 70-4480

PEDERSON, Olen Thagaard, 1935-
THE UNIVERSITY OF OKLAHOMA SPEECH
TEST #6.

The University of Oklahoma, Ph.D., 1969
Health Sciences, hearing

University Microfilms, Inc., Ann Arbor, Michigan

THE UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

THE UNIVERSITY OF OKLAHOMA SPEECH TEST #6

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

DOCTOR OF PHILOSOPHY

BY

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Oklahoma City, Oklahoma

1969

THE UNIVERSITY OF OKLAHOMA SPEECH TEST #6

APPROVED BY

DISSERTATION COMMITTEE

ACKNOWLEDGMENTS

The author wishes to express his gratitude to Dr. Gerald Studebaker, director of this study, for his guidance, encouragement and criticism throughout the preparation of this dissertation.

Appreciation is expressed to Dr. Joseph Barry, Dr. William Cooper and Dr. Howard Ruhm, not only for their constructive comments concerning the design of this study, but for their participation as members of the dissertation committee. Appreciation is also expressed to Dr. R. B. Deal, Jr. and to Mr. Doyle Stewart, for counsel and assistance in the preparation of the statistical analysis of the data, to Mrs. Rose Titsworth, typist, without whom the paper probably never could have been finished and to each of the subjects who participated in this investigation.

Mr. and Mrs. Ole T. Pederson, parents of the author, are given a special "Thank You" for all the support and enthusiasm extended throughout a rather lengthy program of higher education.

To each of the above: THANK YOU.

This study was planned and conducted at the University of Oklahoma Medical School Speech and Hearing Center in Oklahoma City, Oklahoma. It was supported in part by Rehabilitation Grant # RD-2401-S-67 of the Rehabilitative Services Administration, Department of Health, Education and Welfare, Washington, D.C.

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CHAPTER I

INTRODUCTION

For many years researchers have striven to develop speech tests which will reliably and validly evaluate speech-discrimination ability. Investigators have improved their testing methods as knowledge concerning the speech stimulus has expanded. They have directed their attentions primarily toward the development of speech tests which indicate the extent of a patient's handicap and his ability to benefit from amplification. Major efforts have been directed toward the development of tests which differentiate degrees of assistance offered by different amplification devices for a given patient.

Speech-sound tests were originally designed for testing communication systems. The speech tests currently used for clinical hearing evaluations and for hearing-aid evaluations are based on those early communications-systems tests. The tests used most commonly today for testing speech discrimination are constructed of monosyllabic, meaningful test items (words); are fifty words in length and are phonetically or phonemically balanced.

Phonetics is the science of speech sounds in which a specific symbol always represents the same sound. Phonemics is the linguistic science which involves the study of phonemes. Phonemes are catagories of related speech sounds which may vary under different conditions, but which are interpreted by the listener as belonging to the same group and representing the same sound.

Lehiste and Peterson (21) disagree with the use of the term phonetic balance, as applied to classic speech-discrimination tests, and substitute the term phonemic balance. Their disagreement is based upon the observation that the phonetic structure of a sound within a particular phoneme class varies because of speaker differences, context differences, etc. They contend that phonetic balance is not possible within a word list of reasonable length but that phonemic balance is possible because listeners will perceive and classify each speech sound into one of a relatively small number of phonemic catagories.

The fifty-word tests provide a general indication of a patient's discrimination ability but attempts to evaluate speech-reception analytically have not been successful (2, 29, 33). Reliable and valid differentiations between hearing aids also have not been achieved (2, 34).

Realization of the need for better tests and attempts to satisfy this need have resulted in discussions among audiologists, otologists, hearing-aid dealers and hearing-aid manufacturers which have underscored the need for new test materials and formats. Thus, researchers have been led to seek other approaches to the evaluation of speech discrimination.

Investigators concerned with speech-reception abilities of normal listeners during the past ten years have given attention to the development of new test paradigms; paradigms which necessarily abandon phonetic or phonemic balance. Among these procedures are the Rhyme Test of Fairbanks (6); the Closed-Response Set of House, et al. (17) and the Minimal Contrasts Test of Griffiths (10). The authors utilized these tests in attempts to study speech-reception abilities more analytically; that is, to evaluate the kind of errors made in addition to enumerating how many errors are made. Some preliminary efforts also have been made toward analyzing speech-reception abilities of hard-of-hearing listeners with these newer procedures (27, 28, 38).

Catagorization of speech sounds with certain commonalities into groups is often used in linguistic and phonetic discussions. The catagories most commonly used have as their basis certain features of the articulatory production of speech sounds which are assumed to produce discriminable acoustic characteristics. These catagories are voicing (i.e. comprised of voiced, voiceless and nasal classifications), duration (i.e. differentiated on the basis of the temporal length of production), place of articulation (i.e. the major characteristic is the point of the greatest vocal passage restriction) and manner of production (i.e. plosives, fricatives, etc.).

Although all of the implications of the results are not as yet clear a number of interesting indications are revealed by the results of the above studies. Some of these are:

1. A closed-response-set format restricts the available response vocabulary and, thereby, reduces learning effects, word-frequency effects and word-familiarity effects (17, 32).
2. The closed-response formats are more amenable to the analysis of error patterns because of a reduction in the influence of the contaminating factors noted in 1.

3. Both normally-hearing and hard-of-hearing individuals seldom confuse voiced, voiceless and/or nasal consonant sounds with each other (25, 26, 27, 38).
4. Both normally-hearing and hard-of-hearing subjects confuse consonant sounds which have different manners of production with only moderate frequency (25, 26, 27, 38).
5. The most prevalent area of consonant confusion appears to be among consonant sounds with a common voicing mode and a common manner of production. Sound groups of this type differ from each other primarily in place of articultation, i.e. productions occurring in the front of the mouth versus productions occurring in the mid-mouth region or back of the mouth, etc. (25, 36, 38).
6. There are indications that speech discrimination deteriorates in a hierarchial manner with increased noise interference. A step-like discrimination deterioration occurs which appears to be the result of confusions among phoneme groups with successive resistances to intelligibility breakdown rather than confusions among individual phonemes (10, 25, 37, 38).
7. Limited research with vowel sounds also indicates a hierarchial resistance to interference. The sound confusions among the vowels also appear to occur in accordance with some scheme, however, the research presently available is not sufficient to allow concise description of any definitive patterns (38).

The obvious shortcomings of the PB speech tests currently being used clinically suggest the need for new approaches. A review of the literature indicates that test formats derived in recent years for the evaluation of speech perception by normal listeners may be applicable to the evaluation of defective hearing. The closed-response set was chosen as the basic experimental paradigm for this study after comparing the advantages and disadvantages of various procedures. This paradigm has been modified in a manner suggested by the minimal-contrasts concept of Griffiths (10) to enhance error-matrix-analysis potentialities.

This project is directed toward the development of such a speech-discrimination test and presents the results of a study designed to establish the performance of normally-hearing subjects on that test.

CHAPTER II

A REVIEW OF THE LITERATURE

Clinicians have used speech tests in the evaluation of defective hearing since the early part of this century. A fundamental goal in the design of auditory tests is to compare individual's abilities to respond to auditory stimuli. Speech has high face validity as a test stimulus because of man's obvious dependence upon it in his day-to-day affairs.

Speech tests have been used primarily as diagnostic tools to support results obtained with the more analytical pure-tone tests. Attempts also have been made to use speech tests to estimate the usefulness of an individual's hearing and to indicate the need for rehabilitation procedures, but the results of these attempts have been less than completely satisfactory. Tests of discrimination have been used to determine how the auditory system functions at intensities above threshold, but entirely acceptable results have not been obtained. The tests are less reliable than is desirable and current speech-discrimination tests cannot be used to evaluate hearing defects in an analytical manner (on the basis of error patterns).

The present investigation is concerned with speech-discrimination testing, exclusively. Consequently, the following review will be restricted to investigations principally concerned with this aspect of speech-reception testing.

Phonetically- and Phonemically-Balanced Tests

Discrimination tests assess the ability of a listener to repeat speech signals correctly in controlled sound environments. Although studies at the Bell Te.ephone Laboratories before 1930 were responsible for establishing the basic method of articulation testing with speech stimuli (8), the test materials used in the original clinical tests for determining a patient's speech-discrimination loss were developed at the Psycho-Acoustic Laboratory of Harvard University (5). These test lists, the PAL PB-50's developed by Egan, consisted of twenty, monosyllabic word lists with fifty test words each (5). Each list was assembled according to the criterion of phonetic balance. Phonetic balance refers to the use of a phonetic composition in each list which is representative of the frequency of usage of phonemes in spoken American English. Phonetic balance was used in order to develop test materials which were capable of evaluating the ability of electronic devices in transmitting speech or which were capable of evaluating the degree to which hearing loss interferes with the understanding of speech.

The PAL PB-50's were named for their origin at the Harvard Psycho-Acoustic Laboratories, their phonetic balance and their fifty item length (5). These lists were constructed within the confines of the following criteria: (1) monosyllabic structure, (2) equal average difficulty, (3) equal range of difficulty, (4) equal phonetic composition, (5) a composition representative of English Speech (Phonetic Balance) and (6) words in common usage (5). Initially, the word lists were only twenty-five words in length but they were lengthened to fifty words after Egan found that the shorter lists were not sufficiently reliable.

The PB-50 lists were developed for the evaluation of military communications equipment, however, Davis (3), in 1948, reported on their use as diagnostic, clinical hearing tests. The tests were found to differentiate between conductive and non-conductive hearing losses. This differentiation was later reported to be due to the manner in which the lists were spoken and recorded rather than any inherent characteristic of the lists themselves (35).

In 1947, Hirsh (15) reported a consensus from clinicians, based on their test results, indicating that the PB-50's vocabulary was not sufficiently familiar to many patients and that the available PB-50 recordings were not in an adequately standard form. Hirsh, Davis, Silverman, Reynolds, Eldert and Benson (16) developed and published the CID (Central Institute for the Deaf) Auditory Test W-22 articulation-test lists in conjunction with other speech-test materials. These lists were, in essence, modifications of the Egan lists developed with the intention of eliminating some of the aforementioned problems. The modifications involved two basic improvements. First, the basic PB-list vocabulary was restricted to increase patient familiarity with the test items and to increase the rigidness of the phonetic balance within the test. Second, the tests were recorded on magnetic tape in order that test items could be copied and, as a result, would be more nearly identical from test to test. (The PB-50's were recorded on a disc recorder so that each scrambling was a separate recording). Hirsh selected one-hundred-twenty of the more familiar Egan items and added eighty words of similar familiarity and difficulty in developing a test-word vocabulary of two-hundred words. The use of familiar words had the effect of reducing the influence of learning on the results. The test vocabulary then was divided into four, fifty-word, phonetically-balanced lists and six randomizations were made of each list. The phonetic composition of the Hirsh lists was based on a study of the phonetic composition within a series of business calls recorded by the Bell Telephone Laboratories (9) and Dewey's investigation of phonetic composition (4). Hirsh then rerecorded the words for equal intelligibility which increased the slope of the articulation-gain function and the homogeneity of the lists. A different talker (Hirsh) from the person who recorded the Egan lists (Ruth Hughes) was used (35).

The intelligibility of the W-22 tests was found to be higher at comparable intensities for normally-hearing subjects than that of the PB-50's (22). This finding caused Hirsh and his co-workers to hesitate in recommending the W-22 lists for determination of discrimination loss (35). Also, soon after the W-22's were published informal reports indicated that the W-22's would not distinguish between conductive and non-conductive losses (35). Although Silverman and Hirsh were not certain which variables were creating the differences between the PB-50's and the W-22's, they reported that the differences were not attributable to phonetic balance because both materials utilized phonetic balance as a design criterion. Comparisons subsequently were conducted between the original PB-50 recordings (spoken by Hughes), PB-50 lists spoken by Hirsh and PB-50 lists spoken by Reynolds (a female talker) to investigate the significance of talker differences among the different recordings. The results of this inquiry indicated consistent differences between the Hirsh and Hughes recordings and the Hughes and Reynolds recordings, but only small differences between the recordings of Hirsh and Reynolds (35). The differences noted among these recordings were concluded to result from differences among talker presentations but the specific speaking characteristics which were responsible were not determined.

Silverman and Hirsh (35) then suggested that one of these characteristics may be differences in the duration of test-item presentations by Hughes and the other speakers. They reported that differences were easily noticed between the talkers' productions during casual listening, but they had not studied them formally. This contention was supported by the results from a study by Fairbanks (7) in which he compared recordings of good talkers before and after compressing the speech so that the duration of the words was shortened. His results indicated that intelligibility decreased as the durations of the speech signals decreased.

The next major development in speech-discrimination tests occurred in 1959 when Lehiste and Peterson (31) presented a series of word lists for speech-discrimination testing based on the concept of phonemic balance. These authors stressed the use of the term "phonemic balance" rather than "phonetic balance" because listeners may be expected to perceive a sound as falling within a particular phoneme catagory even though considerable phonetic variations may occur within different pronunciations of that same phoneme. The Lehiste-Peterson speech-discrimination testing materials, named CNC lists, were ten, fifty-item, monosyllabic-word lists composed of initial-consonant, vowel-nucleus, final-consonant combinations. The phonemic balance was achieved by using each phoneme within a list in proportion to those found in Thorndike and Lorge's list of 1,000 most common words. A limited amount of information is available concerning the validity, reliability and interchangability of these lists, however, standard recordings of the Lehiste-Peterson lists are not available. As a result, each investigator must record his own lists and the outcome of such studies is likely to depend as much or more on the recording technique as on the lists themselves.

Tillman, Carhart and Wilber developed the Northwestern University (NU) Auditory Test #4 first reported in an Air Force technical report in 1963 (40). This test includes two lists, each consisting of fifty CNC monosyllables, with six randomizations for each list. The one-hundred word vocabulary was drawn from the Lehiste-Peterson word lists. These lists were designed in accordance with the principle of phonemic balance advocated by Lehiste and Peterson. The N.U. #4 lists, however, were designed to conform more precisely to a phonemic-balance objective than the Lehiste-Peterson test lists (40). Research with the N.U. #4 lists at Northwestern indicated that the test materials were so restricted in number that learning effects and possibly other variables produced differential results when the tests were used repeatedly with individual subjects. Tillman and Carhart, therefore, developed the NU #6 test, as an expansion of NU #4 (39).

The NU #6 test has four, fifty-word lists with six randomizations for each list. List 1 and list 2 are essentially the same lists as those which make up NU #4. Lists 3 and 4 represent two entirely new word groups, but, like the words in NU #4, they were selected from the original Lehiste and Peterson CNC vocabulary and conform to the same phonemic-balance design. Comparisons of studies of reliability and interchangability of the two N.U. tests conducted by Tillman and Carhart (39) indicated that the tests are essentially identical and interchangable. The percent-per-dB increase in discrimination score for both Northwestern tests was 5.6 percent per dB.

Sommerville (36), in 1967, used the NU #6 vocabulary in a study designed to investigate whether independently produced recording's would produce results comparable to standard recordings offered by commercial organizations and whether the results would be similar to those obtained by Carhart and Tillman. The results of her study indicated that the Oklahoma University recordings of the NU #6 lists were equally reliable and interchangeable, and produced essentially the same percent-per-dB slope as obtained by Carhart and Tillman with the NU #6 (39) and by others (13, 16) using the W-22 lists (approximately 5.0 percent-per-dB discrimination-score increases). These results supported her contention that clinics could produce their own lists, independently, obtaining comparable results when the recordings are produced carefully.

All of the aforementioned tests were developed basically as quantitative tests of overall speech-discrimination ability. The desirability of using error patterns to differentiate among the various types of hearing loss has been recognized for some time. However, attempts to evaluate speech discrimination in this manner, to date, have been somewhat unsuccessful.

Oyer and Doudna (29), in 1959, attempted an analysis of the responses made by hard-of-hearing subjects with varying hearing-loss etiologies. The W-22 word lists were employed as the speech stimuli for this study. The subject's incorrect responses were analyzed with respect to frequency of occurrence and the phoneme confusions which occurred. A greater proportion of errors was found among the vowel phonemes, but consonant errors occurred more frequently. Discrimination losses were found to decrease with repeated testing which indicated that learning effects were significant variables in the test situation. Oyer and Doudna also report that essentially the same sound confusions occur in all the etiological catagories studied. The authcrs reported, however, that the error information was too limited with this test to distinguish specific error patterns or phoneme-error tendencies. In all instances substitutions occurred more frequently than either omissions or additions, although omissions and additions occurred more frequently in the final than in the initial positions of the test words.

Schultz (33), in 1964, also employed the W-22 lists in an attempt to determine a pattern of phonemic-confusion in auditory-discrimination errors. Schultz stated that responses logically should exhibit phonemic lawfulness and, as a consequence, evaluation of the subject's incorrect responses should yield predictable patterns. He was unable to analyze the errors made on W-22 lists, however, into such patterns. This outcome, in fact, is not surprising in view of the large number of constraints imposed on the subjects' responses which are not acoustic in character (e.g. the need to respond in words, the subjects' vocabulary, etc.). Schultz attributed this failure to the fact that the W-22 lists do not yield enough information to identify a hierarchy of error confusions or even specific error patterns. He did conclude that vowels, which had previously been reported as contributing little to auditory discrimination, were of sufficient significance in discrimination to warrant further exploration. He also suggested that tests should be devised to provide for separate testing and analysis of vowel and consonant speech elements.

Multiple-Choice Tests

The discrimination tests discussed thus far have all been tests designed within phonetic- or phonemic-balance formats in order to approximate more closely the phonemic content of common English messages. They are also all "open-response" tests. That is, when a test-item is presented, the only restrictions imposed upon the response are the limits of the subjects' vocabulary and the very large number of ways in which the subject may perceive the test-signal.

In fact, however, no speech test developed to date is entirely open with respect to the response alternatives available to the subject. Tests using meaningful words constrain the subjects to use meaningful-word responses and tests using nonsense syllables constrain the subjects to use nonsense-syllable responses. Even the Miller and Nicely study (24) imposes constraints on the subject's responses and may be considered a closed-response test with a fairly large but well known number of alternatives in the set. The term "open response" is used here to mean that the subject may choose any response he wishes within the constraints of the total vocabulary available to him. A principal problem is that the response alternatives available may vary widely from subject to subject.

In recent years, several researchers (6, 10, 17, 26, 38) have developed new test forms and paradigms which limit the response alternatives available to the subject. Fairbanks (6) utilized a "semi-closed" set in which each test stimulus and all of the acceptable responses for it have common phoneme roots. (Tests of this type are called rhyme tests because the words of a set rhyme with each other when the variable phoneme is in the initial positions). The subject's task is to select any response that he can think of with the given phoneme root. Later researchers (10, 17, 26, 38) have limited the response choices to a specific set which are given to the subject in advance. This latter design has become known as the closed-response set.

Closed-response sets were used in a number of early hearing tests (24), but they were not used for the analytical study of discrimination abilities. The Victoria University Education of the Deaf New Standard Testing Lists (24), for example, utilized a six-choice nonsense-word set for speech-discrimination testing, but this test was utilized to obtain only quantitative total scores. The closed-response set has probably most often been used in children's testing as in the Macfarland's Test Method (24). This test utilized the closed-response set as a means of determining quantitative discrimination-score totals with no attempts to describe discrimination errors analytically. The set, in this instance, was a series of pictures of familiar monosyllabic words. The child's task involved pointing to a picture when a test word was presented.

Tests also were constructed for early hearing-aid evaluations which employed rhyming words in two-, three- and four-choice sets (24). These tests were used in attempts to determine gross frequency ranges involved in patient's speech-reception problems and, as such, were perhaps the earliest efforts to evaluate the qualitative aspects of speech hearing using the closed-response set. These tests were used in attempts to select hearing aids for individual patients.

