(12.24)	57.30	(7.93)
0 dB	46.90	(9.78)	66.30	(7.23)
+5 dB	67.10	(12.82)	73.90	(5.92)

¹Doris Mary Higgins, "The Effects of White Noise and Speech Babble on the Intelligibility of Phonetically Balanced Lists of Monosyllabic Words" (unpublished Masters Thesis, University of Tennessee, 1965), pp. 22-23.

Another source of variation was signal-to-noise ratio. Ratios varied from -17 dB to +15 dB.

Finally, age and Summary of subjects comprising the

various investigations were often not specified.

As has been stated in Chapter I of this study, if it is true that all of these variables affect speech discrimination, then the results of the investigations reviewed cannot rightfully be compared with one another. This can be adequately pointed out by observing the number and variety of methods utilized in testing this phenomenon.

In the studies reviewed, speech was tested under extreme caution that the following general conclusions of the various studies are summarized. It was generally concluded by Hawkins and Stevens² and Sambataro and Pestalozza² that thresholds are affected most by high intensity noise as opposed to low intensity noise. Cluff,³ however, obtained

Speech materials used were not specified on occasion. Those that were mentioned ranged from phonetically balanced words to continuous discourse. Specifically, the CID W-22 lists, Harvard PB lists, and logatomes composed the phonetically-balanced word lists materials. One study reported the use of half-lists.

Type of noise used also varied. White noise, speech babble, and airplane noise are three examples.

In several studies, articulation curves were plotted. In other studies presentation of the speech ranged from 10 dB to 80 dB above speech audiometric zero. One study presented speech at the subjects' most comfortable loudness level.

Another source of variation was signal-to-noise ratio. Ratios varied from -17 dB to +15 dB.

Finally, age and number of subjects comprising the various investigations were often not specified.

If it is true that all of these variables affect speech discrimination, then the results of the investigations reviewed cannot rightfully be compared with one another. As might be expected, speech discrimination scores ranged from 0 percent to 100 percent.

With the above limitations in mind, it is only with extreme caution that the following general conclusions of the various studies are summarized. It was generally concluded by Hawkins and Stevens¹ and Sambataro and Pestalozza,² that thresholds are affected most by high intensity noise as opposed to low intensity noise. Cluff,³ however, obtained conflicting results. He obtained highest discrimination scores at 60 dB rather than at 20 dB, regardless of signal-to-noise ratio. Miller⁴ concluded that type of noise used for masking had little effect on discrimination scores, as long as the spectral range was generally from 100-5000 Hz.

¹J. E. Hawkins and S. S. Stevens, "The Masking of Pure Tones and of Speech by White Noise," Journal of the Acoustical Society of America, XXII (1950), 6-13.

²Carlo Sambataro, M. D., and Guilio Pestalozza, M. D., "Masking and Fatigue Effect of White Noise in Connection with Speech Tests," Laryngoscope, LXII (1952), 1197-1204.

³Gordon L. Cluff, "A Comparison of the Effects of Speech Noise and White Noise on the Discrimination of Speech," Dissertation Abstracts, 1967, 27 (9-A), 3144-3145.

⁴George A. Miller, "The Masking of Speech," Psychological Bulletin, XLIV, No. 2 (1947), 105-129.

Higgins¹ and Cluff,² however, reported differential effects on discrimination performance when white noise or speech babble was employed.

The review of the literature pertaining to the NU Auditory Test No. 6 suggests that this test should produce consistent results across various conditions. The verity of this statement might be questioned, however, when one notes the results of the two standardization studies accomplished at Michigan State University. In the Rintelmann and Jetty³ study, although the correlations between test and retest were high, they are not quite as high as would be expected using phonetically-balanced words. In the Lovering⁴ study, the correlation coefficients were low, and List I was found to differ significantly from List II (Form A, NU Auditory Test No. 6). The implications of these data must be born in mind since the results of the present investigation rest

¹Doris Mary Higgins, "The Effects of White Noise and Speech Babble on the Intelligibility of Phonetically Balanced Lists of Monosyllabic Words" (unpublished Masters Thesis, University of Tennessee, 1965), pp. 22-23, 34.

²Gordon L. Cluff, "A Comparison of the Effects of Speech Noise and White Noise on the Discrimination of Speech," Dissertation Abstracts, 1967, 27 (9-A), 3144-3145.

³William F. Rintelmann and Albert J. Jetty, "Reliability of Speech Discrimination Testing Using CNC Monosyllabic Words" (unpublished study, Michigan State University, 1968).

⁴Larry J. Lovering, "Reliability of Speech Discrimination Testing in Two Types of Background Noise Using CNC Monosyllabic Words" (unpublished study, Michigan State University, 1968).

heavily on the validity and reliability of the Northwestern lists.

In conclusion, for purposes of clinical utility, it is felt that normative data should be obtained in such a manner as to facilitate repeated measurement. The information available at present does not fulfill this stipulation. For these reasons, the data available pertaining to speech discrimination in the presence of noise is an inadequate source of normative data for use in the clinical situation.

used in the study and the calibration procedures employed. The third section deals with a description of the test environment and test materials. The fourth section presents a discussion of the procedures used in subject selection. The fifth section presents the experimental procedures will be presented. The sixth section presents the statistical measures employed.

Subjects employed normal hearing. The discrimination materials were speech and speech babble. Tests were conducted at a hearing level and at a 50 dB hearing level. The noise ratio was retained at zero. Four scores were obtained for each subject. Retest scores were also obtained under similar conditions. All testing was accomplished in a sound field.

Subjects

A total of 24 subjects were employed in the study.

Eighteen of these subjects were male, the age range was 18-27 years. Most of the subjects were undergraduate students in the Department of Audiology and Speech Sciences at Michigan State University. The other subjects

CHAPTER III

EXPERIMENTAL PROCEDURES

This chapter will be divided into six sections. First, information regarding the selection of subjects will be presented. The second section deals with the equipment used in the study and the calibration procedures employed.

All subjects had normal hearing as determined by pure-tone audiometry. Speech reception thresholds were also obtained. These hearing test results were obtained under typical conditions in a sound-treated room. The third section deals with a description of the test environment and test materials. The fourth section presents a discussion of screening procedures used in subject selection. In the fifth section, experimental procedures will be presented. The final section presents statistical measures employed in the study.