Haagen (12), in 1945, and Black (1), in 1957, reported multiple-choice, speech-intelligibility tests used in rating speakers intelligibility over communications systems. The test vocabulary for these tests consisted of one- and two-syllable words which were combined into comparison sets. There was no apparent study of phoneme difficulty or phoneme-confusion patterns incorporated in these early studies. These tests were designed primarily to evaluate the talker rather than the listener. The authors, therefore, did not attempt to evaluate defective hearing or make an acoustic analysis of the error patterns (the latter being nearly impossible because of the way the words are combined in the sets). Hutton, Curray, and Armstrong (18) attempted to use the Haagen lists to evaluate hard-of-hearing subjects discrimination abilities, however, they did not use an error-pattern analysis.

In 1955, Miller and Nicely (25) investigated the phoneme error-substitution patterns of normal listeners in a format where the constraints of vocabulary and language were removed. They studied sixteen consonants, placed in nonsense syllables formed by adding the vowel /a/, and investigated the influences of increasing noise and of various filter settings upon the nonsense-syllable (consonant sound) identification. Miller and Nicely's work made use of the forced-choice concept in that the subjects' responses were limited to the sixteen nonsense words; however, the response range was sufficiently large that the format placed little restriction upon the subjects' responses. The test items and response vocabulary were presented to the subjects prior to the data collection in order to familiarize them with the task and the nonsense words. The errors of the individual subjects were not investigated nor quantified since significant differences in performance among the normal subjects were not expected. The data were analyzed to study the sounds involved in the discrimination errors (designated as sound confusions) and the effects of noise and filtering upon the confusions and error frequency. The data were presented in error matrices.

The authors grouped the confusions according to features of the articulation process for summarization. This allowed the evaluation of each feature as if it were a separate communication channel, and also permitted the evaluation of the combined data. Voicing and nasality identifications were only influenced by noise levels great enough to make response performance nearly random. Frication and duration identifications were affected less than place of articulation identifications by increased noise levels, but the noise levels had a much greater effect on identification of these features than on voicing and nasality identifications. It was also indicated that while high-pass filter systems create a problem primarily attributable to "audibility", low-pass filter systems create a problem better described as "confusibility". Considerable correspondence was noted between the effects of low-pass filtering and those of random-noise interference. It was noted that those phonemes hardest to hear correctly in test situations were those which would be most easily seen on the talker's lips. Increased noise levels interfered with the correct identification of the test items in a manner which appeared to have structure and pattern; however, the experimental design employed by Miller and Nicely (25) did not include a means of identifying and specifying specific error-confusion pairs.

The Rhyme Test was published by Fairbanks (6) in 1958. Fairbanks selected a vocabulary of 250 common monosyllabic words which contain fifty groups (sets) of five rhyming words. He developed five comparable, 50-item, test forms from this vocabulary as test-presentation materials to study phonemic differentiation. An answer sheet was developed which displayed the rhyming portion of the test words with a blank before the common word ending. The subject responded by adding the appropriate consonant to form the word he hears.

The Rhyme Test used essentially the same format as Miller and Nicely (25) (i.e., common root for possible responses, fill-in-the-blank response task), however, the Fairbanks test differed from that of Miller and Nicely in the use of meaningful words and in the response limitation imposed by the use of rhyming words. The use of meaningful words increased the face validity of the test while somewhat narrowing the number of possible response choices and obscuring the basis upon which the subject made his choice. These latter limitations varied according to the number of meaningful words meeting each rhyme structure available to the individual subject. It was estimated that from six to sixteen choices (with a median of eleven) were available for the different test words. Fairbanks also noted that the chance probability varied from subject to subject according to each subject's vocabulary. The vocabulary involves eighteen consonants which have been reported to account for approximately 90.0 percent of all consonant occurrences in English (9).

Tests were presented to normal-hearing subjects at approximately 65-dB Sl in a range of vowel/noise (VN) environments ranging from +15 to -6 dB (the noise characteristics were not specified). Word recognition percentage between the 9-dB and -6-dB V/N ratios became poorer linearly as the noise was increased. The slope was determined to be approximately 3.0 percent per dB. Fairbanks (6) felt that the heterogeneity of the test lists and the intelligibility slope (because of the similarity with results from studies of PB words in noise) suggest that this test may be suitable for determining discrimination functions. Although the test was not designed for detailed analysis of the substitution pattern, Fairbanks noted that both the acoustical characteristics of the consonant itself and those of the vowel-consonant transition influenced identification of the test word. He interpreted this to indicate that the Rhyme Test "intercepts the speech-reception process at a stage in which a substantial portion of the variance in word identification is attributable to the distinctive features of phonemes" (6, p. 599). Fairbanks indicated that other variaties of test forms (i.e. exclusive distributions of consonants, vowel/consonant transitions, voiceless consonants, etc.) were possible with this design permitting analytical studies of speech reception of individuals or communication systems.

In 1965, House, Williams, Hecker and Kryter (17), presented the MRT (Modified Rhyme Test), a modification of Fairbanks' Rhyme Test (6) which is composed of CVC (consonant-vowel-consonant) words. The MRT is a speech-test which limits the number of possible responses available to a subject for each test-item presentation and which presents the complete vocabulary of each set on an accompanying response sheet (the closed-response set). This technique appreciably reduces the subject-training time necessary in order to insure the subject's familiarity with the test vocabulary and greatly reduces response variations attributable to word-frequency effects. The MRT consists of fifty sets of six, "rhyming", CVC words which occur commonly in English. In twenty-five sets, the words differ within a set only for the initial-consonant position. The remaining twenty-five sets differ in the final-consonant position. The listener's task is to select the word from each set which he hears presented to him. Six signal-to-noise (S/N) ratios and two talkers were employed in the study. House, et al. (17) report the following results: (a) a 5.0 percent-per-dB correct-response curve, (b) improved discrimination ability as the S/N ratio became increasingly more favorable, (c) variations in the discrimination scores obtained which were dependent upon the talker, (d) no significant alteration in the discrimination score resulted from repeated testing, (e) a greater frequency of discrimination errors occurred for the final-consonant test words and (f) a greater frequency of discrimination errors was noted for voiced than unvoiced consonant sounds (6).

The previously cited studies pointed out the possibility of evaluating discrimination-error patterns and served as forerunners to several more detailed investigations of phoneme identification.

In 1967, Griffiths (10) presented a "diagnostic articulation test", the Rhyming Minimal-Contrasts Test. This work is based on the House, et al. study (17), information derived from Miller and Nicely's work (25), experiments at the Haskin's Laboratory (23) and an analysis of single-dimensional, or minimal-feature, phoneme contrasts which occur in English. Griffiths' features or dimensions of a phoneme refer to the differences between phonemes which occur as a result of the way in which each phoneme is articulated (10). Griffiths catagorizes phonemes according to place (position in the mouth most involved in the phoneme production), manner (describes the release of the vocal air stream) or voicing (voiced, voiceless or nasal). This means of classifying speech sounds has been shown to describe best the way in which they are perceived.[1] Griffiths' test consists of 250 monosyllabic words (primarily CVC's), with 150 of them taken from the House, et al. vocabulary (17). The vocabulary includes fifty sets of five words each which have common CV or VC phoneme composition and differ only in the consonant to be tested. The test consonants within each set differ unidimensionally or multidimensionally. The sets were designed to offer minimal-contrast comparisons but often included the variations among several dimensions (i.e. place and manner, manner and voicing, etc.) within a single set because of the problem of locating meaningful words involving comparison along only one articulatory dimension. These sets make up the closed-response vocabulary available to the subject for each test item presentation.

Griffith's complete test (10) consists of five lists of test presentation items with fifty words to the list. A different word from each set is used as the test item in each list. In twenty-five sets the initial consonant represents the test-item. The final-consonant phoneme is the test phoneme in the other twenty-five sets. Griffiths presented the lists in seven S/N ratios, ranging from -12 to +8 in 4 dB S/N steps, and in quiet. The noise power spectrum approximated the long-term power spectrum of speech. Griffiths' data reveals a response-score slope which changes over noise levels by approximately 3.0 percent per dB with intelligibility decreasing as noise levels are successively increased.

Although House, et al. (17) and other earlier studies (6, 25, 29) have indicated that initial consonants are more easily recognized than

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[1] For a description of the motor theory of speech perception see Lehiste (20).

final consonants, Griffiths' results failed to agree with this indication. Final consonant items, however, did deteriorate in intelligibility more rapidly in the presence of increased noise levels than the initial consonant items. Analytical evaluation of the data by confusion matrices revealed no unusual confusion patterns but did demonstrate large numbers of confusions occurring between the /v/ and /ð/ phonemes and between the /f/ and /θ/ phonemes throughout all S/N and quiet conditions. Further study of these phonemes indicated that the acoustic cues for these sound pairs offer little auditory basis for distinguishing between them even in quiet and even with the talker exaggerating their characteristics. Griffiths stated that the analysis of the Minimal-Contrasts Test revealed that it is a valid and reliable diagnostic tool, offering, additionally, a means of analytically evaluating the errors in a speech-communications system (10). He points out, however, that some response choices in the test are probably based on the fact that they are the only available words in that particular set with a certain dimensional characteristic.

Kruel, Nixon, Kryter, Bell, Lang and Schubert (19) published a proposed clinical, speech-discrimination test in 1968 which involved a further modification of the MRT by House, et al. (17). This test includes essentially the same vocabulary as the House, et al. test, but the items are arranged in three original test forms with six randomizations each. The test sets include six "rhyming" test items varying either in the initial-consonant or the final-consonant position. The major changes in this test from the House, et al. work include recordings of the speech signals combined with the noise on the tapes, different S/N levels for each talker to equate the intelligibility of different talkers, more answer sheets, the use of a carrier phrase, and separate noise levels accompanying comparable forms of the test to produce discrimination scores of 96.0, 83.0 and 75.0 percent with normally-hearing subjects. Performances falling below 90.0, 70.0 and 60.0 percent at the three signal-to-noise levels respectively were considered to be abnormal. An analysis of the errors was not carried out. It was suggested, however, that an item analysis may offer further information.

In 1968, Owens and Schubert (27) presented a report on a test designed for use with hard-of-hearing subjects. The test consisted of CVC words arranged in four alternative sets. The variable phoneme was a consonant in either the initial or final position. The items were selected as "popular" alternate choices which confined the alternatives in a set to voice-voiceless comparisons and to consonants that can occur with the stem phoneme. Voiced and voiceless consonants were rarely confused and the liquids /r/ and /l/ were seldom confused with other phonemes. Nasal consonants seemed only to be confused with other nasals. The probability of error for phonemes in the final position appeared to be higher than that for initials. Owens and Schubert discussed the results and their general agreement with similar studies, advocating the closed-set testing method. They stated further that the most efficient sets appear to originate from words differing only in specific phoneme characteristics.

Owens, Talbott and Schubert (28) studied vowel discrimination among hard-of-hearing listeners. All common vowels and diphthongs of English were included in CVC, monosyllabic-word, closed-response sets differing only in the medial-vowel position. The sets for both this vowel study and the previously-discussed consonant study included a fifth, "blank" item (an open-choice item) in each set as an attempt to gather information on distortions taking no recognizable phonemic shape. Although this entry actually changed the test into an open-response format and increased the number of response alternatives, the lack of subject responses to the blank entry on both tests suggests that the test format, in effect, remained a four-item, forced-choice task for both experiments. The vowel test posed little problem for the hard-of-hearing subjects suggesting that vowel items will not make efficient discrimination-test items in a closed-response set.

Studebaker (38) also developed a modification of the House, et al. design (17). His goal, however, was to develop a paradigm in which the dependence of the results upon acoustic cues would be maximized. This work included a test for vowel study, initial-consonant study and final-consonant study. Selection of the consonants for study was based on the work of Heinz and Stevens (14). A modification of the House, et al. design (17) which minimized the number of acoustic variables varied in a given set seemed most promising as a format which would permit the analysis of error patterns. (Although this concept was similar to the goals of Griffiths, his work had not yet been published). Subsequently, the phonemes were classified on the basis of articulation catagories rather than purely acoustical cues in keeping with the motor theory of speech perception. Early investigations in Studebaker's study compared four-word forced-choice sets in which two articulation parameters were compared in pairs within given sets. A total of four parameters were used including voicing, manner of production, place of articulation and nasality. The results from this work were found to be in agreement with indications from Miller and Nicely's 1955 study (25), with studies presented at the 1967 ASHA convention by Owens and Schubert (26) and with other studies in this area (6, 10, 17). Studebaker noted, however, that further investigation within the "manner of production" sections (i.e. plosives, fricatives, etc.) may allow much more useful analyses if the items in a set are varied only in the "place of articulation" (front, mid or back area of the mouth). An initial-consonant test and a final-consonant test were designed to evaluate this concept with four-word, forced-choice items. Each test item within a test set utilized a common word root and varied only in one consonant position, e.g. bail, dale, gale, ail. The consonant contrasts that were selected differed only with respect to their place-of-articulation. The manner of production in each set was held constant.

The results of this latter part of Studebaker's (38) study indicated that the test format was reasonably flexible and efficient so that, with minimal alterations, a clinical and/or research discrimination test may be possible. It was pointed out that normative data would be required before this test format could be applied to the hearing-loss population.

The purpose of this study is to refine and broaden the scope of the test format presented by Studebaker (38) and to gather the normative data required as prerequisite to its use with hearing-loss populations.

CHAPTER III

INSTRUMENTATION AND PROCEDURES

Introduction

Recently, investigators have developed new speech-test paradigms in efforts to reduce the contaminating influences of word frequency, word familiarity and learning effects while producing a test that is reliable, of short duration, easily administered and easily scored. The closed-response set is a test procedure which may meet some or all of these requirements. This investigation used the closed-response set in an attempt to develop a practical test exhibiting these desirable characteristics and which also allows an analytic evaluation of the subject's speech-discrimination ability.

The purposes of this study were to develop and evaluate a speech discrimination test paradigm based on the results of certain previous investigations (6, 10, 17, 25, 38) and to develop the scramblings, answer sheets and recordings needed to evaluate the procedure. The resulting test is referred to as the University of Oklahoma Speech Test #6 (UOST #6). Another principal goal of this investigation was to obtain normative data on the developed test. The design of the UOST #6 and a description of the instrumentation and procedures utilized in this study follow.

Test Development

Test-Item Selection

Recent research efforts of House, et al. (17), Griffiths (10) and Studebaker (38) have suggested that the closed-response set is a technique which may be useful in clinical speech-reception testing. The following discussion concerns the development of UOST #6, a speech-discrimination test of the closed-response-set type.

UOST #6 is made up of three independent subtests. The three subtests are an initial-consonant subtest, a final-consonant subtest and a medial-vowel subtest (i.e., referring to the position of the phoneme varied in the items of a set).

The following criteria were applied to the selection of the test stimuli:

1. Meaningful words were selected as test items whenever possible because these stimuli are easier for the subject than nonsense materials. Meaningful words reduce learning effects by reducing the time needed for a subject to familiarize himself with the test item.
2. All test items are CVC words because CVC's conveniently lend themselves to the varying of the sound in one phoneme position at a time within a set, while maintaining a meaningful word.
3. All test items within a set are identical except for those sounds in the test position of the item.
4. Test items were chosen for familiarity, when a choice was possible, in order to reduce to a minimum the time necessary for familiarization by the subject.

Consonant Tests. Two additional requirements that were applied in the case of the consonant subtests are:

1. The variable phonemes in each set were selected to vary only in the place of articulation, to the greatest extent possible. It was necessary, however, to deviate from this criterion for one word within each consonant test set. In this instance the variable phoneme position was left vacant.
2. Identical test-phoneme groups were used in both initial and final positions.

Four common meaningful English words which fit the test-phoneme set /f/, /θ/, /s/, /-/[2] in the final position are not available. It was necessary, therefore, to use one "word" in this final-consonant set which is not meaningful. The set that seemed the most reasonable choice of those available was selected. It includes the words roof, Ruth, rue and the nonsense syllable produced as /rus/.

Three phonemes to be evaluated within each test set were selected to have identical manners of production. The phonemes in each set were attached to a common root. Thereby, the items of a set differed only in the initial or in the final position. Word constructions of -vc and cv- were included in each set because most of the catagories used contain only three members, e.g. /b/,/d/, /g/. A salutary effect is that the absence of the consonant can be compared with the presence of consonants. Voiced and voiceless sound groups were included but were contained within separate sets.

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[2]The symbol /-/ is used to indicate that the phoneme test position is left vacant.

The consonant groups chosen for study in both initial and final positions were:

(1) /p/, /t/, /k/, /-/

(2) /b/, /d/, /g/, /-/

(3) /f/, /s/, /θ/, /-/

(4) /v/, /z/, /ð/, /-/

(5) /tʃ/, /ʃ/, /st/, /-/

The words used in the consonant subtests are as follows:

Initial Consonant Subtest

pair	tear	care	air
bail	dale	gale	ail
fin	thin	sin	in
vee	thee	zee	e
stop	chop	shop	hop

Final Consonant Subtest

pop	pot	pock	pa
robe	rode	rogue	row
roof	Ruth	ruse	rue
live	lithe	lies	lie
least	leech	leash	lee

<u>Vowel Test</u>. The vowel sounds chosen for study are /i/, /I/, /ɛ/, /ae/, /e/, /o/, /ʌ/, /u/. These particular vowels were chosen because they represent a broad sample of the vowels utilized in American-English speech. They also are all pure-vowel sounds. Dipthongs were excluded in order to simplify the interpretation of the results. (Recognition is

given to the fact that many classify /e/ as a dipthong. However, in the present study every effort was made to pronounce this vowel in a manner as near to a pure vowel as possible). Each vowel is located within a b - t sound environment for this test. This particular sound environment was chosen over other sound combinations only because meaningful words were available within this construction for all the vowels under test.

The words which make up the vowel subtests of UOST #6 are below:

Vowel Subtest

beat bit bet bat bait boat but boot

Test Paradigm

UOST #6 has an independent section or subtest for each of the three phoneme word positions investigated. The test design is identical for the initial-consonant subtest and the final-consonant subtest but the design for the medial-vowel subtest is different.

The initial-consonant subtest and the final-consonant subtest each consist of five, four-item, closed-response sets as noted above. Each item is used as the presentation stimulus four times with it's subtest. This design offers a within-test check upon the subject's response consistency and produced an eighty-item subtest for both initial- and final-consonant phonemes (4 items by 5 sets by 4 replications).

Four-item test sets were used because these reduce chance performance to managable levels while permitting the inclusion of phonemes which differ only in the place of articulation. The four-item set also allows for the inclusion of the /-/ alternative since most of the place-of-articulation phoneme groups occur in threes. Enlarging the sets to five or more makes it impossible to find words which keep the stem constant and the test phoneme variable only in the place of articulation.

The vowel subtest consists of one, eight-item, closed-response set. Each word is used as the test item eight times during the subtest producing a sixty-four item subtest. A different design was used for the vowels because: (1) a satisfactory means of subclassifying the vowels could not be found, (2) a larger number of meaningful words were available with the same phonemic stem allowing a larger set to be developed and (3) a larger set reduced the percent correct on the basis of chance.

The test-item presentation order for each of the subtests is quasi-random within each half of each subtest, i.e. the order dictated by a random-numbers table was carried out without replacement. Hence, an equal number of presentations of each item was maintained in each half of each subtest. This arrangement allowed a simple statistical comparison of the scores obtained for the first half of the presentations with those obtained for the second half of the presentations.

The basis for the error-matrix studies is formed by varying the speech sounds in only one phoneme position within a set and by offering as the responses available to the subject only those sounds which are most likely to be confused with the presented sound. Finally, the test is arranged so that all the alternatives are equally probable. Thereby, the influences of vocabulary, context and learning are reduced to a minimum. An additional expected advantage of the closed-response set of this type is that for each item presented a cross-comparison of all items within that particular set is made possible. The subject's response denotes not only which item is selected but also which items are rejected.

Talker

Only one talker was recorded for this investigation although it is recognized that talker differences are major sources of variation in speech-test results. The use of more than one talker was rejected because of the additional time requirement that would have been imposed on each subject and the great increase in design complexity which would be necessary. Using more than one talker would have made an across-subject analysis untenable because all subjects could not have been tested using all talkers within a reasonable time period. Results from an earlier study by Studebaker (38) indicate that these intersubject comparisons may be a principal asset of the closed-response design. Therefore, only one talker was used for this study.