In brief review, the present study employed normal hearing subjects who listened to speech discrimination materials in the presence of white noise and speech babble.

Tests were presented at a 25 dB hearing level and at a 50 dB hearing level; the signal-to-noise ratio was retained at zero. Four scores were obtained for each subject. Retest scores were also obtained under similar conditions. All

In addition, the following equipment was employed for testing was accomplished in a sound field.

for calibration of stimulus sources:

Sound level meter	(Brüel and Kjaer, Type 2203)
Octave band filter network	(Brüel and Kjaer, Type 1613)
Artificial ear	(Brüel and Kjaer, Type 4152)

Subjects

A total of 24 subjects were employed in the study. Eighteen of these subjects were female, six were male, the age range was 18-27 years. Most of the subjects were undergraduate students in the Department of Audiology and Speech Sciences at Michigan State University. The other subjects were willing volunteers from the community outside the University. Precautions were taken to insure that no subject was familiar with the test materials.

All subjects had normal hearing as determined by pure-tone audiometry. Speech reception thresholds were also obtained. These hearing test results were obtained under typical clinical conditions in a sound-treated room.

Equipment

The following is a list of equipment utilized for the presentation of the auditory stimuli employed in the investigation:

Pure-tone audiometer	(Belton, Model 10C)
Speech audiometer	(Grason-Stadler, Model 162)
Record player	(Garrard, Model 80)
Loudspeakers	(Electro-Voice, Model 15TRX)
Earphones	(Telephonics, Model TDH - 39)
Earphone cushion	(Model MX 41/AR)
Tape recorder	(Ampex, Model 601-2)

In addition, the following equipment was employed for calibration of stimulus sources:

Sound level meter	(Bruel and Kjaer, Type 2203)
Octave band filter network	(Bruel and Kjaer, Type 1613)
Artificial ear	(Bruel and Kjaer, Type 4152)

Condenser microphone (Bruel and Kjaer, Type 4132, used in conjunction with the levels specified for ISO calibration, artificial ear)
 Condenser microphone (Bruel and Kjaer, Type 4131, used for sound field measurements)

To accomplish all pure-tone air conduction testing, a pure-tone audiometer driving TDH-39-10Z transducers housed in MX 41/AR biscuit-type cushions, was employed.

For the necessary speech testing, a commercially available speech audiometer was used to amplify and attenuate the electrical output of both the record player used to present disc recorded test material, and the white noise generator. The speech audiometer was also used in conjunction with the tape recorder which presented tape recorded test materials and speech babble noise.

Depending on the specific test condition, the output of the speech audiometer was used to drive either the TDH-39-10Z earphones housed in an MX41/AR cushion or the loudspeakers.

Calibration of the equipment was done prior to and following the experiment. The pure-tone audiometer used for air-conduction testing was calibrated by means of the sound level meter and its associated octave band filter network. The TDH-39 earphone was connected to the 6 cc coupler of the artificial ear, and this assembly was coupled to the sound level meter. The audiometer output was checked at a 60 dB

Jerome R. Cox, Jr., and Robert C. Bilger, "Suggestion Relative to the Standardization of Loudness-Balance Data for the Telephonics TDH-39 Earphone," *Journal of the Acoustical Society of America*, XXXII (1960), 1081-1082.

attenuator setting and was found to be in agreement with levels specified for ISO calibrated audiometers.¹

For calibration of the loudspeakers, the sound level meter together with the sound field condenser microphone were placed at the subject's head position. The diaphragm of the condenser microphone was situated so that it was perpendicular to the floor and ceiling of the test chamber, facing the loudspeaker. An observer remained in the field during all measurements.

The speech audiometer used in this research was calibrated so that audiometric zero was 20 dB above 0.0002 dynes/cm². Caution was taken to insure that all other outputs of the system were of equal intensity. This was done in order to satisfy the criteria of a 0 dB signal-to-noise ratio.

Test Environment

The test room (IAC, 1200 series) and all audiometric equipment were located in the Audiology Research Laboratory. A schematic diagram of the test room and adjoining control room are shown in Figure 1.

The subjects were seated in the test room during all audiometric procedures of this study.

¹Jerome R. Cox, Jr., and Robert C. Bilger, "Suggestion Relative to the Standardization of Loudness-Balance Data for the Telephonics TDH-39 Earphone," Journal of the Acoustical Society of America, XXXII (1960), 1081-1082.