A male clinical audiologist, experienced in monitored live-voice, speech-test administration, was selected as the talker. He was judged to speak with the General-American dialect. Practice sessions were conducted during which the talker was trained by a Speech Pathologist to ensure the use of General-American dialect in all test-item utterances. Further, the talker was trained to speak the test items with consistency and with a speed and duration approximately equal to that of conversational speech. The latter training was specifically intended to reduce exaggeration, prolongations and individual word-production variations.

Recording Instrumentation

The UOST #6 was recorded in a sound-isolated, two-room test suite at the University of Oklahoma Medical Center Speech and Hearing Clinic. Visual communication between the test-room and the control-room was possible through an acoustically-damped window. The ambient noise levels within the test room at the octave bands centered at 250 Hz and above were found to be no greater than 16-dB SPL. The levels observed in the octave bands below the 250-HZ-centered band were as high as 40-dB SPL. These noise levels were assumed to be acceptable because the signal-to-noise ratio at the recording microphone was at least 30 dB and because the major portion of the noise intensity was concentrated well below 250 Hz.

The frequency responses of the Ampex tape recorders were measured before the recording sessions to insure that the frequency-response characteristics were within the manufacturer's tolerance specifications.

All of the test recordings were made on one-and-one-half mil acetate recording tape at a tape speed of seven-and-one-half inches per second. The master (first phase) recordings were made with an Altec microphone, model 628A and a dual-channel Ampex, model-354 tape recorder. Second-phase recordings were made with the Ampex 354 used as a tape transport and playback unit connected to an Electronic Instruments Co. decade-resistance box, model 1171, adjusted to 600Ω resistance. The line of transmission continued from the decade-resistance box through a Daven 1-dB-step attenuator to a two-channel Ampex model-601 tape-recorder. The third phase of recording consisted of the Ampex 601, serving as transport and playback unit, connected to the decade-resistance box and then to the Ampex 354, serving as the recording unit. The Ampex 354 again served as transport and playback unit for the fourth phase. It was connected to the Ampex 601 for recording through the decade-resistance box. The fifth phase was an exact duplication, electronically, of phase three. All recordings were obtained with the complete electronic lash-up receiving power through a Sola Electronics constant-voltage transformer to reduce the influence of any power fluctuations.

Test Assembly and Recording Procedures

The entire UOST #6 test battery has five test scramblings (item orders) for each of the three subtests. A scrambling refers to a different order of the same words. The item sequences for all fifteen test scramblings were developed from a ten-thousand-number list of random numbers applied without replacement.

Each test scrambling was introduced by the talker with the following introduction:

This is Oklahoma Speech Test #6. Initial Consonant Test (the latter varied as to Initial Consonant Test, Final Consonant Test, Medial Vowel Test). Are you ready?........

The above introduction was followed by the initial items of the particular scrambling. The test presentations were incorporated into a common carrier sentence to have the test items more closely approximate conversational utterances and to notify the subject of the approaching presentation. The carrier phrase was "The word is...". The talker monitored the phrase to produce a 0-dB deflection on a separate VU meter, allowing the following test word to follow as a natural combination with the utterance. A five-second interval elapsed between the onsets of each successive introductory phrase.

The recording of the test lists for the UOST #6 required several separate recording phases. First, the talker recorded a master list for each subtest. These lists were then monitored on a VU meter by a jury of five individuals to obtain a consensus judgment determining the observed differences in dB among the test-word-presentation peaks. Second, each master list was rerecorded for equal intensity (a Daven one-dB-step attenuator was inserted into the instrumentation between the two recorders) to present the VU peaks of the test items as nearly as possible at one intensity level.

The third phase consisted of rerecording each of the three rerecorded masters five times. This produced five equal recordings of the test list for each subtest. Four of the recordings of each list were then cut, reordered and spliced in sequences which matched the second, third, fourth and fifth test-presentation orders of each subtest. Fourth, each of the five test-order tapes of each subtest then was rerecorded on whole tapes to prevent breaking, clicks, etc. during the experimental runs. These tapes could have been used as the experimental tapes; however, the fourth recordings were made on the Ampex 601 and the original master tapes had been recorded on the Ampex 354. The possibility of introducing an uncontrolled variable into the study by using a playback machine different from that used to record the lists, and factors of convenience, made it desirable to use the Ampex 354 as the test-presentation instrument. Thus, for the fifth phase, another rerecording was made on clean unmarred tape to have the final test tapes recorded on the Ampex 354. These latter recordings are the fifteen experimental scramblings used in this investigation. Each subtest form was recorded on an individual tape to allow testing in any scrambling sequence conveniently.

The talker monitored his voice on a VU meter which was set up so that a 0-dB VU reading would produce a -10 dB deflection of the meter of the recorder. All tapes subsequently were recorded at approximately

-10 dB on the recording tape recorder's VU meter. The experimental test tapes were monitored at various times during the rerecording procedure for intensity variations, stress variations, duration variations, abnormal pronunciations and temporal-spacing variations between test items in order to insure that there were no apparent differences or abnormalities among them.

A 1000-Hz calibration-tone tape was recorded, cut into sections and spliced to each test tape preceding the test introduction. The calibration-tone was recorded at an intensity level which was about 10 dB more intense than the presentation level of the test words. The difference between the level of the tone and the test words allowed a mid-meter calibration reference (for accurate calibration control) while the test words were presented at lower levels, minimizing the distortion due to system saturation.

The previously-recorded test tapes were played for the subject test sessions by means of an Ampex model-354 tape recorder. The tape recorder output was connected to a Grason-Stadler model-162 speech audiometer. A pair of TDH-39 air-conduction earphones mounted in MX-41-AR cushions held by a standard clinical headband was connected to the output from the speech audiometer. The noise generator within the speech audiometer was used as the masking-noise source. Intensity control of the speech and noise signals was maintained during the experimental sessions with the two 120-dB range, 2-dB-per-step attenuators which were an integral part of the speech audiometer.

Response Sheets

Each subtest had four different response sheets. The subjects' response task with the consonant-subtests was to circle the presented word. The correct response for the vowel subtest was to put a check in the space under the appropriate test item. Copies of the response sheets are found in Appendix A.

Each initial-consonant-subtest and final-consonant-subtest response sheet consisted of sixteen replications of the five, four-item closed-response sets for each of the respective consonant subtests. Each item was counter-balanced for position such that an item appeared in each position within the set an equal number of times (two) in each half of the response sheet. This counterbalance was controlled within each half of every response sheet so that first-half and second-half portions of a sheet were identical. The purpose of this tactic was to prevent a response-sheet item-position bias which could interfere with the analysis of the results from the two halves of each subtest. Item-placement counterbalance also was controlled across response sheets so that comparable item-position sequences on different sheets appeared at different locations on the forms.

The vowel-subtest response sheets had the single closed-response set printed across the top of the sheet and sixty-four sets of blank spaces aligned in columns beneath the test items. The four response sheets for the vowel test differed only within the sequential alignment of the test-word's positions across the top of the sheet. The counterbalance for these items was developed by dividing the eight response items into four two-item pairs. Each pair of items was placed in a different position on each of the response sheets. Furthermore, each item within an item pair was rotated in position from response sheet to response sheet. The counterbalancing of the eight test items is illustrated below in numerically-coded form:

1 2, 3 4, 5 6, 7 8

4 3, 2 1, 8 7, 6 5

7 8, 5 6, 3 4, 1 2

6 5, 8 7, 2 1, 4 3

There were not enough response sheets to utilize each item in every item position. This counterbalance pattern, however, was considered to be adequate to largely counteract any item-position bias.

Test Presentation

An experimental investigation of the performance of normally-hearing subjects on the UOST #6 was conducted following its development. The purposes of the study were to establish norms for the UOST #6 in the presence of various levels of interferring noise, to determine the inter-subject variability associated with the UOST #6, to evaluate the interchangability of the test scramblings, to estimate the differences in scores obtained with the two halves of each subtest and to study the error patterns produced by normally-hearing subjects.

Subjects

The subjects for this investigation included ten males and ten females from the age of eighteen to twenty-five years, inclusive. Each subject volunteered for participation in the study while attending either St. Anthony's School of Nursing in Oklahoma City; Central State College in Edmond, Oklahoma; Phillips University in Enid, Oklahoma or the University of Oklahoma Medical School in Oklahoma City. Homogeneous aspects of the subjects which are pertinent to this experiment are their ages, their hearing sensitivity (tested to be no poorer than 10 dB for the frequencies 250, 500, 1000, 2000, 4000 and 8000 Hz, RE 1964 ISO reference levels) and the fact that all subjects had passed the entrance requirements for their respective schools.

Procedures

Each subject was seated in the inner room of a two-room audiological test suite at the University of Oklahoma Medical Center Speech and Hearing Clinic during the experimental sessions. The subject wore a pair of earphones, one of which was non-functional. Either the right ear or the left ear was used as the test ear with alternate subjects so a total of five males and five females were tested using the right ear and five males and five females were tested using the left ear.

Each experimental session began with the establishment of the subjects' most-comfortable-listening level and a demonstration of the test. The subject's task included listening to each test-item presentation, selecting the item that he felt had been presented from the appropriate closed-response set and marking that item on the response sheet. After the procedure and task were understood the subject began a series of five test runs for each of the three subtests. Each of the five test scramblings for each subtest was paired with one of five different noise environments. The subjects' responses were recorded on one of the four response forms available for each subtest. Each of the five test lists of each subtest was recorded on a different response form during each subject's experimental session within the counterbalanced presentation design. Further, all test scramblings, noise conditions and response sheets were counterbalanced with respect to temporal order and coincidence across subjects. The counterbalanced presentation order is displayed in Table 1. The counterbalancing and test-item randomization were such that:

1. Each subtest was used first, second, and third with approximately an equal number of subjects. The scrambling presentation order varied according to a balanced design throughout the experiment.
2. Test scramblings, S/N ratios and response sheets were used in different temporal orders with various combinations of these factors appearing together an equal number of times.
3. The male- and female-subject groups were paired so that a male and a female subject received the same test and S/N-ratio combinations.

The competing signal selected for this study was white noise. This noise was selected from several alternatives. Sawtooth noise and other noises characterized by heavy low-frequency components were rejected because of the problems of high intensity-level requirements for adequate masking and the problems associated with low-frequency masking spread at the higher intensity levels. During recent years there has been a trend in speech reception studies toward the use of competing messages and "cafeteria noise" type of interferences. They have an obvious strongpoint of high face validity in that these noises are similar to "noises" most often encountered in daily communication. This trend was not overlooked, but these noises were rejected due to the difficulties presented by the considerable variations in intensity over time.

Many earlier studies have used white noise, thus selection of

TABLE 1

COUNTERBALANCE SCHEDULE FOR SUBJECTS INCLUDING S/N RATIOS, SCRAMBLINGS, RESPONSE SHEETS, SUBTEST SEQUENCES, AND TEST EARS

Subject	1st	2nd	3rd	4th	5th	Subtest	Test Ear
I	A,5,d	B,2,c	C,4,b	D,1,a	E,3,d	I,F,V	L
II	B,1,a	D,4,b	A,2,c	E,5,d	C,3,a	V,F,I	R
III	C,2,c	E,1,a	B,3,d	A,4,b	D,5,c	F,V,I	L
IV	D,3,6	C,5,d	E,2,a	B,4,c	A,1,b	I,V,F	R
V	E,4,d	A,3,c	D,2,b	C,1,a	B,5,d	V,I,F	L
VI	A,5,a	B,2,b	C,4,c	D,1,d	E,3,a	F,I,V	R
VII	B,1,c	D,4,a	A,2,d	E,5,b	C,3,c	I,F,V	L
VIII	C,2,b	E,1,d	B,3,a	A,4,c	D,5,b	V,F,I	R
IX	D,3,d	C,5,c	E,2,b	B,4,a	A,1,d	F,V,I	L
X	E,4,a	A,3,b	D,2,c	C,1,d	B,5,a	F,I,V	R
XI	A,5,c	B,2,a	C,4,d	D,1,b	E,3,c	F,I,V	L
XII	B,1,b	D,4,d	A,2,a	E,5,e	C,3,b	V,I,F	R
XIII	C,2,d	E,1,c	B,3,a	A,4,b	D,5,d	I,V,F	L
XIV	D,3,a	C,5,b	E,2,c	B,4,d	A,1,a	F,V,I	R
XV	E,4,c	A,3,a	D,2,d	C,1,b	B,5,c	V,F,I	L
XVI	A,5,b	B,2,d	C,4,a	D,1,c	E,3,b	I,F,V	R
XVII	B,1,d	D,4,c	A,2,b	E,5,a	C,3,d	F,I,V	L
XVIII	C,2,a	E,1,b	B,3,c	A,4,d	D,5,a	V,I,F	R
XIX	D,3,c	C,5,a	E,2,d	B,4,b	A,1,c	I,V,F	L
XX	E,4,b	A,3,d	D,2,a	C,1,c	B,5,b	I,F,V	R

Roman Numerals = Subjects

Capital Letters (A,B,C,D,E) = S/N Ratios (A is worst S/N ratio for each subtest)

Numbers = Scramblings

Lower Case Letters = Answer Sheets

Capital Letters (I,F,V) = Subtest (Initial-Consonant Subtest, Final-Consonant Subtest and Vowel Subtest, respectively)

Capital Letters (R,L) = Test Ear (Right and Left, respectively) this noise permitted comparison with these previous efforts. Further, many audiology clinics have this noise available permitting direct application of the results of this study in the clinical situation. Finally, it is a masker that offers interference in all frequency bands and a masker that produces masking of speech signals which increases linearly with increasing noise levels. Other noises which met essentially all of the aforementioned criteria were "pink" noise and "speech" noise. White noise was selected primarily because of its more extensive use in previous research.

The noise was presented at five different intensity levels in order to develop intelligibility (S/N) functions for UOST #6 with normally-hearing individuals and to establish normative values at various interference levels. The S/N ratios used with the three subtests were not identical. They were determined on the basis of the work by House, et al. (17), the data obtained by Studebaker (38) and the requirements of the proposed analysis method.

The above reports indicated that the S/N ratios to be used with the initial-consonant subtest should be approximately 4 dB poorer than S/N ratios used with the final-consonant subtest in order to produce approximately equal performance. Pilot-study data with the UOST #6, however, indicated that a 2 dB difference between S/N ratios of the final-consonant and initial-consonant subtests of the UOST #6 would result in approximately equal performance. The initial-consonant subtest, therefore, was presented at S/N levels which were 2 dB poorer than the final consonant subtest in this investigation. The fifty-percent intelligibility point on the vowel subtest function was found to occur at a 6 dB poorer S/N ratio on the average than did this same point on the initial-consonant subtest function. Further pilot work was done to investigate the range of S/N ratios necessary to represent adequately the intelligibility functions of the UOST #6 subtests. Five S/N ratio steps of 4 dB intervals appeared to be adequate to indicate the intelligibility (S/N) function of the consonant subtests, however, five 2 dB steps in S/N improvement (a steeper gain function) were more appropriate to plot the intelligibility (S/N) function for the vowel subtest.

The S/N ratios for this test battery were set at the following values on these bases.

Final Consonant Subtest	-8 dB, -4 dB, 0 dB, +4 dB, +8 dB
Initial Consonant Subtest	-10 dB, -6 dB, -2 dB, 2 dB, 6 dB
Vowel Subtest	-16 dB, -14 dB, -12 dB, -10 dB, -8 dB.

In all instances speech- and noise-signal levels were noted on the Grason-Stadler, Model-162 speech-audiometer meter.

CHAPTER IV

RESULTS AND DISCUSSION

Introduction

The present project was designed to develop a speech-discrimination hearing test and to evaluate its performance using a group of normally-hearing persons. This test, labeled the UOST #6, utilizes the closed-response set as its basic paradigm. It is a three-part test including initial-consonant, final-consonant and medial-vowel subtests. The test phonemes are placed in constant phonemic environments of the consonant-vowel-consonant type construction.

The function of each of the subdivisions of UOST #6 is to evaluate an individual's ability to select the correct phoneme from among a group of phonemes which differ from the presented phoneme in certain ways. In the consonant subtests the items in a set vary only in the place of production, with a few exceptions which are discussed elsewhere.

UOST #6 was administered to ten female and ten male subjects using five different test scramblings and four different response sheets for each of the three subtests. UOST #6 was presented to each subject at five different S/N ratios. All test forms, response forms and noise levels were counterbalanced for order and for appearance together within sex groups, within first and second halves of each subtest, within the presentation of the materials to each subject and, finally, over the entire sequence of the conditions used in this investigation.

Quantitative Analysis

Tables 2, 3 and 4 present the quantitative results for each of the three subtests. The results are summarized over the variables investigated and are expressed as percentages of correct performance.

A separate analysis of variance was carried out for the data analysis of each of the three subtests. This was necessary because each subtest was designed to evaluate a different parameter of speech-sound recognition, because the consonant and vowel test formats were not alike and because it was necessary to use different S/N ratios with each of the subtests. Each of the three analyses of variance employed factored arrangements in which the main effects were test scramblings, S/N ratios, sex groups and first-half versus second-half comparisons.

The results of the analyses of variance for the final-consonant subtest, the initial-consonant subtest and the vowel subtest, respectively, are presented in Tables 5, 6, and 7.

The data for each subtest will also be presented in error-matrix form and discussed descriptively in later sections.

Final Consonant Subtest

The results of the analysis of variance for the final-consonant subtest, as shown in Table 5, indicate that the main effect S/N ratio is significant well beyond the .01 level. This, of course, is an expected outcome. All other main effects and interactions are not significant at the .05 level. The nonsignificant main effects (except for S/N ratio) and nonsignificant interactions suggest that the two halves of the

TABLE 2

RESULTS OBTAINED ON THE FINAL-CONSONANT SUBTEST BROKEN DOWN BY S/N RATIO, SCRAMBLING, SEX, AND FIRST HALF-SECOND HALF IN PERCENT CORRECT

First Half vs Second Half

S/N Ratio	Scrambling 1		2		3		4		5		Total	
in dB	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2
-8	57.5	44.4	51.9	46.2	46.9	41.2	45.6	49.4	40.6	47.5	48.5	45.8
-4	55.0	57.7	49.4	58.7	53.7	60.6	63.1	68.7	55.6	62.5	55.4	60.8
0	71.2	70.6	67.5	69.4	68.7	71.9	68.1	65.0	71.2	73.7	69.4	70.0
4	72.5	80.0	73.7	77.5	66.2	75.0	76.9	75.6	74.4	74.4	73.0	76.5
8	86.2	83.7	86.9	85.6	82.5	82.5	83.1	82.5	85.0	83.1	85.0	83.5
Total	68.5	66.5	65.9	67.5	63.6	66.2	67.4	68.2	65.4	68.2	66.1	67.3

Male vs Female

S/N Ratio	Scrambling 1		2		3		4		5		Total	
in dB	M	F	M	F	M	F	M	F	M	F	M	F
-8	50.0	51.9	53.1	45.0	46.2	41.9	46.9	48.1	42.5	45.6	47.7	46.5
-4	58.1	50.6	55.0	53.1	63.1	51.2	63.7	68.1	56.9	61.2	59.4	57.0
0	73.1	68.7	67.5	69.4	71.9	68.7	62.5	70.6	68.1	76.9	68.6	71.0
4	74.4	78.1	77.5	73.7	71.2	70.0	81.9	70.6	81.2	67.5	77.2	72.0
8	87.5	82.5	84.4	88.1	86.9	78.1	84.4	81.2	81.2	86.9	85.0	83.0
Total	68.6	66.4	67.5	65.9	67.9	62.0	67.9	67.7	66.0	67.6	67.6	65.9

Combined

S/N Ratio in dB	Scrambling 1	2	3	4	5	Total
-8	50.9	49.0	44.1	47.5	44.1	47.0
-4	54.4	54.0	57.2	65.9	59.0	58.4
0	70.9	68.4	70.3	66.6	72.5	70.0
4	76.3	75.6	70.6	76.3	74.4	75.5
8	85.0	86.3	82.5	82.8	84.1	84.0
Total	67.5	66.7	64.9	67.8	66.8	66.7

TABLE 3

RESULTS OBTAINED ON THE INITIAL-CONSONANT SUBTEST BROKEN DOWN BY S/N RATIO, SCRAMBLING, SEX, AND FIRST HALF-SECOND HALF IN PERCENT CORRECT

First Half vs Second Half												
	Scrambling											
S/N Ratio	1		2		3		4		5		Total	
in dB	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2
-8	64.4	50.6	48.1	54.4	49.4	50.6	53.1	51.9	51.9	56.2	53.3	53.0
-4	62.5	68.1	60.0	61.9	66.9	64.4	70.6	67.5	69.4	72.5	66.2	67.4
0	79.4	76.2	73.1	66.2	79.4	73.7	75.0	73.7	75.0	76.2	77.0	73.5
4	80.0	82.5	88.7	85.6	82.5	86.9	78.7	79.4	78.1	82.5	81.6	83.4
8	87.5	89.4	90.0	93.7	90.0	95.6	90.0	86.2	93.1	90.6	90.0	91.0
Total	74.7	73.4	72.0	72.4	73.6	74.2	73.5	72.0	73.5	75.6	73.5	73.5

Male vs Female												
	Scrambling											
S/N Ratio	1		2		3		4		5		Total	
in dB	M	F	M	F	M	F	M	F	M	F	M	F
-8	60.6	54.4	55.0	47.5	48.7	51.2	56.9	48.1	47.5	60.6	53.7	52.4
-4	70.6	60.0	62.5	59.4	67.5	63.7	70.0	68.1	73.7	68.1	68.9	63.9
0	76.9	78.7	70.6	68.7	78.7	74.4	72.5	76.2	73.1	78.1	74.4	75.2
4	80.6	81.9	88.7	85.6	86.2	83.1	85.6	72.5	83.7	76.9	85.0	80.0
8	91.2	85.6	95.0	88.7	91.2	94.4	88.1	88.1	95.0	88.7	92.0	89.0
Total	76.0	72.1	74.4	70.0	74.5	73.4	74.6	70.6	74.6	74.5	74.8	72.1

Combined						
	Scrambling					
S/N Ratio in dB	1	2	3	4	5	Total
-8	57.5	51.2	50.0	52.5	54.0	53.0
-4	65.3	60.9	65.6	69.0	70.9	66.0
0	77.8	69.9	76.7	74.4	75.6	75.0
4	81.3	87.2	84.7	79.1	80.3	83.0
8	88.4	91.9	92.8	88.1	91.9	90.8
Total	74.0	72.2	74.0	72.6	74.6	73.5

TABLE 4

RESULTS OBTAINED ON THE VOWEL SUBTEST BROKEN DOWN BY S/N RATIO, SCRAMBLING, SEX, AND FIRST HALF-SECOND HALF IN PERCENT CORRECT

First Half vs Second Half												
	Scrambling											
S/N Ratio	1		2		3		4		5		Total	
in dB	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2
-8	42.2	43.7	35.2	30.5	46.1	37.5	41.4	39.8	24.2	23.4	38.0	35.4
-4	46.9	40.6	51.6	36.0	64.1	56.2	73.4	56.2	63.3	68.0	60.0	51.0
0	68.0	80.5	68.7	64.8	71.9	69.5	45.3	58.6	81.2	71.1	67.0	70.0
4	67.2	71.1	82.8	85.9	72.6	84.4	79.7	82.8	83.6	85.9	77.0	83.0
8	86.7	94.5	85.9	93.7	85.9	88.3	82.0	84.4	87.5	90.6	86.0	90.0
Total	62.2	66.1	65.0	62.2	68.0	67.2	64.4	64.4	68.0	68.0	65.5	65.5

Male vs Female												
	Scrambling											
S/N Ratio	1		2		3		4		5		Total	
in dB	M	F	M	F	M	F	M	F	M	F	M	F
-8	53.9	32.0	50.0	15.6	36.7	46.9	47.6	33.6	27.3	20.3	43.0	29.1
-4	60.1	27.3	41.4	46.1	58.6	61.7	70.3	59.4	69.5	61.7	60.0	51.0
0	76.6	71.9	68.0	65.6	81.2	60.1	51.6	52.3	75.8	76.6	70.6	65.3
4	58.6	79.7	89.1	79.7	80.5	76.6	84.4	78.1	83.6	85.9	80.0	80.0
8	91.4	89.8	92.2	87.5	77.3	96.9	82.8	83.6	93.0	85.1	87.3	88.5
Total	68.1	60.1	68.1	58.9	66.9	68.4	67.3	61.4	69.8	65.9	68.0	63.0

Combined						
	Scrambling					
S/N Ratio in dB	1	2	3	4	5	Total
-8	43.0	33.0	41.8	40.6	23.8	36.8
-4	43.7	43.7	60.2	65.0	65.6	55.8
0	74.2	66.8	70.7	51.9	76.2	68.0
4	69.1	84.4	78.5	81.2	84.8	80.0
8	90.6	90.0	87.1	83.2	89.0	88.0
Total	64.1	63.5	67.6	64.0	67.8	65.5

TABLE 5

SUMMARY OF THE ANLAYSIS OF VARIANCE
OF THE FINAL-CONSONANT SUBTEST

Source	Degrees of Freedom	Mean Square	F
Sex (S)	1	21.78	2.05
Subtest Half (H)	1	11.52	1.08
Scrambling (Sc)	4	7.98	0.75
S/N Ration (S/N)	4	1331.90	125.41[b]
S X H	1	2.42	0.23
S X Sc	4	12.50	1.18
S X S/N	4	11.63	1.10
H X Sc	4	6.14	0.58
H X S/N	4	18.72	1.76
Sc X S/N	16	12.70	1.20
S X H X Sc	10	6.69	0.63
S X H X S/N	4	2.47	0.23
S X Sc X S/N	16	12.93	1.22
H X Sc X S/N	16	7.11	0.67
S X H X Sc X S/N	16	5.14	0.48
Error	100	10.62	

[a]Significant at the .05 level.

[b]Significant at the .01 level.

TABLE 6

SUMMARY OF THE ANALYSIS OF VARIANCE OF THE INITIAL-CONSONANT SUBTEST

Source	Degrees of Freedom	Mean Square	F
Sex (S)	1	58.32	6.44[a]
Subtest Half (H)	1	0.00	0.00
Scrambling (Sc)	4	6.59	0.73
S/N Ratio (S/N)	4	1351.11	149.13[b]
S X H	1	0.02	0.00
S X Sc	4	5.99	0.66
S X S/N	4	10.08	1.11
H X Sc	4	4.00	0.44
H X S/N	4	6.09	0.67
Sc X S/N	16	14.03	1.55
S X H X Sc	4	5.97	0.66
S X H X S/N	4	7.88	0.87
S X Sc X S/N	16	11.29	1.25
H X Sc X S/N	16	8.02	0.89
S X H X Sc X S/N	16	5.18	0.57
Error	100	9.06	

[a]Significant at the .05 level.

[b]Significant at the .01 level.

TABLE 7

SUMMARY OF THE ANALYSIS OF VARIANCE
OF THE VOWEL SUBTEST

Source	Degrees of Freedom	Mean Square	F
Sex (S)	1	132.84	9.82[b]
Subtest Half (H)	1	0.00	0.00
Scrambling (Sc)	4	17.83	1.32
S/N Ratio (S/N)	4	1693.67	125.23[b]
S X H	1	17.40	1.29
S X Sc	4	18.36	1.36
S X S/N	4	40.39	2.99[a]
H X Sc	4	5.94	0.44
H X S/N	4	32.78	2.42
Sc X S/N	16	63.04	4.66[b]
S X H X Sc	4	9.02	0.67
S X H X S/N	4	4.65	0.34
S X Sc X S/N	16	38.88	2.87[b]
H X Sc X S/N	16	10.03	0.74
S X H X Sc X S/N	16	13.27	0.98
Error	100	13.52	

[a]Significant at the .05 level.

[b]Significant at the .01 level.

subtest are not different in the total score they produce, that male- and female-subject groups perform similarly, that the various subtest scramblings produce essentially similar results overall and that scramblings do not interact with the other factors. The data upon which these results are based may be inspected in Table 2 (page 46).

The significant S/N-ratio main effect for the final-consonant subtest is presented graphically in Figure 1. The plotted values are based on data combined across sex, test halves and test scramblings. As expected, the percentage of correct responses increases at successively better S/N ratios, ranging from about 47.0 percent at the poorest listening environment (-8 dB S/N ratio) to about 84.0 percent at the best listening environment (+8 dB S/N ratio). These scores fulfill the desired goal that scores below about 35.0 percent (10.0 percent above chance) and above about 90.0 percent (10.0 percent below perfect performance) should be avoided in order to reduce biasing the outcome of the analysis of variance through artificial restrictions on the variability of the results.

The slope of the function reported in Figure 1 is approximately 2.3 percent per dB. This is considerably less than the 5.0 percent per dB usually associated with balanced fifty-word CNC lists but is not substantially different from the 3.0 percent-per-dB slope reported by Fairbanks for the Rhyme Test (6).

Although the sex-group main effect for the final-consonant subtest is not significant, this main effect is significant in the initial-consonant subtest and the vowel subtest. As a result, the final-consonant-subtest sex-group comparison is presented in Figure 2 with the sex-group comparisons for the initial-consonant test and the vowel test. This

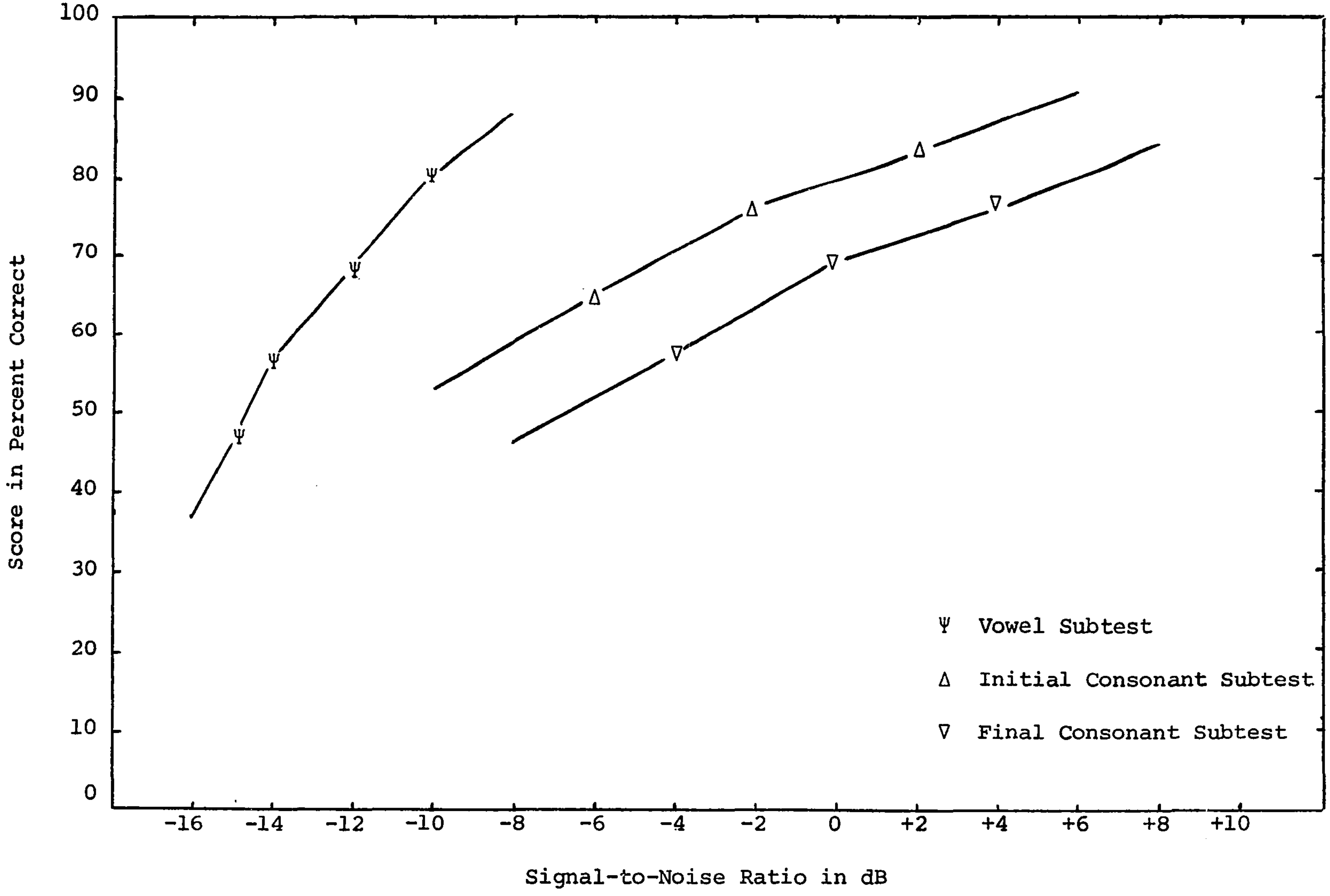

Figure 1--Percent correct as a function of signal-to-noise ratio for the vowel, initial-consonant and final-consonant subtests combined across all other factors.

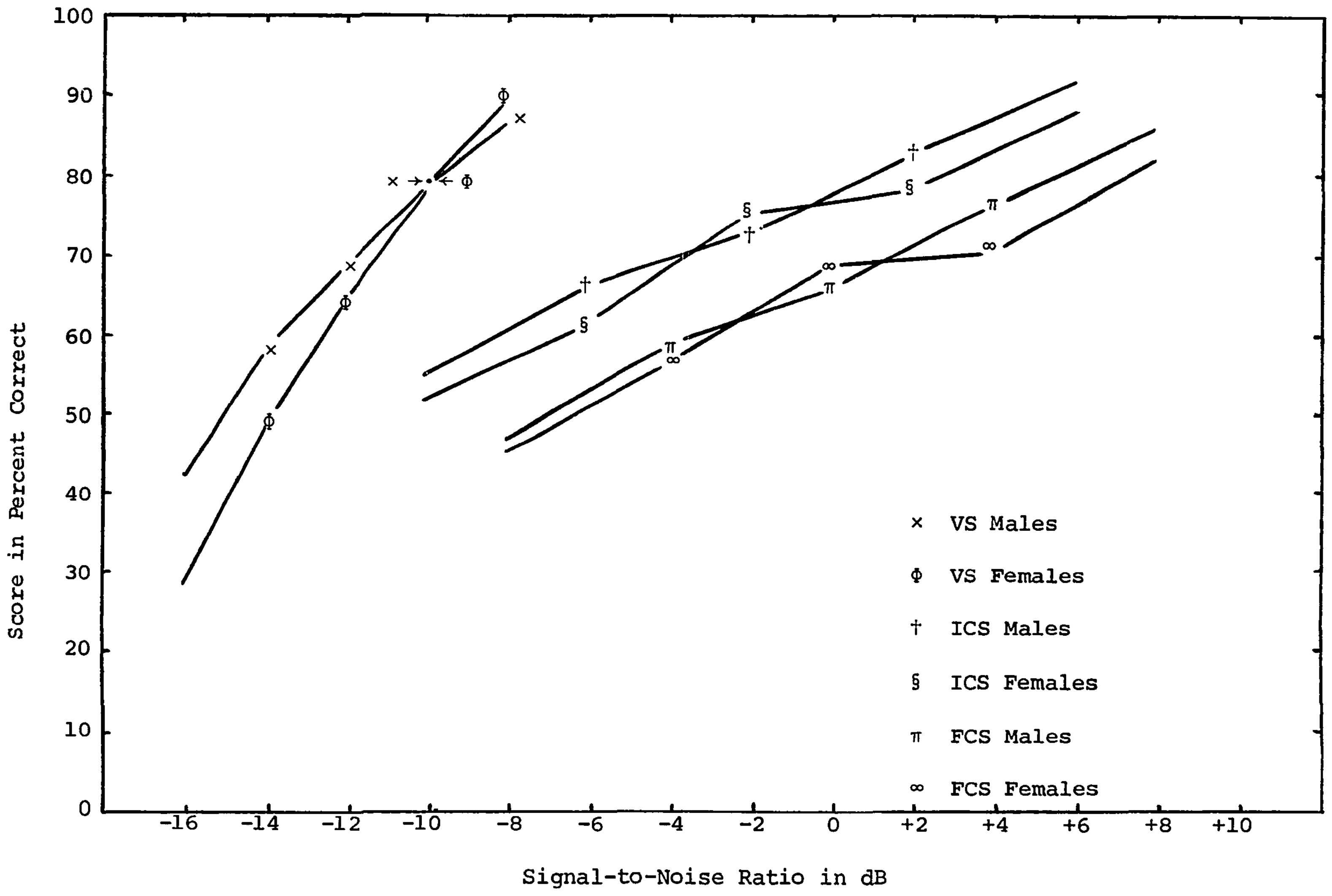

Figure 2--Percent correct as a function of signal-to-noise ratio for the vowel, initial-consonant and final-consonant subtests for male and female groups.

combined presentation permits easy comparison of the sex-group functions. This aspect will be discussed further in subsequent sections.

Initial-Consonant Test

The analysis of variance for the initial-consonant subtest, presented in Table 6 (page 50), resulted in significant F values for the main effects S/N ratio (.01 level) and sex groups (.05 level). The F values for the other main effects and interactions are not significant at the .05 level. The data upon which these results are based may be inspected in Table 3 (page 47).

As in the final-consonant subtest, test scramblings appear interchangable and the two halves of the subtest are not significantly different in percentage scores produced. Scores for the two sexes, however, do differ. Graphical representation of this difference is depicted in Figure 2 (page 54).

The F value for the sex-group main effect for initial consonants is significant at the .05 level and represents a correct-response-percentage difference of 2.7 percent (Table 3, page 47). The male group produced a score of 74.8 percent (across all conditions for the initial-consonant subtest) while the female group produced a score of 72.1 percent. The 2.7 percent difference represents an average of approximately two more correct responses for each male subject than for each female subject. The noise-by-sex interaction is not significant and the sex factor did not interact significantly with other factors. It would seem, therefore, that this difference between the two groups remains consistent (at the .05 level of significance) across the conditions of test scramblings, test halves and S/N ratios. It is concluded, therefore, that combining the results across sex groups would result in a distortion of the results which is small from a practical point of view (about 1.4 percent) and which remains consistent across conditions.

A graphic presentation of the percent correct as a function of S/N ratio for initial consonants is presented in Figure 1 (page 53). The scores recorded in this figure are averaged over sex groups, test scramblings and test halves. They extend from about 53.0 percent obtained at the -10 dB S/N ratio to about 91.0 percent obtained at the +6 dB S/N ratio. The slope of this function is about 2.4 percent per dB. The scores extended slightly beyond the 90.0 percent upper limit set at the outset of the study in order to avoid restrictions in the dispersion of the results; however, it was felt that the 91.0 percent value is not so high as to unduly bias the outcome of the analysis of variance.

Vowel Subtest

The results of the analysis of variance for the vowel subtest indicate several significant F values, both among the main effects and the interactions (Table 7, page 51). The F scores for the main effects S/N ratios and sex groups, the first-order interaction subtest scramblings - S/N ratios and the second-order interaction subtest scramblings-noise levels-sex groups are all significant at the .01 level. The first-order interaction S/N ratio-sex groups is significant at the .05 level. Performance differences for other main effects and interactions tested are not significant. The data upon which these results are based may be inspected in Table 4 (page 48).

The S/N-ratio main-effect results for the vowel subtest, combined across sex groups, subtest scramblings and subtest halves, are presented in Figure 1 (page 53). Examination of this figure reveals an increase in the percentage of correct responses at the rate of 6.4 percent per dB as the S/N ratios become more favorable. This slope is substantially steeper than the consonant-test slopes and, further, is steeper than the slope typical of balanced, fifty-word, CNC tests (36) (about 5.0 percent per dB). It is not, however, as steep as typical spondee word-test functions (13) (about 8.0 percent per dB). The percentage of correct responses increased successively from about 37.0 percent to about 88.0 percent as the S/N ratios changed from -16 dB to -8 dB.