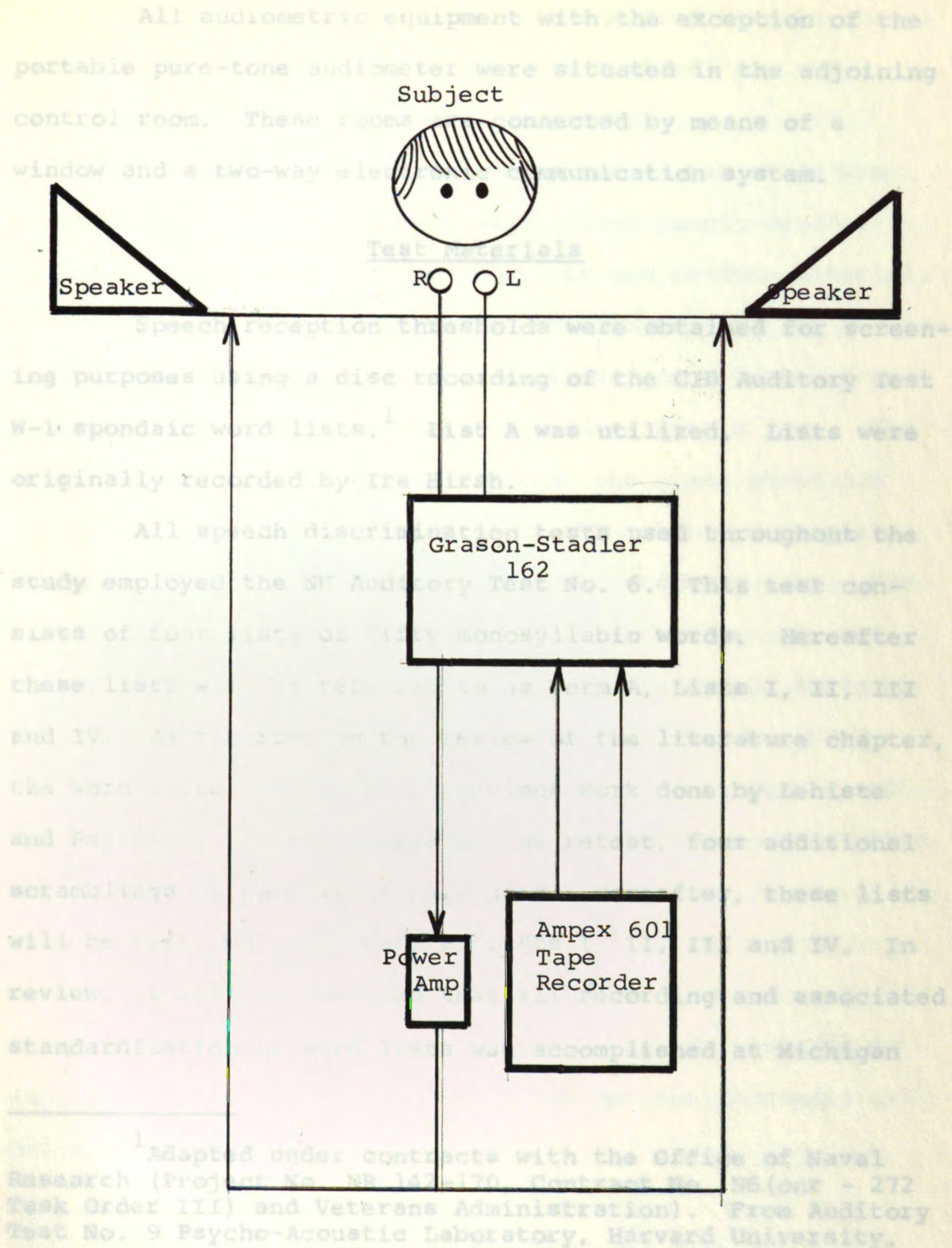


Fig. 1. Schematic diagram of test room and control room.

All audiometric equipment with the exception of the portable pure-tone audiometer were situated in the adjoining control room. These rooms are connected by means of a window and a two-way electronic communication system.

Test Materials

Speech reception thresholds were obtained for screening purposes using a disc recording of the CID Auditory Test W-1 spondaic word lists.¹ List A was utilized. Lists were originally recorded by Ira Hirsh.

All speech discrimination tests used throughout the study employed the NU Auditory Test No. 6. This test consists of four lists of fifty monosyllabic words. Hereafter these lists will be referred to as Form A, Lists I, II, III and IV. As reported in the review of the literature chapter, the word lists are based on previous work done by Lehiste and Peterson.² For purposes of the retest, four additional scramblings of word lists were used. Hereafter, these lists will be referred to as Form B, Lists I, II, III and IV. In review, it will be recalled that all recording and associated standardization of word lists was accomplished at Michigan

¹Adapted under contracts with the Office of Naval Research (Project No. NR 142-170, Contract No. N6(onr - 272 Task Order III) and Veterans Administration). From Auditory Test No. 9 Psycho-Acoustic Laboratory, Harvard University.

²Lehiste and Peterson, "Revised CNC Lists for Auditory Testing," Journal of Speech and Hearing Disorders, XXVII (1962), 62-70.

State University. Standardization procedures were identical to procedures utilized by Tillman and Carhart¹ and the results of the two studies were comparable.

The speech babble noise utilized in the study was produced by recording approximately forty people reading simultaneously. Each person chose his own reading material. An Ampex, Model 601 tape recorder was used during the recording session. The tape was then monitored on a VU meter and a section of the tape was cut and spliced into a loop. The criterion for this tape loop was that the noise peaks did not exceed a ± 3 dB deflection on the VU meter. A complete half-hour (1200 foot) tape was recorded from the loop. For purposes of the present study, a dual track tape was used. On one track the speech babble noise was recorded, while on the other track, the NU Auditory Test No. 6 was recorded.

Again, the white noise generator, an integral part of the Grason-Stadler speech audiometer, generated the white noise utilized throughout the study.

Screening Procedures

The following screening tests were administered to each subject, to determine whether he met the necessary criteria to participate.

¹Tillman and Carhart, "An Expanded Test for Speech Discrimination," pp. 1-12.

The thresholds of each subject were initially determined for the frequencies of 500, 1000 and 2000 Hz by air conduction. The revised Hughson-Westlake technique for obtaining pure-tone thresholds as described by Carhart and Jerger¹ was used. Subjects obtaining thresholds better than 0 dB and poorer than 10 dB at any frequency were not included in the study. For the purpose of this study then, normal hearing was defined as a range of audible thresholds at the speech frequencies of 0-10 dB.

For inclusion in the study, a speech reception threshold within the range of 0-10 dB was required. Speech reception thresholds were not ultimately used in the present study as reference intensities above which the discrimination lists were administered. The usual clinical procedure followed is to present the discrimination test 25 dB or 40 dB above the speech reception threshold. The above procedure was not used in this study because it would have required an inordinate amount of adjustment and calibration of the audiometer. However, it was felt that by restricting the range of acceptable speech reception thresholds, presenting the discrimination test at 25 dB and 50 dB hearing level would not deviate to any great extent from the accepted level of presentation. For example, a subject obtaining a speech

¹Raymond Carhart and James F. Jerger, "Preferred Method for Clinical Determination of Pure-Tone Thresholds," Journal of Speech and Hearing Disorders, XXIV (1959), 330-345.

reception threshold of 10 dB would, using ordinary clinical procedures, hear the discrimination words at 25 dB above threshold (35 dB) or 40 dB above threshold (50 dB). As indicated previously, this does not deviate greatly from the 25 dB and 50 dB hearing levels utilized in the present study.

Speech reception thresholds were obtained using a recording of the CID W-1 spondaic word lists.

Test Procedures

The speech discrimination test was administered to 24 subjects. The test consisted of listening to the NU Auditory Test No. 6, Form A, Lists I, II, III and IV in a sound field. The stimuli were presented at two different hearing levels, under two different noise conditions. The hearing levels employed were 25 dB and 50 dB; broad-band white noise and speech babble were used. Two speakers were employed; both speech and noise were presented simultaneously through both speakers. The signal-to-noise ratio of zero dB was retained throughout the study.

Retesting employed identical procedures as outlined above. Retest procedures occurred no later than one week following the original test. Often the test and retest took place in a single session. NU Auditory Test No. 6, Form B, Lists I, II, III and IV was used throughout the retest session.

Each subject was given the following instructions:

You will now listen to several lists of monosyllabic words. The speech will be introduced into the room through the speakers. Along with the words, you will hear two different types of noise. Please write every word that you hear on the recording form. There are four separate lists of words. Introducing each list is the phrase, "This is NU Auditory Test No. 6, List _____, Form _____. Are you ready?" The words are not numbered, so be careful to listen for the introductory phrase so that you will know when to begin.

Subject responses were written to avoid discrimination errors by the examiner.

A counter-balancing technique was used in scheduling the presentation of word lists. Lists I, II, III and IV were arranged in eight possible presentation orders, thus resulting in three complete counter-balanced sets. The lists were arranged in this fashion because of the desirability of presenting a particular type of noise in conjunction with a specific list at a specific hearing level. The white noise, then, was presented only in conjunction with Lists II and IV, while speech babble was presented with Lists I and III. Hearing levels also remained constant in relation to the lists. Lists I and II were presented at a 25 dB hearing level and lists III and IV were presented at a 50 dB hearing level. Table 4 illustrates the order of presentation for subjects 1 through 8.

Statistical Analysis

Each subject response sheet was checked against a key, responses differing from the key were scored as incorrect. Speech discrimination scores were obtained by

Table 4. Method of presentation of lists for subjects 1 through 8 (one complete counter-balanced set)

Subjects	TEST ORDER			
	1	2	3	4
S ₁	I* 25 dB (SB)	II 25 dB (WN)	III 50 dB (SB)	IV 50 dB (WN)
S ₂	II 25 dB (WN)	III 50 dB (SB)	IV 50 dB (WN)	I 25 dB (SB)
S ₃	III 50 dB (SB)	IV 50 dB (WN)	I 25 dB (SB)	II 25 dB (WN)
S ₄	IV 50 dB (WN)	I 25 dB (SB)	II 25 dB (WN)	III 50 dB (SB)
S ₅	IV 50 dB (WN)	III 50 dB (SB)	II 25 dB (WN)	I 25 dB (SB)
S ₆	III 50 dB (SB)	II 25 dB (WN)	I 25 dB (SB)	IV 50 dB (WN)
S ₇	II 25 dB (WN)	I 25 dB (SB)	IV 50 dB (WN)	III 50 dB (SB)
S ₈	I 25 dB (SB)	IV 50 dB (WN)	III 50 dB (SB)	II 25 dB (WN)

*Roman numeral specifies NU Auditory Test No. 6 List.

counting the number of incorrect responses, multiplying that number by two and subtracting the resultant figure from 100 percent.

The results of the speech discrimination tests were subdivided into four categories. Scores were recorded for speech discrimination in speech babble at a 25 dB hearing level and at a 50 dB hearing level and they were

similarly divided with respect to white noise. Thus, each subject obtained four scores for both the test and retest.

Several statistical measures were employed to determine whether to accept or reject the null hypotheses and to answer the question proposed at the outset of this study.

A two-way analysis of variance was employed to determine whether the four columns of discrimination scores differed from one another and whether subjects (rows) differed in their performance across the conditions. In addition correlations were obtained between test and retest performance in both white noise and speech babble. The standard error of measurement was employed as the measure of absolute reliability.

CHAPTER IV

RESULTS AND DISCUSSION

First, in order to look at the conditions alluded to in the null hypotheses presented at the outset of this study, various statistical measures, including an analysis of variance will be presented. In brief summary, the null hypotheses were concerned with three conditions. It was proposed that: (1) no difference would occur between speech discrimination scores as a function of presentation level; (2) no difference would occur between speech discrimination scores against a background of white noise and those obtained against a background of speech babble when both are presented at a 0 dB signal-to-noise ratio; and (3) no differences would occur in speech discrimination scores among subjects.

Secondly, reliability information will be reported. This is presented in an attempt to answer the questions proposed regarding the speech discrimination tasks. These questions concerned test-retest relationships. A discussion and summary of the results will follow.

Analysis of Variance

Mean speech discrimination scores and their respective standard deviations were obtained across the conditions of noise and presentation level. These data are shown in Table 5.

Table 5. Mean speech discrimination scores and standard deviations as a function of presentation levels and type of background noise

Presentation Level	Type of Background Noise	
	Speech Babble	White Noise
25 dB HL	38.42 (9.93)*	49.25 (9.41)
50 dB HL	13.67 (7.99)	21.83 (6.59)

*Standard deviation.

Mean scores and standard deviations were utilized as normative data. These norms for speech discrimination in noise were available under four conditions: (1) speech babble at 25 dB hearing level; (2) speech babble at 50 dB hearing level; (3) white noise at 25 dB hearing level and (4) white noise at 50 dB hearing level. For example, two-thirds of normal hearing adults between the ages of 18-27 years would be expected to obtain a speech discrimination score ranging from 29-47 percent in speech babble at a 25 dB hearing level. Inspection of Table 5 reveals differences among data in

certain directions. An analysis of variance¹ was computed to determine whether these differences were statistically significant.

Measurement of several parameters utilizing the same subjects and a utilization of a Treatment by Subjects design² made it possible to evaluate three variables. They were noises, levels and subjects, even though a two dimension analysis of variance model was employed. The results of this analysis are presented in Table 6.