The sex-group main-effect F value reflects the finding that female subjects correctly identify a lower percentage of the subtest items than male subjects (the same direction that was observed in the initial-consonant subtest). The reader may compare the sex-group percent-correct functions for all three subtests in Figure 2 (page 54). The correct-response percentage for female subjects averaged across all other conditions is about 63.0 percent as compared to 68.0 percent for male subjects. The 5.0 percent difference represents an average of slightly over three responses per subject, per subtest administration.

The sex group-S/N ratio interaction also is depicted in Figure 2. The figure reveals a lower percentage of correct responses for female subjects at S/N ratios of -16, -14 and -12 dB, while essentially no differences between correct-response percentages for males vs. females are noted at the -10 and -8 dB S/N ratios. The differences between the sex group performances are 13.4, 9.0, 5.3, 0.0 and 1.2 percent for the S/N ratios -16 dB to -8 dB, respectively. These differences all are in favor of the male group with the exception of the difference noted for the

-8 dB S/N ratio. The basis of the significant interaction is apparent in Figure 2 as it is in the raw-data table (Table 4, page 48), however, the cause of causes are not known.

The significant subtest-scrambling S/N-ratio interaction is based on the result that decreases in noise levels with scramblings 2, 3 and 5 always result in an increase in the frequency of correct responses while the same decreases with scramblings 1 and 4 produced a variable trend in correct-response frequency. Intelligibility decreased with scrambling 1 by approximately 5.0 percent as the S/N ratio was changed form -12 dB to -10 dB. Another intelligibility-score decrease of approximately 13.0 percent is noted to have occurred between the -14 dB and the -12 dB S/N ratios with scrambling 4. It is also noteworthy that between the -16 dB and the -14 dB S/N ratios for scrambling 1, as well as between the -10 dB and the -8 dB S/N ratios for scrambling 4 there were intelligibility increases of less than 2.0 percent. Some subtest scrambling-noise level combinations also resulted in markedly fewer responses than other combinations. Subtest scramblings 2 and 5 resulted in performance approximately 9.0 percent and 19.0 percent poorer, respectively, in the -16 dB S/N ratio than that obtained for other subtest scramblings. Subtest scramblings 1 and 2 resulted in approximately 20.0 percent poorer performance in the -14 dB S/N ratio, subtest scrambling 4 produced approximately 15.0 percent to 25.0 percent poorer performance in the -12 dB S/N ratio and scrambling 1 resulted in scores approximately 10.0 percent to 15.0 percent poorer than other scramblings in the -10 dB S/N environment. Differences are noted even in the best S/N ratio (-8 dB), although the difference is not as large as those noted in the poorer S/N environments. In the -8 dB

S/N ratio, scrambling 4 produced from approximately 4.0 percent to 7.0 percent poorer performance than the other scramblings.

The sex group-test scrambling-S/N ratio triple interaction was also significant. A search for the basis of this finding revealed little other than that the results do not appear to follow particular trends nor appear to offer reasonably-explained relationships.

Discussion

The discussion of the quantitative results of this investigation will be presented in two sections: (1) a discussion of the results obtained with the two consonant subtests and (2) a discussion of vowel-subtest findings. The discussion of the two consonant subtests is presented in one section because of the similarity of the consonant-subtest formats and of the results. It should be recalled, however, that the two consonant subtests were presented at two different series of S/N ratios. As a result, comparison of the scores obtained on the two subtests may be made only after this factor has been taken into consideration.

Final- and Initial-Consonant Subtests. The results of each of the consonant tests indicate that the scramblings within each of the consonant subtests do not produce significantly different scores. Subjects may be expected to score comparably on any of the five scramblings for either the initial- or final-consonant subtests. The ability to use these subtest scramblings interchangably reduces the opportunity for a subject to learn the test-item sequences should it be necessary to test a person repeatedly. It has been indicated frequently (16, 17, 38, 39) throughout the development of speech-test materials that this is a necessity for a useful clinical and/or research speech-discrimination test.

The observation that the ability to identify speech sounds decreases with increases in noise levels is, of course, commonplace and has been demonstrated by many investigations. It is notable, however, that the correct-response curves for the final-consonant subtest and the initial-consonant subtest, for this study, increase only at the rate of 2.3 percent per dB and 2.4 percent per dB, respectively.

These slopes are in contrast to the approximate 5.0 percent per dB slopes generally reported for fifty-word, phonetically-balanced, word-list tests. House, et al. (17) also obtained a slope of about 5.0 percent per dB with the closed-response-set procedure. Griffiths (10) using a similar procedure obtained a slope of about 3.4 percent per dB. Studebaker (38), with the closed-response set, using a test procedure very similar to that used in this study obtained slopes of 2.8 percent per dB for an initial-consonant test and 2.6 percent per dB for a final-consonant test.

A possible explanation of these differences may be related to the use of carrier phrases in association with equal intensity recordings. Harris (13) in 1948 noted that when PB lists are rerecorded for equal intensity the slope of the obtained function is decreased to about 1.8 percent per dB as compared to original-recording slopes of approximately 4.0 percent per dB. The recordings used in the present study were rerecorded for equal intensity and, as predicted by the Harris results, produce relatively flat functions.

It seems that the method by which test words are usually recorded (monitored carrier followed by the word spoken naturally) is one which gives the talker the opportunity to adjust the intensity of his utterance in a way that partially compensates for the differences in basic audibility (if presented at equal intensity) of the words. When the words are rerecorded for equal intensity these compensations are removed, resulting in an increase in heterogeneity of the words within the list and in a slope that is less steep.

In the Griffiths study (10) no carrier phrase was used and the talker monitored the level of the test word itself. It seems probable that this produces a recording which is nearer to an equal-intensity recording, thus flattening the slope. It also should be noted that Fairbanks (6) used no carrier phrase and obtained a slope of approximately 3.0 percent per dB with the Rhyme Test. Studebaker's (38) test was not rerecorded for equal intensity. However, the lists were observed for VU meter deflection associated with the individual test word productions and words which were observed to deviate in level ($> \pm$ 2 dB) were rerecorded.

Most speech-intelligibility tests use a monitored test word or a monitored carrier phrase with the test word following naturally. The UOST #6 is somewhat unique in that the lists were rerecorded for equal intensity of the test items themselves (i.e. the carrier-phrases intensities differed in the final recording). This was done because of a desire to produce a test in which the dependence of the subjects upon acoustic differences other than intensity were maximized. Further, while the desirability of homogeneity of intelligibility in speech-threshold tests is unquestioned, the desirability of this characteristic in an intelligibility test is less clear. It seems desirable, in fact, to have a test which produces a slope which is neither too flat nor too steep. The specific slope that is most desirable, as yet, has not been demonstrated.

Results of the first-half-second-half comparison indicate that the quantitative results obtained for each half of each consonant subtest are not significantly different. Furthermore, the lack of significant interactions between the main effects for each consonant test indicate that the respective consonant half-test scramblings may be used interchangably, at least with normally-hearing subjects. If this result remains constant with hard-of-hearing subjects, the use of half-list scramblings in clinical testing would reduce the required testing time from approximately eight minutes (maximally) to approximately four minutes per consonant-subtest scrambling. As a result, both initial-consonant discrimination and final-consonant discrimination could be clinically evaluated (quantitatively) in less than 10 minutes.

It will be recalled that the sex-group main effect is not significant for the final-consonant subtest, but that the sex-group main effect for the initial-consonant subtest is significant at the .05 level. This significant difference in correct-response frequency favored male subjects and although the final-consonant-subtest, sex-group scoring difference is not significant there is a noticable trend favoring the male subjects. This somewhat surprising outcome is noted to an even greater extent in the vowel-subtests results. The reasons for the differences between the two groups are unclear because the male and female subjects were not matched on factors other than demonstration of the ability to pass a pure-tone screening test. Whether this difference actually represents a difference between the abilities of the two sexes, in general, to perform on this test, or whether the difference is a result of some uncontrolled factor such as dialect, intelligence, education, etc. will have to await further study.

It is concluded that the results of this investigation indicate that the consonant subtests of the UOST #6 offer sufficient promise as tests of speech discrimination to justify a study or studies of hearing-loss populations using them. It remains for further investigation to determine if these subtests will be worthwhile additions to the clinical hearing-test batteries currently in use.

Vowel Subtest. Numerous main effects and interactions for the vowel subtest were found to have significant F ratios (Table 7, page 51). The significant S/N-ratio main effect is, of course, expected. However, the slope of the function is much steeper in the vowel subtest (6.4 percent per dB) than in the consonant subtests (2.3 percent and 2.4 percent per dB).

The greater steepness of the vowel subtest was also observed by Studebaker (38), who obtained a slope of about 5.4 percent per dB on a similar test. No other directly comparable results are available; however, the CID-W1 spondee-word test produced a slope of about 8.0 percent per dB (13).

It should be noted that the results of this study and those observed by Studebaker (38) indicate that a difference of approximately 8 dB (at the poorest performance end of the scale) to 16 dB (near 100.0 percent performance) separates the interference levels producing comparable performance for the vowel subtest and the consonant subtests. Stated differently, the noise must be made more intense relative to the signal (about 8 dB) to produce some interference for vowel-subtest items but then performance drops to chance level over a much narrower range of

S/N ratios for the vowel-subtest items than for the consonant-subtest items.

The main effect subtest halves was not significant (.05 level) and subtest halves did not interact significantly with any other factor. These results indicate that the subtest halves may be useful as relatively quick clinical tests.

Test scramblings of the vowel subtest were not significantly different (.05 level) however, scramblings interacted significantly with S/N ratios (.01 level) and with sex and S/N ratio (.01 level) suggesting that the scramblings are not comparable and that they cannot be used interchangeably.

As observed for the initial-consonant subtest, differences in the performance of the two sexes on the vowel subtest were noted. The differences favor the male sample. This result is not readily explainable because of the large number of uncontrolled and unknown differences existing between the two groups.

The main effect S/N ratio is present in all of the significant interactions. This suggests that there are differences between the performance of sexes with the differences varying with S/N ratio. Furthermore, while the scramblings main-effect is not significant, it interacts significantly with S/N ratio.

In general, although the main effects of the vowel subtest of UOST #6 appear to indicate that the test has the desirable features of interchangeability and reliability, the multiplicity and complexity of the interactions indicate that the vowel subtest would be of little use, clinically, in its present state. Future studies may be directed profitably toward the determination of the variables involved in producing the interactions noted for the vowel subtest.

Error-Pattern Analysis

Introduction

The UOST #6 also was developed in an attempt to devise a tool which could be used to evaluate a subject's error patterns. To this end, error matrices were developed. The following discussion presents a descriptive analysis of the sound confusions which occur within sound groups, across noise levels, between sex groups and within subtests.

Final-Consonant Subtest

The summarized confusion-matrix data for the final-consonant subtest are shown in Tables 8, 9, 10, 11 and 12. More sound confusions occur in the voiced-plosive sound group (Table 9) than in the other sound groups tested in the final-consonant subtest. The voiced-fricative group (Table 11) follows closely in confusion count, with the voiceless-plosive group (Table 8), the voiceless-fricative group (Table 10) and the affricative-blend group (Table 12), respectively, evidencing successively fewer confusions per sound group.

These findings agree with the House, et al. results (17) in that the voiceless contrasts appear to be heard better than the voiced, but, as House, et al. pointed out, differ from the Fairbanks results (6) and "classical descriptions of the results of speech-sound discrimination tests" (17, p. 163). House, et al. considered this disagreement to be based on differences in the noises used in their study and that of Fairbanks. However, the results of this study and Fairbanks' differ even

TABLE 8

FINAL-CONSONANT, VOICELESS-PLOSIVE ERROR-MATRIX RESULTS AT VARIOUS S/N RATIOS, COMBINED OVER ALL OTHER FACTORS (RAW SCORES)

	Signal-to-Noise Ratio (in dB)				
Presented-Responded	-8	-4	0	+4	+8
pp	71	70	75	76	80
pt	8	8	5	1	0
pk	1	2	0	2	0
p-	0	0	0	1	0
tt	64	66	72	76	77
tp	5	6	3	2	0
tk	8	7	5	1	2
t-	3	1	0	1	1
kk	28	35	39	47	55
kp	5	2	0	0	1
kt	38	37	36	32	23
k-	8	6	5	1	1
--	62	69	69	72	74
-p	7	8	5	5	4
-t	3	0	2	1	1
-k	8	3	4	2	1

TABLE 9

FINAL-CONSONANT, VOICED-PLOSIVE-ERROR MATRIX RESULTS AT VARIOUS S/N RATIOS, COMBINED OVER ALL OTHER FACTORS (RAW SCORES)

	Signal-to-Noise Ratio (in dB)				
Presented-Responded	-8	-4	0	+4	+8
bb	13	15	20	22	35
bd	15	11	6	5	5
bg	27	24	28	32	28
b-	24	30	26	21	12
dd	22	36	48	64	77
db	12	8	3	4	1
dg	17	19	19	11	2
d-	29	11	10	1	0
gg	29	30	39	38	42
gb	18	8	13	9	7
gd	11	26	17	26	27
g-	22	16	11	7	4
--	47	67	66	67	79
-b	10	6	4	2	0
-d	10	4	2	3	0
-g	12	3	8	8	1

TABLE 10

FINAL-CONSONANT, VOICELESS-FRICATIVE ERROR-MATRIX RESULTS AT VARIOUS S/N RATIOS, COMBINED OVER ALL OTHER FACTORS (RAW SCORES)

	Signal-to-Noise Ratio (in dB)				
Presented-Responded	-8	-4	0	+4	+8
ff	29	40	50	43	47
fs	8	7	1	1	0
fθ	33	19	17	23	28
f-	10	14	12	13	5
ss	22	35	65	73	80
sf	23	16	1	2	0
sθ	24	22	12	4	0
s-	10	7	2	1	0
θθ	24	26	38	54	69
θf	24	34	22	17	7
θs	17	7	5	3	1
θ-	15	13	15	6	3
--	32	41	60	60	70
-f	22	11	10	8	5
-s	10	13	2	5	1
-θ	15	15	8	7	4

TABLE 11

FINAL-CONSONANT, VOICED-FRICATIVE ERROR-MATRIX RESULTS AT VARIOUS S/N RATIOS COMBINED, OVER ALL OTHER FACTORS (RAW SCORES)

	Signal-to-Noise Ratio (in dB)				
Presented-Responded	-8	-4	0	+4	+8
vv	21	20	30	42	61
vz	12	19	11	7	2
vð	31	21	21	17	12
v-	15	20	18	14	5
zz	19	41	65	68	80
zv	17	11	3	0	0
zð	31	17	8	8	0
z-	13	11	4	4	0
ðð	34	26	24	27	28
ðv	11	13	22	21	28
ðz	14	17	8	6	4
ð-	20	24	26	26	20
--	63	67	75	76	79
-v	9	8	1	0	1
-z	0	2	2	0	0
-ð	8	3	2	4	0

TABLE 12

FINAL-CONSONANT, AFFRICATIVE-BLEND ERROR-MATRIX RESULTS AT VARIOUS S/N RATIOS, COMBINED OVER ALL OTHER FACTORS (RAW SCORES)

	Signal-to-Noise Ratio (in dB)				
Presented-Responded	-8	-4	0	+4	+8
st st	33	75	79	78	80
st ʃ	14	3	1	2	0
st tʃ	20	1	0	0	0
st -	13	1	0	0	0
ʃ ʃ	51	59	69	69	76
ʃ st	3	2	0	0	0
ʃ tʃ	18	16	11	10	4
ʃ -	8	3	0	1	0
tʃ tʃ	47	57	70	72	77
tʃ st	1	3	2	1	0
tʃ ʃ	19	11	3	4	2
tʃ -	13	9	5	3	1
- -	44	50	67	75	80
- st	6	8	6	0	0
- ʃ	15	10	1	1	0
- tʃ	14	12	6	3	0

though both studies utilize uniform spectrum noises. Studebaker's data (38) indicates that the voiced and voiceless groups do not differ significantly in error frequency. A reasonable explanation for these inconsistencies is not apparent at this time.

Within the voiced-plosive group, (Table 9), the /b/ presentations were responsible for the greatest number of errors. These errors were primarily /g/ for /b/ substitutions and secondarily /-/ for /b/ substitutions. Very few /d/ for /b/ errors occurred. The /g/ for /b/ and /-/ for /b/ errors were present at all S/N ratios and did not decrease appreciably at the better S/N ratios. The /g/ presentations exhibited the next largest number of errors. The /d/ for /g/ substitutions were seen at all S/N ratios and improved with decreases in the noise-interference levels. The /d/ presentation group exhibited only a few errors. These confusions clustered in the three poorest S/N situations and were primarily /g/ for /d/ substitutions. The presentations of the test item which have no final consonant in the voiced-plosive set were seldom confused with the other voiced-plosive-group items. The few confusions which occurred are essentially randomly distributed among the three choices (/b/, /d/, /g/) in the poorest listening environment.

Studebaker's data (38) exhibited essentially the same error patterns within this phoneme group with the exception that the /b/ for /g/ error was the error seen most often. Otherwise, the patterns of the data for the two studies were virtually identical.

Among the voiced-fricative group (Table 11, page 69), the /v/ presentations and the /ð/ presentations produced approximately the same number of confusions. The /v/ presentation errors were primarily /ð/ for

/v/ substitution errors, however, the /-/ for /v/ category had a notable number of responses at the four poorest listening environments. The frequency of /-/ for /v/ errors remained relatively constant over the four poorest S/N ratios but the /ð/ for /v/ errors increased at the greater noise levels. The voiced-fricative error patterns also were essentially identical to the data of Studebaker (38). Even the exceptional number of /-/ for /ð/ and /-/ for /v/ errors that he mentioned in his discussion because of their unexpected frequency were present. Griffith's data (10) also evidenced a high frequency of /v/ and /ð/ sound confusions. In a special pilot study contrasting these two sounds he further indicated that the /v/ and /ð/ are virtually indistinguishable by acoustic cues alone. The /v/ for /ð/ and the /-/ for /ð/ errors were essentially evenly distributed over all S/N levels, however, the /-/ for /ð/ confusion occurred more often than the /v/ for /ð/ confusion as higher interference levels. The /z/ presentation errors were confined to the two poorest S/N ratios and there were essentially no confusions in evidence for the item presentations which utilized no final consonant in the voiced-fricative set.

The voiceless-fricative group (Table 10, page 68) was next in error frequency but the number of errors in this group was substantially less than in the two previously-described groups. The majority of the errors in this group were confined to either the /θ/ for /f/ confusion or the /f/ for /θ/ confusion. The /θ/ for /f/ confusion occurred most often and occurred across all noise environments, but the /f/ for /θ/ confusion occurred only in the four poorest S/N situations. There were a notable number of errors of the /θ/ for /s/ type in the three poorest S/N environments but other errors for the voiceless-fricative group followed no identifiable pattern.

Studebaker's data (38) for the voiceless-fricative group did not show the smaller number of errors relative to the number exhibited by the voiced-fricative group evidenced here. The patterns of the confusions made within the voiceless-fricative group were in good agreement. The one exception is that Studebaker noted a larger number of /-/ for /s/ confusions rather than the /θ/ for /s/ confusion pattern exhibited with the UOST #6.

The voiceless-plosive results (Table 8, page 66) exhibited only a pronounced /t/ for /k/ substitution confusion which was more frequent at the poorer S/N ratio. There were very few other errors within the voiceless-plosive group.

Studebaker's data (38) also showed few errors for this group. The /t/ for /k/ was the major substitution in the group, however, the /t/ for /v/ confusion also was seen in his results.

The affricative-blend group (Table 12, page 70) exhibited very few errors with no identifiable error-patterns. The errors occurred in groups only occasionally and only at the two poorest S/N ratios. There have been no other reports on error-matrix data obtained with these sounds.

The strong agreement exhibited between the Studebaker (38) and UOST #6 data would seem to indicate that final-consonant phoneme confusions occur according to some reasonable and consistent heirarchy which is not, as yet, well defined. It seems reasonable to assume however, that further study of the consistency of the individual subject's confusion patterns is justified. Exploration of the UOST #6 data by individual subject break-down is planned for the future.