Table 6. Summary of two-way analysis of variance comparing differences of background noise, hearing level and subjects

Source of Variance	df	Sum of Squares	Mean Square	F - Statistic
Columns (Noises and HL)	3	18,536.83	6178.94	137.92*
Rows (Ss)	23	4,127.83	179.47	4.01*
Residual	<u>69</u>	<u>3,091.17</u>	44.80	
Total	95	25,755.83		

*Significant at the 0.01 level with df = 3 & 69, and 23 & 69.

¹Wilfred J. Dixon and F. J. Massey, Introduction to Statistical Analysis (New York: McGraw-Hill Book Co., Inc., 1957), pp. 155-163.

²E. F. Lindquist, Design and Analysis of Experiment in Psychology and Education (Boston: Houghton Mifflin Co., 1956), pp. 220-253.

An inspection of Table 6 reveals that a significant difference was obtained across conditions--noise, hearing level and subjects. The significant F does not tell us, however, which means differ from which others.

In order to obtain the above information, an individual comparison technique as outlined by Lindquist¹ was used. The results of individual comparisons, at the 1 percent level of confidence, are shown in Table 7.

Table 7. Results of individual comparisons

Mean = x_{1-4}		2	3	4
$x_1 = 38.42$	1	24.75*	10.83*	16.59*
$x_2 = 13.67$	2		35.58*	8.16*
$x_3 = 49.25$	3			27.42*
$x_4 = 21.83$				

*Significant mean differences at 1 percent level.
(Critical difference = 4.98.)

Inspection of Table 7 reveals that the conditions of noise and presentation level differ significantly from each other. Subjects were also found to differ from each other. Specifically, which subjects differed from which others, however, is not known. Although this information might be

¹Ibid., pp. 220-253.

of clinical significance, the question was not proposed as a purpose of this study and, therefore, was not pursued.

Reliability

In addition to the null hypotheses presented at the outset of this experiment, two questions were proposed. These questions pertained to the reliability of measures of speech discrimination in the presence of noise.

To determine test-retest reliability, a Pearson Product-Moment correlation coefficient was computed.¹ The results of this computation for various conditions are presented in Table 8.

Table 8. Coefficients of correlation (Pearson r) between test and retest for two types of background noise at two hearing levels

<u>Noise</u> (<u>Level</u>)	<u>Pearson Product-Moment</u> <u>Correlation</u>
SB ₂₅	.324
SB ₅₀	.342
WN ₂₅	.560
WN ₅₀	.623

Absolute consistency or reliability of test-retest measures was also obtained by computing a standard error of

¹Allen L. Edwards, Statistical Methods for the Behavioral Sciences (New York: Rinehart and Co., Inc., 1960), pp. 145-148.

measurement (SE_m).¹ Absolute reliability measures are shown in Table 9.

Table 9. Standard error of measurement (SE_m) for two conditions of noise at two hearing levels

<u>Noise</u> (<u>Level</u>)	<u>Standard Error of Measurement</u> (SE_m)
SB ₂₅	8.2
SB ₅₀	4.5
WN ₂₅	6.0
WN ₅₀	3.9

Inspection of Table 9 reveals that for slightly greater than two-thirds of the obtained scores (about 68%), retest scores varied from original test scores in the following order of magnitude. Greatest variability ($\pm 8.2\%$) was found for speech babble noise presented at a 25 dB hearing level. Variability in white noise at a 25 dB HL was ± 6.0 percent; for speech babble at a 50 dB HL it was ± 4.5 percent. Least variability (3.9%) was noted under conditions of white noise at a 50 dB hearing level.

¹Robert L. Ebel, Measuring Educational Achievement (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1965), pp. 331-333, 465.

Discussion

Normative data were collected on the speech discrimination ability of normal hearing young adults. Means and standard deviations were obtained for each of the four listening conditions: (1) speech babble at 25 dB hearing level, (2) speech babble at 50 dB hearing level, (3) white noise at 25 dB hearing level and (4) white noise at 50 dB hearing level. For example, two-thirds of the normal hearing population ranging in age from 18-27 years, should obtain speech discrimination scores ranging from 6-22 percent when the NU Auditory Test No. 6 is presented at a 50 dB hearing level against a background of speech babble noise. This represents a loss in discrimination from normal (100%) of approximately 85 percent. A question might be proposed at this time concerning the speech discrimination performance of the hard-of-hearing population in the presence of background noise. Indeed if these normative data are to be used clinically, the hearing impaired population should be of major concern. The experimental design of this study does not allow for documented scores obtained by persons with hearing impairments. At this point, the normative data represent only a source of comparison. Thus, if a hard-of-hearing person obtained a speech discrimination score in speech babble at a 50 dB hearing level that ranged from 6-22 percent, we could say that he did not deviate from a normal hearing person's performance under the same listening conditions.

Several general trends were noted in the statistical analysis of speech discrimination in the presence of white noise and speech babble.

The results of the present investigation generally support the conclusion that of the two types of noise utilized as masking stimuli in the study, speech babble has a more deleterious effect on speech discrimination than white noise, regardless of presentation level.

This conclusion is in direct opposition to the findings of the Miller¹ study. He found that none of the eight narrow bands nor speech babble noises used to mask speech were any more effective than white noise.

This difference might be explained by the fact that in the Miller study, speech was presented at 95 dB SPL. At this intensity level, it is possible that the differential effects of types of masking noise might be minimal. It is also possible, of course, that type of speech material and method of presentation used were instrumental in the results obtained.

¹George A. Miller, "The Masking of Speech," Psychological Bulletin, XLIV, No. 2 (1947), 105-129.

More recent studies by Higgins¹ and Cluff² both give supporting evidence to the differential effects of white noise and speech babble on discrimination performance. The direction of poorer discrimination, however, differed in the two studies. This seemed to be a function of signal-to-noise ratio in the Cluff study. Higgins found speech discrimination to be poorer in speech babble regardless of signal-to-noise ratio. Cluff, however, found generally lower scores in speech noise below the zero dB signal-to-noise ratio, while lower scores were obtained in white noise at positive signal-to-noise ratios. Since signal-to-noise ratio was not a variable in the present study, the resolution of this question must rest on further experimentation.

Another trend of the present study was quite unexpected, even though there is general agreement in the literature. Generally, it was found that speech discrimination scores were higher at the 25 dB hearing level than at the 50 dB hearing level (see Table 5).

¹Doris Mary Higgins, "The Effects of White Noise and Speech Babble on the Intelligibility of Phonetically Balanced Lists of Monosyllabic Words" (unpublished Masters Thesis, University of Tennessee, 1965), pp. 22-23, 34.

²Gordon L. Cluff, "A Comparison of the Effects of Speech Noise and White Noise on the Discrimination of Speech," Dissertation Abstracts, 1967, 27 (9-A), 3144-3145.

Results of the Hawkins and Stevens¹ study indicated that speech thresholds are affected most by high intensity levels of noise and are hardly affected by low intensity levels of noise. In addition, Sambataro and Pestalozza² concluded that for low intensities of noise, threshold shift was much lower than at high intensities of noise. At a 20 dB level, a 7 dB rise in threshold of perception was noted; at a 40 dB level there was a 21 dB shift. Cluff,³ states, however, that regardless of signal-to-noise ratio, lowest discrimination scores were obtained at 20 dB and the highest scores were obtained at 60 dB.

It must be kept in mind that many differences existed in methodology among these studies. The results of the Cluff study would seem most logical, however, since discrimination scores increase relative to increase in intensity when tested in quiet.

A possible explanation could be presented when two phenomena are viewed simultaneously. One is the type of speech stimuli used and the other is the differential effect of high intensity noise. PB Max. is approximated on the NU

¹J. E. Hawkins and S. S. Stevens, "The Masking of Pure Tones and of Speech by White Noise," Journal of the Acoustical Society of America, XXII (1950), 6-13.

²Carlo Sambataro, M. D., and Guilio Pestalozza, M. D. "Masking and Fatigue Effect of White Noise in Connection with Speech Tests," Laryngoscope, LXII (1952), 1197-1204.

³Gordon L. Cluff, "A Comparison of the Effects of Speech Noise and White Noise on the Discrimination of Speech," Dissertation Abstracts, 1967, 27 (9-A), 3144-3145.

Auditory Test No. 6 at about 24 dB sensation level. At the two presentation levels of this study (25 dB and 50 dB hearing level) it may be assumed that a normal-hearing person taking the test in quiet would achieve approximately the same score at both presentation levels. If we then look at the higher threshold shift at higher intensities of noise, the scores obtained in the present investigation seem warranted. On the Northwestern lists, then, absolute discrimination ability is being affected greatest by the higher noise intensity.

This phenomenon of threshold shift relative to noise level becomes much more complex when the variable of signal-to-noise ratio is a factor. This is evidenced by the results of the Higgins¹ study. She found that presenting the speech stimuli at a 65 dB sensation level with a plus 5 dB signal-to-noise ratio resulted in higher scores than were obtained at a 55 dB sensation level with a minus 5 dB signal-to-noise ratio. It is also interesting to note that both Cluff² and Higgins, who obtained higher discrimination scores at higher presentation levels, utilized the CID W-22 word lists as speech stimuli.

¹Doris Mary Higgins, "The Effects of White Noise and Speech Babble on the Intelligibility of Phonetically Balanced Lists of Monosyllabic Words" (unpublished Masters Thesis, University of Tennessee, 1965), pp. 22-23, 34.

²Gordon L. Cluff, "A Comparison of the Effects of Speech Noise and White Noise on the Discrimination of Speech," Dissertation Abstracts, 1967, 27 (9-A), 3144-3145.

Two questions were proposed at the outset of this investigation relative to reliability. Correlation coefficients and standard errors of measurement were computed in an attempt to answer these questions.

Correlation coefficients were positive but low. It is interesting to note the direction of the correlations relative to background noises. That is, lower correlations were obtained in speech babble, regardless of the level at which it was presented (25 dB and 50 dB HL) than were obtained in white noise, again irrespective of presentation level.

Standard errors of measurement were also obtained across conditions (see Table 6). Standard errors ranged from 3.9 percent to 8.2 percent. This variability is quite reasonable when compared to results of the Rintelmann and Jetty¹ study. Their standardization of the NU Auditory Test No. 6 at a 24 dB sensation level in quiet resulted in standard errors of measurement ranging from 2.82 percent to 4.51 percent (see Table 1). So when the increased difficulty of the task of listening to the Northwestern lists in the presence of noise is taken into account, the obtained standard errors seem to be in order.

¹William F. Rintelmann and Albert J. Jetty, "Reliability of Speech Discrimination Testing Using CNC Monosyllabic Words" (unpublished study, Michigan State University, 1968).

It is again of interest to note the direction of the standard errors. In this reliability measure highest percent variations were obtained at 25 dB hearing level regardless of background noise, whereas lowest variability was obtained at 50 dB hearing level. It might be recalled at this point that higher discrimination scores were obtained at 25 dB HL in speech babble and in white noise than were obtained at 50 dB HL in the two background noises (see Table 5).

There is a subtle interaction which seems to be taking place between the variables of the background noise and hearing levels employed in this investigation. This interaction, however, cannot be adequately interpreted at this time. Further research is needed to take a closer look at these two variables.

Summary

Normative data were collected for speech discrimination of normal hearing young adults in the presence of background noise. These norms encompass four listening conditions: (1) speech babble at 25 dB HL, (2) speech babble at 50 dB HL, (3) white noise at 25 dB HL and (4) white noise at 50 dB HL.

From the statistical analysis of data in this chapter, it can be seen that all of the null hypotheses cited at the outset of this investigation can be rejected.

Specifically, the first null hypothesis was concerned with significant differences between speech discrimination scores as a function of presentation level. It was theorized that no significant difference existed between scores obtained at 25 dB hearing level and those obtained at 50 dB hearing level. This null hypothesis can be rejected. There was a difference, and upon inspection of two statistical measures, it may be noted that differences are statistically significant.

The second null hypothesis proposed that no significant difference occurred between speech discrimination scores against a background of white noise and those obtained against a background of speech babble when a zero dB signal-to-noise ratio was employed. Again, this hypothesis could be rejected. There was a statistically significant difference between speech discrimination scores as a function of background noise.