As noted earlier, the only main effect other than S/N ratio which was significant was the male-female difference on two of the three subtests. For this reason comparisons of the error-matrix results produced by the male and female subjects seemed particularly desirable. These comparisons for the final-consonant subtest are presented in Tables 13, 14, 15, 16 and 17.

The male-female factor was not a significant factor for this particular subtest and inspection of Tables 13-17 reveals no patterns of differences in the confusion matrices which are identifiable by eye.

The half-subtest error-matrix results were also considered for presentation. However, this was not done in separate tables in order to conserve space. This was felt to be a reasonable course since the quantitative data showed no significant differences on this variable and because inspection of the data so broken down revealed little that could be interpreted meaningfully. If this information should be desired it can be extracted from the tables used to present the male and female results (Tables 13, 14, 15, 16, and 17).

Initial-Consonant Subtest

The error-matrix data for the different sound groups of the initial-consonant subtest are presented in Tables 18, 19, 20, 21 and 22.

More errors were observed among the voiceless-plosive sound group (Table 18) for the initial-consonant subtest than for the other sound groups. The voiceless-fricative group (Table 20) evidenced the next-largest error frequency followed, successively, by the voiced-plosive group (Table 19), the voiced-fricative group (Table 21) and the

TABLE 13

FINAL-CONSONANT, VOICELESS-PLOSIVE, ERROR-MATRIX RESULTS AT VARIOUS S/N RATIOS FOR MALE- AND FEMALE-SUBJECT GROUPS

	MALES									
	Signal-to-Noise Ratio (in dB)									
	-8		-4		0		+4		+8	
Presented-Responded	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2
pp	18	16	19	17	19	18	20	20	20	20
pt	2	4	1	3	1	2	0	0	0	0
pk	0	0	0	0	0	0	0	0	0	0
p-	0	0	0	0	0	0	0	0	0	0
tt	18	17	15	19	17	17	17	19	20	19
tp	1	1	4	0	1	2	1	1	0	0
tk	1	1	1	1	2	1	1	0	0	1
t-	0	1	0	0	0	0	1	0	0	0
kk	9	7	12	13	7	11	8	14	14	16
kp	1	1	0	0	0	0	0	0	1	0
kt	9	8	7	4	11	7	11	6	5	3
k-	1	4	1	3	2	2	1	0	0	1
--	15	18	14	20	19	18	19	19	18	20
-p	3	2	4	0	0	1	1	0	1	0
-t	1	0	0	0	0	0	0	0	1	0
-k	1	0	2	0	1	1	0	1	0	0

TABLE 13--Continued

	FEMALES									
	Signal-to-Noise Ratio (in dB)									
	-8		-4		0		+4		+8	
Presented-Responded	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2
pp	19	18	19	15	20	18	18	18	20	20
pt	0	2	0	4	0	2	0	1	0	0
pk	1	0	1	1	0	0	1	1	0	0
p-	0	0	0	0	0	0	1	0	0	0
tt	15	14	14	18	19	19	20	20	20	18
tp	2	1	2	0	0	0	0	0	0	0
tk	3	3	3	2	1	1	0	0	0	1
t-	0	2	1	0	0	0	0	0	0	1
kk	5	7	9	1	8	13	11	14	10	15
kp	0	3	1	1	0	0	0	0	0	0
kt	11	10	10	16	11	7	9	6	10	5
k-	3	0	0	2	1	0	0	0	0	0
--	16	13	19	16	12	20	15	19	16	20
-p	1	1	1	3	4	0	4	0	3	0
-t	0	2	0	0	2	0	0	0	0	0
-k	3	4	0	1	2	0	1	1	1	0

TABLE 14

FINAL-CONSONANT, VOICED-PLOSIVE, ERROR-MATRIX RESULTS AT VARIOUS S/N RATIOS FOR MALE- AND FEMALE-SUBJECT GROUPS

MALES										
	Signal-to-Noise Ratio (in dB)									
	-8		-4		0		+4		+8	
Presented-Responded	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2
bb	6	3	4	4	3	3	5	6	10	4
bd	2	2	0	0	3	0	1	0	3	1
bg	5	7	5	5	6	10	8	10	7	8
b-	7	8	11	11	8	7	6	4	0	7
dd	2	3	9	12	11	13	19	15	20	19
db	3	6	1	2	1	1	0	2	0	0
dg	3	4	4	2	6	4	1	3	0	1
d-	12	7	6	4	2	2	0	0	0	0
gg	8	7	8	5	12	12	12	13	9	10
gb	3	4	1	3	4	4	3	2	3	3
gd	4	1	5	8	2	2	5	4	8	5
g-	5	8	6	4	2	2	0	1	0	2
--	9	16	18	19	16	17	16	18	20	20
-b	3	1	0	1	1	1	0	1	0	0
-d	5	0	2	0	0	0	0	0	0	0
-g	3	3	0	0	3	2	4	1	0	0

TABLE 14--Continued

	FEMALES									
	Signal-to-Noise Ratio (in dB)									
	-8		-4		0		+4		+8	
Presented-Responded	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2
bb	2	2	5	2	10	4	9	2	14	7
bd	5	6	4	7	2	1	1	3	0	1
bg	9	6	3	11	3	9	5	9	5	8
b-	4	5	8	0	5	6	5	6	1	4
dd	11	6	9	12	13	11	17	13	20	18
db	2	1	2	3	1	0	0	2	0	1
dg	3	7	8	5	2	7	3	4	0	1
d-	4	6	1	0	4	2	0	1	0	0
gg	9	5	10	7	5	10	7	6	11	12
gb	3	8	2	2	2	3	2	2	1	0
gd	4	2	5	8	9	4	8	9	7	7
g-	4	5	3	3	4	3	3	3	1	1
--	10	12	16	14	18	15	15	18	19	20
-b	5	1	3	2	0	2	1	0	0	0
-d	2	3	0	2	1	1	2	1	0	0
-g	3	3	1	2	1	2	2	1	1	0

TABLE 15

FINAL-CONSONANT, VOICELESS-FRICATIVE, ERROR-MATRIX RESULTS AT VARIOUS S/N RATIOS FOR MALE- AND FEMALE-SUBJECT GROUPS

MALES										
	Signal-to-Noise Ratio (in dB)									
	-8		-4		0		+4		+8	
Presented-Responded	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2
ff	8	6	7	10	12	13	12	9	10	12
fs	1	3	2	1	0	0	0	0	0	0
fθ	8	9	8	5	4	4	6	6	7	8
f-	3	2	3	4	4	3	2	5	3	0
ss	7	6	5	12	18	14	19	19	20	20
sf	8	4	7	2	0	0	0	0	0	0
sθ	4	8	6	5	2	6	1	1	0	0
s-	1	2	2	1	0	0	0	0	0	0
θθ	6	7	6	7	7	8	13	13	18	18
θf	4	4	9	8	5	5	4	6	1	1
θs	8	3	2	3	2	2	1	0	0	0
θ-	2	6	3	2	6	5	2	1	1	1
--	12	6	11	10	15	11	14	16	16	19
-f	2	9	2	4	2	4	2	2	2	1
-s	3	0	2	4	1	1	3	1	0	0
-θ	3	5	5	2	2	4	1	1	2	0

TABLE 15--Continued

	FEMALES									
	Signal-to-Noise Ratio (in dB)									
	-8		-4		0		+4		+8	
Presented-Responded	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2
ff	8	9	8	15	12	13	12	10	15	10
fs	1	3	2	2	1	0	1	0	0	0
fθ	8	5	3	3	5	4	5	6	5	8
f-	3	3	7	0	2	3	2	4	0	2
ss	3	6	8	10	14	19	17	18	20	20
sf	7	4	4	3	1	0	1	1	0	0
sθ	5	7	6	5	4	0	2	0	0	0
s-	4	3	2	2	1	1	0	1	0	0
θθ	2	9	6	7	12	11	13	15	17	16
θf	11	5	10	7	8	4	4	3	1	4
θs	4	2	0	2	0	1	1	1	1	0
θ-	3	4	4	4	0	4	2	1	1	0
--	6	8	8	12	20	14	13	17	18	17
-f	7	4	3	2	0	4	3	1	2	0
-s	3	4	4	3	0	0	1	0	0	1
-θ	4	3	5	3	0	2	3	2	0	2

TABLE 16

FINAL-CONSONANT, VOICED-FRICATIVE, ERROR-MATRIX RESULTS AT VARIOUS S/N RATIOS FOR MALE- AND FEMALE-SUBJECT GROUPS

	MALES									
	Signal-to-Noise Ratio (in dB)									
	-8		-4		0		+4		+8	
Presented-Responded	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2
vv	4	3	5	5	7	6	8	15	17	18
vz	4	5	5	5	4	3	2	0	0	0
vϑ	10	7	5	6	5	7	5	4	2	1
v-	2	5	5	4	4	4	5	1	1	1
zz	5	5	9	9	16	17	14	20	20	20
zv	3	4	4	1	1	1	0	0	0	0
zϑ	8	9	1	6	1	1	4	0	0	0
z-	4	2	6	4	2	1	2	0	0	0
ϑϑ	9	5	5	11	10	6	8	9	8	7
ϑv	1	4	2	3	4	6	5	3	9	5
ϑz	5	5	3	4	2	2	1	1	2	1
ϑ-	5	6	10	2	4	6	6	7	1	7
--	16	18	19	19	17	19	19	20	19	20
-v	3	1	1	1	1	0	0	0	1	0
-z	0	0	0	0	1	1	0	0	0	0
-ϑ	1	1	0	0	1	0	1	0	0	0

TABLE 16--Continued

FEMALES										
Signal-to-Noise Ratio (in dB)										
	-8		-4		0		+4		+8	
Presented-Responded	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2
vv	4	7	5	5	4	13	8	11	13	13
vz	4	0	3	6	4	0	5	0	0	2
vð	10	8	4	6	7	2	5	3	5	4
v-	2	4	8	3	5	5	2	6	2	1
zz	6	3	12	11	17	15	17	17	20	20
zv	4	6	2	4	0	1	0	0	0	0
zð	7	7	5	5	3	3	1	3	0	0
z-	3	4	1	0	0	1	2	0	0	0
ðð	9	11	4	6	6	2	4	6	7	6
ðv	2	4	3	5	3	9	8	5	10	4
ðz	4	0	3	7	2	2	4	0	1	0
ð-	5	4	10	2	9	7	4	9	2	10
--	13	16	16	13	19	20	18	19	20	20
-v	4	1	3	3	0	0	0	0	0	0
-z	0	0	0	2	0	0	0	0	0	0
-ð	3	3	1	2	1	0	2	1	0	0

TABLE 17

FINAL-CONSONANT, AFFRICATIVE-BLEND, ERROR-MATRIX RESULTS AT VARIOUS S/N RATIOS FOR MALE- AND FEMALE-SUBJECT GROUPS

MALES										
	Signal-to-Noise Ratio (in dB)									
	-8		-4		0		+4		+8	
Presented-Responded	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2
st st	8	8	20	20	20	19	20	19	20	20
st ʃ	3	4	0	0	0	1	0	1	0	0
st tʃ	4	4	0	0	0	0	0	0	0	0
st -	5	4	0	0	0	0	0	0	0	0
ʃ ʃ	13	13	14	17	17	18	16	19	20	19
ʃ st	2	0	1	0	0	0	0	0	0	0
ʃ tʃ	3	6	4	3	3	2	3	1	0	1
ʃ -	2	1	1	0	0	0	1	0	0	0
tʃ tʃ	15	8	12	19	20	17	19	18	20	19
tʃ st	0	1	1	0	0	0	0	0	0	0
tʃ ʃ	1	8	4	1	0	1	1	1	0	1
tʃ -	4	3	3	0	0	2	0	1	0	0
- -	11	12	15	13	13	19	19	20	20	20
- st	1	1	1	2	4	0	0	0	0	0
- ʃ	3	3	2	3	1	0	0	0	0	0
- tʃ	5	4	2	2	2	1	1	0	0	0

TABLE 17--Continued

Presented-Responded	-8 1/2	-8 2/2	-4 1/2	-4 2/2	0 1/2	0 2/2	+4 1/2	+4 2/2	+8 1/2	+8 2/2
	FEMALES									
	Signal-to-Noise Ratio (in dB)									
st st	8	9	17	18	20	20	20	19	20	20
st ʃ	4	3	2	1	0	0	0	0	0	0
st tʃ	5	7	0	1	0	0	0	0	0	0
st -	3	1	1	0	0	0	0	0	0	0
ʃ ʃ	14	11	13	15	16	18	19	15	19	18
ʃ st	0	1	1	0	0	0	0	0	0	0
ʃ tʃ	6	3	5	4	4	2	1	5	1	2
ʃ -	0	5	1	1	0	0	0	0	0	0
tʃ tʃ	15	9	9	17	20	13	19	16	20	18
tʃ st	0	0	2	0	0	1	0	1	0	0
tʃ ʃ	3	7	4	2	0	3	1	1	0	1
tʃ -	2	4	5	1	0	3	0	2	0	1
- -	15	6	10	12	17	18	17	19	20	20
- st	1	3	3	2	0	1	0	0	0	0
- ʃ	4	5	2	3	1	0	1	0	0	0
- tʃ	0	5	5	3	2	1	1	1	0	0

TABLE 18

INITIAL-CONSONANT, VOICELESS-PLOSIVE ERROR-MATRIX RESULTS AT VARIOUS S/N RATIOS, COMBINED OVER ALL OTHER FACTORS (RAW SCORES)

	Signal-to-Noise Ratio (in dB)				
Presented-Responded	-10	-6	-2	+2	+6
pp	28	29	29	39	61
pt	31	25	24	26	12
pk	14	15	11	1	0
p-	7	11	16	14	7
tt	24	27	32	50	69
tp	22	17	16	6	1
tk	20	23	15	8	3
t-	12	13	17	16	7
kk	23	33	42	50	70
kp	16	8	2	2	1
kt	22	17	9	11	1
k-	19	22	27	17	8
--	45	57	71	73	78
-p	9	7	4	2	2
-t	13	10	5	5	0
-k	13	6	0	0	0

TABLE 19

INITIAL-CONSONANT, VOICED-PLOSIVE ERROR-MATRIX RESULTS AT VARIOUS S/N RATIOS, COMBINED OVER ALL OTHER FACTORS (RAW SCORES)

	Signal-to-Noise Ratio (in dB)				
Presented-Responded	-10	-6	-2	+2	+6
bb	36	45	39	50	63
bd	22	30	37	30	16
bg	15	1	2	0	0
b-	7	4	2	0	1
dd	28	35	55	66	74
db	22	28	13	7	4
dg	22	15	8	4	2
d-	10	2	4	3	0
gg	54	64	77	80	79
gb	5	2	0	0	0
gd	4	5	2	0	1
g-	16	9	1	0	0
--	38	52	66	74	79
-b	19	16	8	3	0
-d	10	3	2	2	0
-g	13	9	4	1	1

TABLE 20

INITIAL-CONSONANT, VOICELESS-FRICATIVE ERROR-MATRIX RESULTS AT VARIOUS S/N RATIOS, COMBINED OVER ALL OTHER FACTORS (RAW SCORES)

	Signal-to-Noise Ratio (in dB)				
Presented-Responded	-10	-6	-2	+2	+6
ff	28	27	31	38	47
fs	6	4	1	1	0
fθ	39	42	40	36	30
f-	5	7	8	4	3
ss	51	79	80	79	80
sf	10	0	0	0	0
sθ	16	0	0	0	0
s-	2	1	0	1	0
θθ	41	50	47	64	72
θf	26	19	27	11	7
θs	8	6	1	2	0
θ-	5	5	5	2	1
--	45	62	73	80	78
-f	12	6	1	0	1
-s	4	3	1	0	0
-θ	18	8	5	0	1

TABLE 21

INITIAL-CONSONANT, VOICED-FRICATIVE ERROR-MATRIX RESULTS AT VARIOUS S/N RATIOS, COMBINED OVER ALL OTHER FACTORS (RAW SCORES)

	Signal-to-Noise Ratio (in dB)				
Presented-Responded	-10	-6	-2	+2	+6
vv	31	32	41	36	60
vz	12	8	4	1	0
vð	33	36	34	42	20
v-	4	4	1	1	0
zz	34	62	78	79	80
zv	15	7	0	0	0
zð	30	9	2	0	0
z-	1	1	0	1	0
ðð	42	50	55	68	70
ðv	22	20	16	7	10
ðz	13	8	6	5	0
ð-	3	1	3	0	0
--	37	56	71	79	80
-v	15	11	6	0	0
-z	15	4	0	0	0
-ð	13	9	3	1	0

TABLE 22

INITIAL-CONSONANT, AFFRICATIVE-BLEND ERROR-MATRIX RESULTS AT VARIOUS S/N RATIOS, COMBINED OVER ALL OTHER FACTORS (RAW SCORES)

	Signal-to-Noise Ratio (in dB)				
Presented-Responded	-10	-6	-2	+2	+6
st st	64	77	80	80	78
st ʃ	9	1	0	0	2
st tʃ	5	1	0	0	0
st -	2	0	0	0	0
ʃ ʃ	57	74	80	78	79
ʃ st	3	0	0	0	0
ʃ tʃ	19	6	0	1	0
ʃ -	1	0	0	0	0
tʃ tʃ	65	77	79	80	80
tʃ st	8	0	0	0	0
tʃ ʃ	7	3	1	0	0
tʃ -	0	0	0	0	0
- -	76	76	79	79	80
- st	1	2	1	0	0
- ʃ	0	0	0	0	0
- tʃ	3	2	0	1	0

affricative-blend sound group (Table 22). There were considerably fewer responses noted for each of the three latter sound groups than for either of the first two groups noted above.

The data of Miller and Nicely (25) support this hierarchy of sound-group breakdown. Although their study did not utilize meaningful words, the overall error pattern associated with their nonsense-syllable presentations is identical to the pattern described above. The variable phoneme in the Miller and Nicely study was placed initially.

The hierarchial sequence of sound-group error frequency for the initial-consonant subtest is not the same as for the final-consonant subtest. Although the plosive sound groups for both subtests evidenced more errors than the comparable fricative sound groups, more errors occurred among the voiced sound groups for the final-consonant subtest while more errors occurred among the voiceless sound groups for the initial-consonant subtest. The affricative-blend sound group produced fewer errors than any other sound group for both subtests.

Errors within the voiceless-plosive group for the initial-consonant test (Table 18, page 85) not only appeared to occur with greater frequency but with greater dispersion as well. More errors are noted for the /p/ presentations than for the /t/, /k/ or /-/ presentations with the /t/ for /p/ confusion occurring more often than any other. The /k/ for /p/ and /p/ for /k/ errors occurred more often than other voiceless-plosive errors in the data of Miller and Nicely (25). The /-/ for /k/ substitutions was the next most frequent error followed closely by the /k/ for /t/ substitution. The voiceless-plosive data of Studebaker (38) indicated the /t/ presentations produced more errors than the /p/ or /k/

presentations but the error patterns agreed well, otherwise. It should be noted that within this sound group, except for the /-/ comparisons, each sound was confused relatively frequently with at least two of the three possible choices, rather than only one. This finding was not evident for any of the other sound groups in the initial-consonant subtest but was observed to a lesser degree in the voiced-plosive and voiced-fricative sound groups (Tables 9 and 11, pages 67 and 69, respectively) of the final-consonant test.

There were only two major confusions in the voiceless-fricative groups. The /θ/ for /f/ confusion occurred most often, occurred in all interference environments and occurred with increased frequency as the noise level increased. The /f/ for /θ/ was the next most-frequent confusion. This confusion pair was most prominent at the three poorest S/N ratios. The other errors for this sound group were infrequent and without apparent pattern. These findings also are very consistent with those of Studebaker (38).