The third null hypothesis stated that no significant differences occurred among subjects. This hypothesis could also be rejected in that subjects did significantly differ from each other in their performance.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The purpose of this study was essentially to obtain normative data on the speech discrimination ability of young normal hearing adults in the presence of two types of background noise presented at two clinically useful hearing levels. Specifically, the NU Auditory Test No. 6 was presented at 25 dB and 50 dB hearing level in the presence of white noise and speech babble. All testing was accomplished in a sound field. Speech and noise were presented simultaneously through both speakers at a zero dB signal-to-noise ratio.

Three secondary purposes of the study concerned interaction among the variables. One was to obtain test-retest reliability data on speech discrimination in the presence of both types of noise. A second was to determine whether subjects significantly differed from one another in their discrimination performance. Thirdly, it was questioned whether or not there was a significant difference between scores obtained at 25 dB hearing level as opposed to those obtained at 50 dB hearing level.

Summary

Twenty-four normal hearing young adults were employed in this study. Eighteen of these subjects were female, six were male. The age range was 18-27 years.

Screening procedures included a pure-tone air conduction test for the frequencies 500, 1000 and 2000 Hz. Speech reception thresholds were also obtained. Criteria for selection were pure-tone and speech thresholds within a range of 0 to 10 dB.

The speech discrimination test consisted of listening to NU Auditory Test No. 6, Form A, Lists I, II, III and IV in a sound field. Form B, of the Northwestern Lists was used throughout the retest sessions. The speech stimuli and white noise or speech babble were presented at 25 dB and 50 dB hearing levels. A zero dB signal-to-noise ratio was retained throughout the study. A counter-balancing technique was used in scheduling the presentation of word lists. Lists I and III were heard in speech babble, lists II and IV were heard in white noise. Lists I and II were always presented at 25 dB hearing level, whereas lists III and IV were presented at 50 dB hearing level.

Normative data were collected for speech discrimination of normal hearing young adults in the presence of background noise. These norms encompass four listening conditions: (1) speech babble at 25 dB HL, (2) speech babble at 50 dB HL, (3) white noise at 25 dB HL and (4) white noise at 50 dB HL.

The results of this study further indicate: (1) There is a significant difference between discrimination scores obtained at a 25 dB hearing level and those obtained at a 50 dB hearing level. (2) There is a significant difference between discrimination scores obtained against a background of white noise and those obtained against a background of speech babble when both are presented at zero dB signal-to-noise ratio. (3) There is a significant difference in discrimination scores among subjects.

In addition, the relationship between discrimination performance in white noise and speech babble was found to be positive but quite low. Higher correlations were obtained in speech babble than in white noise regardless of presentation level. A measure of absolute reliability indicated that discrimination score variability from test to retest ranged from 3.9 percent to 8.2 percent. Using the standard error of measurement, it was found that higher percent variations were found at 25 dB hearing level as opposed to 50 dB hearing level irrespective of background noise.

Finally, two general trends were noted in the statistical analysis of data. The first was that of the two types of noise utilized as masking stimuli, speech babble had a more deleterious affect on speech discrimination than white noise, regardless of presentation level. Secondly, it was observed that speech discrimination scores were higher at 25 dB hearing level than at 50 dB hearing level.

Conclusions

Within the limitations of the methodology of the present study, it may be concluded that:

1. Approximately two-thirds of the normal hearing population ranging in age from 18-27 years would obtain speech discrimination scores ranging from 28.49-48.35 percent when the NU Auditory Test No. 6 is presented at a 25 dB hearing level against a background of speech babble noise.
2. Approximately two-thirds of the normal hearing population ranging in age from 18-27 years would obtain speech discrimination scores ranging from 5.68-21.66 percent when the NU Auditory Test No. 6 is presented at a 50 dB hearing level against a background of speech babble noise.
3. Approximately two-thirds of the normal hearing population ranging in age from 18-27 years would obtain speech discrimination scores ranging from 39.84-58.66 percent when the NU Auditory Test No. 6 is presented at a 25 dB hearing level against a background of white noise.
4. Approximately two-thirds of the normal hearing population ranging in age from 18-27 years would obtain speech discrimination scores ranging from 15.24-28.42 percent when the NU Auditory Test No. 6 is presented at a 50 dB hearing level against a background of white noise.

5. Speech discrimination scores are affected most by high intensity levels of background noise, when both speech and noise are presented at a zero dB signal-to-noise ratio.
6. Speech babble has a more deleterious effect on speech discrimination than white noise, regardless of presentation level.
7. Normal hearing subjects differ from each other in their discrimination performance in the presence of background noise.
8. Test-retest correlations were quite low, however standard errors of measurement were not out of keeping with standard errors obtained with similar clinical measures utilized in the routine audiological evaluation. It would seem, therefore, that the normative data could be used reliably in a clinical setting if the conditions of the present study were utilized.

Recommendations for Further Research

Suggestions for additional research would include the following:

1. Further information is needed regarding speech discrimination in a background of both speech babble and white noise, while utilizing several additional signal-to-noise ratios.

2. The interaction between background noise and presentation level, especially when both speech and noise stimuli are presented at zero dB signal-to-noise ratio, should be investigated further.
3. The discrimination ability of normal hearing subjects in a background of noise utilizing both the CID W-22 and NU Auditory Test No. 6 word lists should be investigated.

BIBLIOGRAPHY

BIBLIOGRAPHY

Books

- Dixon, Wilfred J., and Massey, F. J. Introduction to Statistical Analysis. 2nd ed. New York: McGraw-Hill Book Co., Inc., 1957.
- Ebel, Robert L. Measuring Educational Achievement. 1st ed. New Jersey: Prentice-Hall, Inc., 1965.
- Edwards, Allen L. Statistical Methods for the Behavioral Sciences. 1st ed. New York: Rinehart and Co., Inc., 1965.
- Fletcher, Harvey. Speech and Hearing in Communication. 1st ed. New York: D. Van Nostrand Co., Inc., 1961.
- Hirsh, Ira J. The Measurement of Hearing. 1st ed. New York: McGraw-Hill Book Co., Inc., 1952.
- Lindquist, E. F. Design and Analysis of Experiment in Psychology and Education. 1st ed. Boston: Houghton Mifflin Co., 1956.
- Stevens, S. S., ed. Handbook of Experimental Psychology. New York: John Wiley Sons, Inc., 1951.

Periodicals

- Carhart, Raymond, and Jerger, James F. "Preferred Method for Clinical Determination of Pure-Tone Thresholds." Journal of Speech and Hearing Disorders, XXIV (1959), 330-345.
- Carhart, Raymond, Tillman, Tom, and Johnson, Kenneth. "Binaural Masking of Speech by Periodically Modulated Noise." Journal of the Acoustical Society of America, XXXIX (1966), 1037-1050.

- Cox, Jerome R., and Bilger, Robert C. "Suggestion Relative to the Standardization of Loudness-Balance Data for the Telephonics TDH-39 Earphone." Journal of the Acoustical Society of America, XXXII (1960), 1081-1082.
- Davis, Hallowell, and Kranz, Fred. "International Standard Reference Zero for Pure-Tone Audiometers and Its Relation to the Evaluation of Impairment of Hearing." Journal of Speech and Hearing Research, VII (1964), 7-16.
- Hawkins, J. E., and Stevens, S. S. "The Masking of Pure Tones and Speech by White Noise." Journal of the Acoustical Society of America, XXII (1950), 6-13.
- Hirsh, Ira J., and Bowman, W. D. "Masking of Speech by Bands of Noise." Journal of the Acoustical Society of America, XXV (1953), 1175-1180.
- Lehiste, I., and Peterson, G. E. "Linguistic Considerations in the Study of Speech Intelligibility." Journal of the Acoustical Society of America, XXXI (1959), 280-286.
- Miller, George A. "The Masking of Speech." Psychological Bulletin, XLIV (1947), 105-129.
- Miller, George A., and Licklider, J. C. R. "The Intelligibility of Interrupted Speech." Journal of the Acoustical Society of America, XXII (1950), 167-173.
- Palva, Tuano. "Studies of Hearing for Pure Tones and Speech in Noise." Acta Oto-Laryngologica, XLV (1955), 231-243.
- Pestalozza, Guilio, and Lazzaroni, Angelo. "Noise Effect on Speech Perception in Clinical and Experimental Types of Deafness." Acta Oto-Laryngologica, XLIV (1954), 350-358.
- Peterson, G. E., and Lehiste, I. "Revised CNC Lists for Auditory Tests." Journal of Speech and Hearing Disorders, XXVII (1962), 62-70.
- Ross, M., Huntington, D., Newby H., and Dixon, R. "Speech Discrimination of Hearing-Impaired Individuals in Noise." Journal of Auditory Research, V (1965), 47-72.
- Sambataro, Carlo, and Pestalozza, Guilio. "Masking and Fatigue Effect of White Noise in Connection with Speech Tests." Laryngoscope, LXII (1952), 1197-1204.
- Simonton, Kinsey M., and Hedgecock, LeRoy D. "A Laboratory Assessment of Hearing Acuity for Voice Signals Against a Background of Noise." Annals of Otology, Rhinology and Laryngology, LXII (1953), 735-747.

Unpublished Materials

- Higgins, Doris Mary. "The Effects of White Noise and Speech Babble on the Intelligibility of Phonetically Balanced Lists of Monosyllabic Words." Unpublished Master's Thesis, 1965.
- Lovering, Larry J. "Reliability of Speech Discrimination Testing in Two Types of Background Noise Using CNC Monosyllabic Words." Unpublished study, Michigan State University, 1968.
- Rintelmann, William F., and Jetty, Albert J. "Reliability of Speech Discrimination Testing Using CNC Monosyllabic Words." Unpublished study, Michigan State University, 1968.

Other Sources

- Abrams, M. H., et al. "Speech in Noise; a Study of the Factors Determining Its Intelligibility." Psycho-acoustic Lab., Harvard University, O.S.R.D., Report 4023, September 1, 1944.
- Cluff, Gordon L. "A Comparison of the Effects of Speech Noise and White Noise on the Discrimination of Speech." Dissertation Abstracts, 1967, 27 (9-A), 3144-3145.
- Tillman, Tom W., and Carhart, Raymond. "An Expanded Test for Speech Discrimination Utilizing CNC Monosyllabic Words (NU Auditory Test No. 6)," U. S. School of Aerospace Medicine - Technical Research, 66-55, June, 1966, pp. 1-12.

APPENDICES

APPENDIX A

DISCRIMINATION TEST SCORES FOR INDIVIDUAL SUBJECTS UNDER ALL EXPERIMENTAL CONDITIONS

Subjects	SB (25 dB)	SB (50 dB)	WN (25 dB)	WN (50 dB)
1	28	18	48	24
2	36	22	52	20
3	60	26	72	36
4	32	12	64	14
5	32	14	54	8
6	34	0	42	22
7	36	10	34	20
8	50	16	54	32
9	58	22	56	20
10	26	12	48	16
11	46	0	58	24
12	42	6	38	10
13	42	18	50	12
14	44	10	52	26
15	40	16	44	38
16	48	12	46	20
17	36	20	58	28
18	32	14	36	26
19	20	0	42	14
20	40	24	46	18
21	48	22	56	28
22	28	12	42	26
23	36	22	56	28
24	28	0	34	14

APPENDIX B

DISCRIMINATION RETEST SCORES FOR INDIVIDUAL SUBJECTS UNDER ALL EXPERIMENTAL CONDITIONS

Subjects	SB (25 dB)	SB (50 dB)	WN (25 dB)	WN (50 dB)
1	34	8	50	28
2	36	4	54	16
3	56	2	72	26
4	36	14	68	18
5	62	16	66	22
6	50	0	66	30
7	46	8	40	22
8	54	8	56	30
9	30	8	52	14
10	32	6	60	12
11	64	4	50	14
12	42	18	54	14
13	44	14	52	12
14	50	0	52	22
15	30	4	58	32
16	50	0	66	12
17	36	12	46	18
18	44	6	44	16
19	40	0	48	16
20	28	10	40	20
21	46	14	54	30
22	36	0	54	24
23	46	10	58	20
24	36	2	38	16

MICHIGAN STATE UNIVERSITY LIBRARIES



3 1293 03177 7067