The voiced-plosive group produced considerably fewer errors than the groups described above. Only the /d/ for /b/ confusion was seen frequently occurring at all S/N levels but showing a relatively stable frequency of occurrence at the three poorest S/N ratios. The /b/ for /d/ confusion are the only other noteworthy confusion occurring within this sound group. These errors occurred only in the three poorest sound environments. The /d/ for /g/ and /g/ for /d/ confusions were the only major confusions exhibited among the voiced-plosive group in the Miller and Nicely data (25). Both of these reversals were noted with approximately equal frequency in Studebaker's work (38).

In the voiced-fricative group the /ð/ for /v/ confusion occurred most often. This error was seen at all S/N situations but the frequency of this error peaks at the +2 dB S/N ratio with a slightly lower occurrence rate for the poorer S/N ratios of -2 dB, -6 dB and -10 dB. There were no other noteworthy error groupings for the voiced-fricative presentations. The /ð/ for /v/ error was noted in both Studebaker's (38) and Miller and Nicely's data (25).

The affricative-blend sound group produced very few errors with no apparent pattern of confusion. The lack of any identifiable pattern may be a result of the low error frequency.

The agreement between the Studebaker (38), Miller and Nicely (25), and UOST #6 data is exceptional, on the whole, and supports the conclusion that the error patterns of individual subjects should be investigated. If individual-subject error patterns can be predicted from a reasonable amount of data, this paradigm would seem to offer a reasonable means for investigating the error patterns of individual hard-of-hearing patients.

Tables 23, 24, 25, 26 and 27 present the initial-consonant-subtest error-matrix results for the male and female subjects. Although the analysis-of-variance sex-group main effect was significant at the .05 level for the initial-consonant subtest, there are no clearly discernable error-frequency differences or pattern differences indicated by the respective tables.

Vowel Subtest

The vowel-subtest error matrices are presented in Table 28. Presentation of the vowel /I/ produced substantially more errors than any of the other vowels studied while the second largest number of errors

TABLE 23

INITIAL-CONSONANT, VOICELESS-PLOSIVE, ERROR-MATRIX RESULTS AT VARIOUS S/N RATIOS FOR MALE- AND FEMALE-SUBJECT GROUPS

	MALES									
	Signal-to-Noise Ratio (in dB)									
	-10		-6		-2		+2		+6	
Presented-Responded	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2
pp	9	6	9	10	9	8	13	14	16	17
pt	8	6	8	4	7	8	6	5	3	3
pk	1	7	1	4	1	0	0	1	0	0
p-	2	1	2	2	3	4	1	0	1	0
tt	4	9	4	10	8	5	15	15	19	18
tp	7	4	7	6	6	5	3	2	0	0
tk	8	5	8	3	2	7	1	2	0	1
t-	1	2	1	1	4	3	1	1	1	1
kk	10	7	10	11	13	10	12	16	17	20
kp	2	4	2	2	0	0	1	1	0	0
kt	4	5	4	4	3	0	3	2	1	0
k-	4	4	4	3	4	10	4	1	2	0
--	16	13	16	15	19	19	17	19	20	19
-p	0	4	0	3	0	0	1	0	0	1
-t	2	2	2	1	1	1	2	1	0	0
-k	2	1	2	1	0	0	0	0	0	0

TABLE 23--Continued

	FEMALES Signal-to-Noise Ratio (in dB)									
	-10		-6		-2		+2		+6	
Presented-Responded	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2
pp	6	7	5	5	6	6	5	7	14	14
pt	10	9	9	4	4	5	9	6	3	3
pk	3	1	4	6	3	7	0	0	0	0
p-	3	1	2	5	7	2	6	7	3	3
tt	3	5	5	8	10	9	9	11	15	17
tp	4	11	3	1	0	5	1	0	1	0
tk	8	2	7	5	4	2	3	2	1	1
t-	5	0	5	6	6	4	7	7	3	2
kk	6	5	7	5	9	10	8	14	15	18
kp	3	6	0	4	1	1	0	0	0	1
kt	4	6	3	6	4	2	3	3	0	0
k-	7	3	10	5	6	7	9	3	5	1
--	10	13	12	14	18	15	18	19	19	20
-p	2	1	2	2	1	3	1	0	1	0
-t	5	2	5	2	1	2	1	1	0	0
-k	3	4	1	2	0	0	0	0	0	0

TABLE 24

INITIAL-CONSONANT, VOICED-PLOSIVE, ERROR-MATRIX RESULTS AT VARIOUS S/N RATIOS FOR MALE- AND FEMALE-SUBJECT GROUPS

	MALES									
	Signal-to-Noise Ratio (in dB)									
	-10		-6		-2		+2		+6	
Presented-Responded	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2
bb	9	6	10	14	10	9	9	14	14	16
bd	6	6	10	5	8	11	11	6	5	4
bg	3	7	0	0	1	0	0	0	0	0
b-	2	1	0	1	1	0	0	0	1	0
dd	10	6	8	8	13	14	19	17	17	19
db	4	6	10	5	3	4	0	3	2	0
dg	5	5	2	5	2	2	0	0	1	1
d-	1	3	0	2	2	0	1	0	0	0
gg	16	12	18	16	20	18	20	20	19	20
gb	2	2	0	1	0	0	0	0	0	0
gd	1	2	1	0	0	2	0	0	1	0
g-	1	4	1	3	0	0	0	0	0	0
--	13	10	15	16	16	16	20	17	20	20
-b	2	7	3	2	2	3	0	3	0	0
-d	3	2	2	0	2	0	0	0	0	0
-g	2	1	0	2	0	1	0	0	0	0

TABLE 24--Continued

	FEMALES									
	Signal-to-Noise Ratio (in dB)									
	-10		-6		-2		+2		+6	
Presented-Responded	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2
bb	10	11	10	11	9	11	14	13	17	16
bd	5	5	9	6	10	8	6	7	3	4
bg	4	1	1	0	1	0	0	0	0	0
b-	1	3	0	3	0	1	0	0	0	0
dd	7	5	12	7	12	16	17	13	20	18
db	7	5	4	9	4	2	1	3	0	2
dg	5	5	4	4	3	1	2	2	0	0
d-	1	5	0	0	1	1	0	2	0	0
gg	13	13	12	18	20	19	20	20	20	20
gb	0	1	1	0	0	0	0	0	0	0
gd	1	0	4	0	0	0	0	0	0	0
g-	6	5	3	2	0	1	0	0	0	0
--	10	5	12	9	17	17	19	18	20	19
-b	3	7	7	4	2	1	0	0	0	0
-d	2	3	0	1	0	0	0	2	0	0
-g	5	5	1	4	1	2	1	0	0	1

TABLE 25

INITIAL-CONSONANT, VOICELESS-FRICATIVE, ERROR-MATRIX RESULTS AT VARIOUS S/N RATIOS FOR MALE- AND FEMALE-SUBJECT GROUPS

	MALES									
	Signal-to-Noise Ratio (in dB)									
	-10		-6		-2		+2		+6	
Presented-Responded	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2
ff	7	6	8	7	8	8	13	11	10	16
fs	0	3	1	3	0	0	0	0	0	0
fθ	11	10	7	10	9	10	6	9	9	4
f-	2	1	4	0	3	2	1	0	1	0
ss	13	13	20	20	20	20	20	20	20	20
sf	4	2	0	0	0	0	0	0	0	0
sθ	3	4	0	0	0	0	0	0	0	0
s-	0	1	0	0	0	0	0	0	0	0
θθ	10	10	9	14	12	9	16	14	19	18
θf	8	6	8	3	7	9	4	4	1	2
θs	1	4	1	3	0	1	0	1	0	0
θ-	1	0	2	0	1	1	0	1	0	0
--	11	13	15	16	20	18	20	20	20	20
-f	3	4	1	0	0	0	0	0	0	0
-s	1	0	3	0	0	1	0	0	0	0
-θ	5	3	1	4	0	1	0	0	0	0

TABLE 25--Continued

	FEMALES									
	Signal-to-Noise Ratio (in dB)									
	-10		-6		-2		+2		+6	
Presented-Responded	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2
ff	8	7	6	6	6	9	6	8	12	9
fs	2	1	0	0	1	0	1	0	0	0
fθ	9	9	12	13	12	9	13	8	7	10
f-	0	2	2	1	1	2	0	3	1	1
ss	13	12	20	19	20	20	19	20	20	20
sf	1	3	0	0	0	0	0	0	0	0
sθ	4	5	0	0	0	0	0	0	0	0
s-	1	0	0	1	0	0	1	0	0	0
θθ	13	8	12	15	12	14	17	17	19	16
θf	5	7	3	5	7	4	1	2	1	3
θs	0	3	2	0	0	0	1	0	0	0
θ-	2	2	3	0	1	2	1	0	0	1
--	13	8	15	16	18	17	20	20	19	19
-f	1	4	2	3	0	1	0	0	1	0
-s	2	1	0	0	0	0	0	0	0	0
-θ	4	6	2	1	2	2	0	0	0	1

TABLE 26

INITIAL-CONSONANT, VOICED-FRICATIVE, ERROR-MATRIX RESULTS AT VARIOUS S/N RATIOS FOR MALE- AND FEMALE-SUBJECT GROUPS

	MALES									
	Signal-to-Noise Ratio (in dB)									
	-10		-6		-2		+2		+6	
Presented-Responded	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2
vv	8	6	9	7	11	7	6	8	16	16
vz	3	2	1	3	0	3	1	0	0	0
vð	8	11	9	8	9	10	13	12	4	4
v-	1	1	1	2	0	0	0	0	0	0
zz	8	7	16	16	20	20	20	20	20	20
zv	3	5	2	1	0	0	0	0	0	0
zð	9	7	2	3	0	0	0	0	0	0
z-	0	1	0	0	0	0	0	0	0	0
ðð	12	11	14	15	15	6	18	19	20	18
ðv	5	5	5	2	3	9	1	1	0	2
ðz	3	3	1	3	2	4	1	0	0	0
ð-	0	1	0	0	0	1	0	0	0	0
--	10	8	13	11	19	18	20	20	20	20
-v	3	4	3	5	1	2	0	0	0	0
-z	3	7	1	2	0	0	0	0	0	0
-ð	4	1	3	2	0	0	0	0	0	0

TABLE 26--Continued

FEMALES										
	Signal-to-Noise Ratio (in dB)									
	-10		-6		-2		+2		+6	
Presented-Responded	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2
vv	6	11	8	8	12	11	12	10	15	13
vz	4	3	2	2	1	0	0	0	0	0
vð	10	4	10	9	6	9	7	10	5	7
v-	0	2	0	1	1	0	1	0	0	0
zz	10	9	18	12	18	20	19	20	20	20
zv	3	4	1	3	0	0	0	0	0	0
zð	7	7	1	3	2	0	0	0	0	0
z-	0	0	0	1	0	0	1	0	0	0
ðð	11	8	9	12	17	17	15	16	14	18
ðv	6	6	7	6	2	2	4	1	6	2
ðz	3	4	3	1	1	0	1	3	0	0
ð-	0	2	1	0	0	1	0	0	0	0
--	9	10	16	16	16	18	19	20	20	20
-v	4	4	1	2	2	1	0	0	0	0
-z	4	1	1	0	0	0	0	0	0	0
-ð	3	5	2	2	2	1	1	0	0	0

TABLE 27

INITIAL-CONSONANT, AFFRICATIVE-BLEND, ERROR-MATRIX RESULTS AT VARIOUS S/N RATIOS FOR MALE- AND FEMALE-SUBJECT GROUPS

	MALES									
	Signal-to-Noise Ratio (in dB)									
	-10		-6		-2		+2		+6	
Presented-Responded	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2
st st	16	17	20	20	20	20	20	20	19	20
st ʃ	2	3	0	0	0	0	0	0	1	0
st tʃ	2	0	0	0	0	0	0	0	0	0
st -	0	0	0	0	0	0	0	0	0	0
ʃ ʃ	12	17	18	18	20	20	20	20	20	20
ʃ st	1	1	0	0	0	0	0	0	0	0
ʃ tʃ	7	2	2	2	0	0	0	0	0	0
ʃ -	0	0	0	0	0	0	0	0	0	0
tʃ tʃ	16	17	20	19	19	19	20	20	20	20
tʃ st	3	1	0	0	0	0	0	0	0	0
tʃ ʃ	1	2	0	1	1	1	0	0	0	0
tʃ -	0	0	0	0	0	0	0	0	0	0
- -	19	20	20	18	20	20	20	20	20	20
- st	0	0	0	0	0	0	0	0	0	0
- ʃ	0	0	0	0	0	0	0	0	0	0
- tʃ	1	0	0	2	0	0	0	0	0	0

TABLE 27--Continued

	FEMALES									
	Signal-to-Noise Ratio (in dB)									
	-10		-6		-2		+2		+6	
Presented-Responded	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2
st st	15	16	18	19	20	20	20	20	19	20
st ʃ	1	3	0	1	0	0	0	0	1	0
st tʃ	3	0	1	0	0	0	0	0	0	0
st -	1	1	0	0	0	0	0	0	0	0
ʃ ʃ	15	13	19	19	20	20	19	19	20	19
ʃ st	1	0	0	0	0	0	0	0	0	0
ʃ tʃ	4	6	1	1	0	0	1	0	0	0
ʃ -	0	1	0	0	0	0	0	0	0	0
tʃ tʃ	15	17	20	18	20	20	20	20	20	20
tʃ st	3	1	0	0	0	0	0	0	0	0
tʃ ʃ	2	2	0	2	0	0	0	0	0	0
tʃ -	0	0	0	0	0	0	0	0	0	0
- -	20	20	19	19	20	19	20	19	20	20
- st	0	0	1	1	0	1	0	0	0	0
- ʃ	0	0	0	0	0	0	0	0	0	0
- tʃ	0	0	0	0	0	0	0	1	0	0

TABLE 28

VOWEL SUBTEST, ERROR-MATRIX RESULTS AT VARIOUS S/N RATIOS, COMBINED OVER ALL OTHER FACTORS (RAW SCORES)

	Signal-to-Noise Ratio (in dB)				
Presented-Responded	-16	-14	-12	-10	-8
ii	64	88	113	131	143
iI	14	8	3	3	0
iɛ	7	5	1	6	3
iæ	12	4	0	0	0
ie	11	7	0	0	2
iʌ	8	3	0	1	0
io	10	1	3	2	1
iu	32	43	40	17	10
II	37	63	93	105	122
Ii	8	9	2	4	3
Iɛ	15	12	17	12	14
Iae	3	3	2	0	1
Ie	38	31	11	16	11
Iʌ	11	6	7	2	2
Io	28	21	19	16	3
Iu	16	15	9	5	3
ɛɛ	51	95	107	125	133
ɛi	8	2	1	1	1
ɛI	6	3	4	0	1
ɛæ	17	11	10	8	6
ɛe	14	6	1	3	0
ɛʌ	40	38	32	23	18
ɛo	15	4	1	0	0
ɛu	9	1	2	0	1
ææ	76	111	114	129	145
æi	6	3	3	0	4
æI	8	3	1	1	0
æɛ	15	12	10	5	5
æe	10	4	2	2	0
æʌ	26	21	23	21	6
æo	11	4	6	0	0
æu	4	0	0	2	0

TABLE 28--Continued

Presented-Responded	-16	-14	-12	-10	-8
	Signal-to-Noise Ratio (in dB)				
ee	61	100	99	129	146
ei	14	4	7	2	1
eI	10	14	4	3	3
eɛ	10	5	9	7	1
eæ	8	2	1	1	0
eʌ	10	1	1	1	0
eo	30	25	33	13	8
eu	14	9	6	4	1
ʌʌ	63	95	106	132	145
ʌi	6	3	3	1	0
ʌI	11	10	8	5	1
ʌɛ	24	21	14	15	8
ʌæ	22	17	17	3	5
ʌe	8	7	6	3	1
ʌo	19	5	5	1	0
ʌu	6	2	1	0	0
oo	61	86	122	135	150
oi	7	4	2	0	1
oI	8	6	2	1	2
oɛ	8	13	4	4	0
oæ	8	4	2	0	0
oe	38	34	22	16	3
oʌ	20	5	3	1	1
ou	9	7	2	3	3
uu	55	81	122	133	145
ui	41	41	18	12	9
uI	12	9	6	3	0
uɛ	9	3	1	5	0
uæ	6	2	1	0	0
ue	16	12	3	4	1
uʌ	7	4	5	1	1
uo	11	6	4	2	3

occurred with presentation of /ɛ/. The number of errors for /ɛ/ presentations was considerably greater than the number of errors produced by the /e/, /u/, /i/, and /ʌ/ phoneme presentations. This group of four vowels was next in error count and displays essentially equal error frequencies. The /o/ and /æ/ matrices reveal considerably fewer errors than those of the other vowels. Essentially the same hierarchy of error frequency was seen in the data of Studebaker (38), although there are some differences between the two studies. The most notable difference between the results of the two studies is that Studebaker's data evidence more errors for the /ɛ/ phoneme than for the /I/ phoneme. The two vowels together, however, do account for the greatest number of errors in both studies. Data presented by Oyer and Doudna (29)indicate that the /I/ and /ɛ/ phonemes are frequently missed and that they are often confused for each other. Peterson and Barney (30), studying vowel-sound intelligibility also noted this confusion as a frequent one.

The error analysis for the vowel test illustrates that each phoneme studied usually was most often confused with only one other vowel within the phonemes available for response. Only the /ʌ/ and /I/ phonemes were confused frequently with more than one vowel. The major confusions, in the order of their frequency of occurrence follow. The greatest number of confusions for single phoneme contrasts were /ʌ/ for /ɛ/ and /u/ for /i/. The confusions /i/ for /u/, /o/ for /e/, /e/ for /I/, /e/ for /o/ and /ʌ/ for /æ/ occurred considerably less often than the /ʌ/ for /ɛ/ or /u/ for /i/ but they are all major confusions and occurred with approximately equal frequency. The groups with the next highest number of error confusions were the /ɛ/ for /ʌ/, /ɛ/ for /I/ and /æ/ for /ʌ/

substitutions. The remaining phoneme contrasts produced relatively few confusions.

The above hierarchy of phoneme-confusions provides several contrasts with earlier studies concerned with vowel discrimination and intelligibility. The most often observed confusion in this study (/ʌ/ for /ɛ/) is in agreement with Owens, Talbott and Schubert's data (28) obtained from hard-of-hearing subjects but is not noted frequently in other works. The /u/ for /i/, /i/ for /u/ reversal seen frequently in this study can be detected but is not prominent in both Peterson and Barney's data (30) and Oyer and Doudna's data (29). Owens, Talbott and Schubert's (28) and Studebaker's (38) works do not show this confusion as a major one. Another very notable difference is the confusion results for the /ɛ/ for /I/, /I/ for /ɛ/ confusions. This reversal has been noted as a very frequent confusion by Oyer and Doudna (29), Peterson and Barney (30) and Owens, Talbott and Schubert (28). This study and Studebaker's (38) found it noticeable but not particularly prominent. In general, the results of this study and earlier studies do not yet agree sufficiently to allow broad generalization concerning a hierarchy of vowel-confusion occurrence.

Table 29 presents the comparison of male and female performance on the vowel subtest. Although the trend of more errors as S/N ratio decreases remains true for both sex groups, inspection of Table 29 reveals that male and female performance often differs sharply for the same vowel phoneme. These differences follow no observable consistent pattern. For some vowel phonemes the males made more errors than females for all S/N environments and for other vowel phonemes the females made more errors than the males for all S/N environments. For other phonemes S/N-ratio

TABLE 29

VOWEL SUBTEST, ERROR-MATRIX RESULTS
AT VARIOUS S/N RATIOS FOR MALE-
AND FEMALE-SUBJECT GROUPS

MALES										
	Signal-to-Noise Ratio (in dB)									
	-16		-14		-12		-10		-8	
Presented-Responded	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2
ii	17	17	23	22	24	31	31	33	34	36
iI	3	4	2	0	0	1	2	1	0	0
iε	3	2	1	4	1	0	0	2	0	1
iæ	0	5	0	1	0	0	0	0	0	0
ie	4	2	1	2	0	0	0	0	0	1
iʌ	1	1	0	0	0	0	0	0	0	0
io	3	1	1	0	1	1	1	0	0	0
iu	9	8	12	11	14	7	6	4	5	2
II	13	13	21	20	30	27	31	26	31	34
Ii	3	2	1	2	0	0	0	1	2	0
Iε	2	3	2	2	3	2	2	1	1	3
Iæ	0	1	0	0	0	1	0	0	0	1
Ie	11	11	10	8	3	1	3	5	4	1
Iʌ	2	3	1	1	1	4	0	2	1	1
Io	6	3	2	1	1	2	2	3	0	0
Iu	3	4	3	6	2	3	2	2	1	0
εε	16	15	28	28	32	25	33	29	29	31
εi	1	2	0	1	0	0	0	0	1	0
εI	1	1	0	1	1	1	0	0	1	0
εæ	4	4	3	1	1	2	1	2	2	2
εe	0	1	2	2	0	0	0	0	0	0
εʌ	13	12	6	7	6	10	6	9	7	7
εo	3	4	1	0	0	0	0	0	0	0
εu	2	1	0	0	0	1	0	0	0	0
ææ	28	23	31	34	30	32	34	34	38	36
æi	1	2	0	0	0	2	0	0	0	1
æI	1	1	0	0	0	0	0	0	0	0
æε	2	5	2	2	1	2	1	2	1	2
æe	0	0	0	2	0	0	0	1	0	0
æʌ	5	7	6	1	9	4	3	3	1	1
æo	2	1	1	1	0	0	0	0	0	0
æu	1	1	0	0	0	0	2	0	0	0

TABLE 29--Continued

	FEMALES									
	Signal-to-Noise Ratio (in dB)									
	-16		-14		-12		-10		-8	
Presented-Responded	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2
ii	17	13	26	17	28	30	35	32	35	38
iI	3	4	3	3	1	1	0	0	0	0
iε	2	0	0	0	0	0	1	3	2	0
iæ	5	2	1	2	0	0	0	0	0	0
ie	3	2	2	2	0	0	0	0	1	0
iΛ	1	5	3	0	0	0	1	0	0	0
io	1	5	0	0	1	0	1	0	0	1
iu	6	9	4	16	10	9	2	5	2	1
II	6	5	9	13	20	16	22	26	26	31
Ii	0	3	2	4	0	2	2	1	1	0
Iε	8	2	4	4	4	8	6	3	6	4
Iæ	0	2	3	0	1	0	0	0	0	0
Ie	7	7	9	4	4	3	3	5	1	5
IΛ	4	2	1	3	0	2	0	0	0	0
Io	10	9	8	10	9	7	6	5	3	0
Iu	2	7	4	2	2	2	1	0	2	0
εε	13	7	20	19	26	24	30	33	34	39
εi	2	3	0	1	1	0	1	0	0	0
εI	3	1	1	1	2	0	0	0	0	0
εæ	5	4	5	2	3	4	2	3	1	1
εe	7	6	1	1	1	0	2	1	0	0
εΛ	4	11	11	14	6	10	5	3	4	0
εo	2	6	2	1	1	0	0	0	0	0
εu	4	2	0	1	0	1	0	0	1	0
æ ae	13	12	27	19	27	25	31	30	36	35
æi	1	2	0	3	1	0	0	0	1	2
æI	3	3	2	1	0	1	1	0	0	0
æε	3	5	5	3	4	3	0	2	1	1
æe	5	5	2	0	1	1	1	0	0	0
aeΛ	7	7	3	11	5	5	7	8	2	2
æo	4	4	1	1	1	5	0	0	0	0
æu	1	1	0	0	0	0	0	0	0	0

TABLE 29--Continued

	MALES									
	Signal-to-Noise Ratio (in dB)									
	-16		-14		-12		-10		-8	
Presented-Responded	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2
ee	22	19	29	27	25	26	30	35	36	35
ei	1	3	0	1	2	1	2	0	1	0
eI	3	3	5	3	1	1	1	0	0	0
eɛ	1	3	1	2	4	3	4	0	0	1
eæ	2	2	0	0	0	1	0	0	0	0
eʌ	1	1	0	0	0	0	0	0	0	0
eo	7	6	3	4	7	6	0	5	3	3
eu	3	3	2	3	1	2	3	0	0	1
ʌʌ	14	20	25	20	23	28	27	33	34	37
ʌi	1	1	0	0	0	0	0	1	0	0
ʌI	5	3	4	3	4	2	4	1	0	1
ʌɛ	6	6	6	8	8	4	5	3	2	2
ʌæ	10	3	3	5	5	1	3	0	4	0
ʌe	0	1	1	2	0	3	1	1	0	0
ʌo	2	4	1	1	0	1	0	1	0	0
ʌu	2	2	0	1	0	1	0	0	0	0
oo	11	17	25	21	27	32	29	35	36	39
oi	1	1	0	1	0	0	0	0	0	0
oI	2	3	2	0	0	1	1	0	1	0
oɛ	0	4	2	5	2	2	1	0	0	1
oæ	3	1	0	1	0	0	0	0	0	0
oe	14	11	9	9	10	3	8	2	1	0
oʌ	5	3	2	1	0	1	0	1	1	0
ou	4	0	0	2	1	0	1	2	1	0
uu	15	16	18	19	32	34	30	37	37	38
ui	10	11	10	13	4	3	3	1	1	1
uI	4	4	2	2	0	1	1	1	0	0
uɛ	3	1	1	0	0	0	3	1	0	0
uæ	0	2	0	1	0	0	0	0	0	0
ue	6	5	5	4	2	1	1	0	0	0
uʌ	0	0	1	1	2	1	1	0	0	0
uo	2	1	3	0	0	0	1	0	2	1

TABLE 29--Continued

	FEMALES									
	Signal-to-Noise Ratio (in dB)									
	-16		-14		-12		-10		-8	
Presented-Responded	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2	1/2	2/2
ee	13	7	26	18	25	23	31	33	36	39
ei	2	8	1	2	2	1	0	0	1	0
eI	1	3	1	5	1	2	1	1	0	1
eɛ	2	4	2	0	4	1	2	1	0	0
eæ	1	3	0	2	0	0	1	0	0	0
eʌ	4	4	1	0	0	0	1	0	0	0
eo	12	5	8	10	7	10	3	5	3	0
eu	4	4	1	3	1	3	1	0	0	0
ʌʌ	17	12	26	24	25	30	36	36	37	37
ʌi	2	2	2	1	3	0	0	0	0	0
ʌI	1	2	2	1	1	1	0	0	0	0
ʌɛ	7	5	1	6	2	0	4	3	1	3
ʌæ	3	6	6	3	7	4	0	0	1	0
ʌe	2	5	2	2	1	2	0	1	1	0
ʌo	7	6	1	2	1	3	0	0	0	0
ʌu	0	2	0	1	0	0	0	0	0	0
oo	17	16	23	17	29	34	32	39	37	38
oi	3	2	3	0	2	0	0	0	0	0
oI	1	2	0	4	1	0	0	0	0	0
oɛ	3	1	4	2	0	0	3	0	0	1
oæ	4	0	2	1	2	0	0	0	0	0
oe	6	7	6	10	4	5	5	1	2	0
oʌ	3	9	1	1	1	1	0	0	0	0
ou	2	3	1	4	1	0	0	0	1	1
uu	10	14	27	17	28	28	32	34	34	36
ui	13	7	5	13	6	5	3	5	4	3
uI	2	2	3	2	2	3	1	0	0	0
uɛ	3	2	0	2	1	0	1	0	0	0
uæ	2	2	1	1	1	1	0	0	0	0
ue	2	3	1	2	1	2	2	1	1	0
uʌ	2	5	1	1	0	1	0	0	1	0
uo	5	3	2	2	1	0	1	0	0	0

decreases often resulted in one sex group making more errors than the other or in one group stabilizing in error count while the other sex group increased in the number of errors made. Another occurrence was that an increase in the noise level resulted in an error-pattern change to another available response for one sex group but not the other. Males produced substantially more errors for the sound confusions /u/ for /i/, /ʌ/ for /ɛ/, /ɛ/ for /ʌ/, /I/ for /ʌ/, /e/ for /o/, /e/ for /u/, and /e/ for /I/ than did the female group. The female subjects produced substantially more errors than the males for the sound confusions /o/ for /I/, /ɛ/, for /I/, /ʌ/ for /ae/, /I/ for /æ/, /e/ for /æ/, /o/ for /æ/, /o/ for /e/, /e/ for /o/, /e/ for /ɛ/, /ʌ/ for /e/, /o/ for /ʌ/, /i/ for /ʌ/, /i/ for /o/ and /i/ for /u/.

The female group also was noticeably more affected by the more intense interference levels than was the male group. The reasons for this poorer performance in intense noises and the reasons for the differences in male and female group performances are unknown at this time. There has been no comparable work done in speech-discrimination hearing testing by other investigators with which to compare.

The first-half of the vowel subtest resulted in only six more errors than the second-half of the subtest. Further, in all instances the data for each half of the subtest across S/N ratios, scramblings, sex groups and phoneme error-matrices were virtually identical. The similarity of the data was so consistent that it was not considered profitable to include the half-subtest error comparisons in separate tables. This information, however, may be extracted from Table 29 if desired.

CHAPTER V

SUMMARY

The speech tests currently used for testing auditory discrimination most commonly are constructed of meaningful, monosyllabic, test words, are fifty words in length and are phonetically or phonemically balanced. These tests are based on tests which were originally designed for evaluating communications systems rather than man's auditory-discrimination abilities. Although these tests provide overall indications of patients' speech discrimination abilities, they have not been used successfully for evaluating speech reception analytically, nor for reliable and valid differentiations between the performances of hearing aids. These limitations and the need for better speech tests have led researchers to seek other approaches to the evaluation of speech-discrimination, including new test materials and new test paradigms.

The most recent of these efforts has been directed toward the development of formats which limit the response alternatives available to the subject (a closed-response set). These response alternatives (the items within a set) are selected without regard to phonetic or phonemic balance. They are selected on the basis of such criteria as varying the speech sound in only one phoneme position across a set of CVC words, reducing the number of articulatory-classification parameters varied within a test set and varying only the place of articulatory production of the test phonemes within the set. Such classification schemes have resulted in the combining of a group of phonemes which are most frequently confused with each other in the absence of contextual information.

This report presents the UOST #6, a discrimination test designed and produced in an effort to create a clinical and/or research tool of the closed-response type. It is hoped that this procedure will provide the basis for an analytical evaluation as well as a quantitative evaluation of subjects' speech-discrimination abilities.

The UOST #6 is a closed-response set, monosyllabic word, speech-discrimination test consisting of three independent subtests. Each subtest was designed to study phoneme identification in different positions in CVC monosyllabic-words. These subtests include a final-consonant subtest, an initial-consonant subtest and a vowel subtest. The consonant subtests are eighty-presentation subtests comprised of five, four-item closed-response sets. Each item within the subtest is presented four times per subtest presentation. The vowel subtest is a sixty-four-presentation subtest comprised of one, eight-item closed-response set. Each item within the vowel subtest is presented eight times per vowel-subtest presentation. Each of the three subtests were developed with five scramblings and four answer sheets to allow repeated subject re-testing while reducing the effect of sequence-familiarity and position-on-the-answer-form biases. One trained General-American-English talker was used to record the words. The scramblings were developed through a series of r-cordings and rerecordings, reordering and splicing. Each subtest was also monitored and rerecorded for equal-intensity presentation of the test items.

The UOST #6 was presented to twenty, normally-hearing subjects (10 males and 10 females) in five different S/N ratios for each subtest in order to develop normative intelligibility functions for each subtest. These normative data was then analyzed quantitatively (subtests, across noise levels, subtest halves, subtest scramblings and sex groups) and analytically (across subtests, across phoneme groups and test halves, and within phoneme groups). The following relationships are indicated.

Quantitative Analysis

1. Intelligibility of the test items for all subtests increased successively as more favorable S/N ratios were used. The percentage of correct responses observed for the final-consonant subtest extended from about 47.0 percent at the poorest S/N ratio (-8 dB S/N ratio) to about 84.0 percent for the best listening environment (+8 dB S/N ratio). The percentage of correct responses observed for the initial-consonant subtest at the poorest S/N ratio (-10 dB S/N ratio) was about 53.0 percent, extending to 91.0 percent for the best listening situation (+6 dB S/N ratio). These findings for the vowel subtest were about 37.0 percent for the worst S/N ratio (-16 dB S/N ratio) and increased to about 88.0 percent for the best S/N ratio (-8 dB S/N ratio). The rate of increase observed was 2.3 percent per dB for the final-consonant subtest, 2.7 percent per dB for the initial-consonant subtest and 6.4 percent per dB for the vowel subtest.
2. All scramblings for each of the UOST #6 subtests produced comparable results as main effects. The consonant-subtest-scrambling

interactions also were not found to be significant indicating that consonant-subtest scramblings are interchangeable. The scrambling-noise and scrambling-noise-sex interaction for the vowel test, however, were significant at the .01 level, reducing the usefulness of this subtest.

3. Subtest first-half-second-half comparisons and their respective interactions were not significant for any of the UOST #6 subtests indicating that comparable quantitative information may be derived from each half of the individual subtests. This finding suggests that the length of a clinically-used UOST #6 may be cut in half if only quantitative total scores are desired.

4. Sex-group performances were not significantly different for the final-consonant subtest but were found to be significant at the .05 and .01 levels for the initial-consonant subtest and the vowel subtest, respectively. The sex-group interactions were not significant for either of the consonant subtests but the sex-noise and sex-scrambling-noise interaction for the vowel subtest were significant at the .05 and .01 levels, respectively. It was concluded that the above differences were not sufficient to preclude further investigation of the consonant subtests as clinical tools with hard-of-hearing populations. The .05 level of significance in the initial-consonant test represents only approximately two more correct responses for males than females over the eighty, subtest presentations. The vowel-subtest findings, however, reflect comparatively larger differences and a number of unexplained interrelationships.

Overall, these results indicate that the UOST #6 consonant subtests offer sufficient promise as quantitative tests of speech discrimination to justify further investigation with hearing-loss populations. The complexity of the interaction results noted for the vowel subtest, however, indicates that further investigation of a fundamental nature must be carried out on the vowel subtest before it can be used further.

Error-Pattern Analysis

A fairly well-defined hierarchy of error patterns was obtained for each subtest. The error patterns, particularly those for the consonant subtests, were in good general agreement with earlier works although there are differences of importance. In the present study more errors were obtained in the voiced-plosive, voiced-fricative and voiceless-plosive phoneme groups, respectively, for the final-consonant subtest with the other groups evidencing considerably fewer errors. The /g/ for /b/ errors and the /-/ for /b/ errors dominated the voiced-plosive category, with the /v/ for /ð/, /ð/ for /v/, /-/ for /v/ and /-/ for /ð/ errors noted most often among the voiced-fricative group and the /f/ for /θ/ and /θ/ for /f/ errors most noticeable among the voiceless-fricative phoneme group. This latter grouping evidenced substantially fewer errors than the preceding groups. The initial-consonant subtest results differed from the above with a hierarchy including substantially more errors for the voiceless-plosives and voiceless-fricatives, respectively, than for the other three phoneme groups. The errors most frequently noted among these two sound groups were the /t/ for /p/, /-/ for /k/ and /k/ for /t/ errors (among the voiceless-plosives) and /f/ for /θ/ and /θ/ for /f/ among the voiceless-fricatives. The agreement between the

UOST #6 consonant subtests and the results reported by other authors (6, 10, 17, 25, 26, 38) is exceptional on the whole and indicates that this paradigm offers a reasonable approach to the investigation of consonant error patterns.

The vowel subtest data reveals more errors among the /I/, /ɛ/, /u/, /i/ and /ʌ/ phonemes, respectively than among the other phonemes studied. The results of the vowel subtest were not as consistent with earlier data as the results of the consonant subtests, although the major errors observed in this study (/ʌ/ for /ɛ/, /u/ for /i/, /i/ for /u/) were noted as prominent errors in several different investigations. This lack of overall agreement prevents broad generalizations concerning vowel errors. There is, however, sufficient agreement among the studies to suggest that individual-subject error analysis may be fruitful.

First-half-second-half error consistency was noted to be excellent among the subtests supporting the reliability of the techniques used. It is not known at this time whether sufficient information can be gleaned from half-test presentations to support the practical use of shorter-test presentation results in error analysis studies. However, this aspect will be evaluated further in the individual-subject data analysis. Differences in error-patterns observed between the male and female subgroups also were interesting but require further study before allowing generalization.

The amount of data collected, the complexity of the necessary analysis and the restrictions on the available time for this project did not permit a complete analysis of the data into error patterns over subtest scrambling, noise levels or individual subjects, separately. A continuation of this analysis has been planned for the near future. At this time, the ability of the UOST #6 subtests to determine the error-patterns of individuals remains unknown. The results of this study do indicate that the closed-response-set format and the techniques of articulation-feature comparisons may be worthwhile developments toward a clinically-useful, analytical speech-discrimination test. Further study is indicated, however, before either the techniques or the UOST #6 subtests can be used to evaluate the error patterns of individual subjects.

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APPENDIXES

APPENDIX A

SUBTEST SCRAMBLINGS

1. Final Consonant Subtest....Scrambling 1

   Final Consonant Subtest....Scrambling 2

   Final Consonant Subtest....Scrambling 3

   Final Consonant Subtest....Scrambling 4

   Final Consonant Subtest....Scrambling 5

2. Initial Consonant Subtest....Scrambling 1

   Initial Consonant Subtest....Scrambling 2

   Initial Consonant Subtest....Scrambling 3

   Initial Consonant Subtest....Scrambling 4

   Initial Consonant Subtest....Scrambling 5

3. Vowel Subtest....Scrambling 1

   Vowel Subtest....Scrambling 2

   Vowel Subtest....Scrambling 3

   Vowel Subtest....Scrambling 4

   Vowel Subtest....Scrambling 5

FINAL CONSONANT TEST

Test Form I

1.	pot	21.	pock	41.	pop	61.	pa
2.	row	22.	row	42.	rogue	62.	row
3.	rue	23.	Ruth	43.	rue	63.	ruse
4.	lithe	24.	live	44.	live	64.	lithe
5.	leash	25.	lee	45.	lee	65.	leech
6.	pop	26.	pock	46.	pock	66.	pot
7.	rode	27.	rogue	47.	robe	67.	rode
8.	Ruth	28.	roof	48.	rue	68.	ruse
9.	lie	29.	lithe	49.	lie	69.	lies
10.	least	30.	leash	50.	lee	70.	leech
11.	pa	31.	pa	51.	pa	71.	pop
12.	robe	32.	robe	52.	rogue	72.	robe
13.	ruse	33.	rue	53.	roof	73.	Ruth
14.	live	34.	lie	54.	lie	74.	lies
15.	lee	35.	leech	55.	least	75.	least
16.	pot	36.	pop	56.	pock	76.	pot
17.	rode	37.	rogue	57.	row	77.	rode
18.	ruse	38.	roof	58.	Ruth	78.	roof
19.	lies	39.	lies	59.	live	79.	lithe
20.	least	40.	leech	60.	leash	80.	leash

FINAL CONSONANT TEST

Test Form II

1. pa
2. rode
3. roof
4. lithe
5. leash
6. pop
7. row
8. rue
9. lie
10. leash
11. pa
12. rode
13. ruse
14. lies
15. leech
16. pock
17. row
18. rue
19. live
20. leech
21. pock
22. robe
23. Ruth
24. live
25. least
26. pop
27. robe
28. Ruth
29. lithe
30. least
31. pot
32. rogue
33. roof
34. lies
35. lee
36. pot
37. rogue
38. ruse
39. lie
40. lee
41. pop
42. robe
43. roof
44. lie
45. leech
46. pot
47. robe
48. ruse
49. lies
50. least
51. pock
52. row
53. roof
54. lithe
55. lee
56. pot
57. rogue
58. Ruth
59. lie
60. leash
61. pop
62. row
63. Ruth
64. lies
65. leech
66. pa
67. rode
68. ruse
69. lithe
70. least
71. pock
72. rogue
73. rue
74. live
75. leash
76. pa
77. rode
78. rue
79. live
80. lee

FINAL CONSONANT TEST

Test Form III

1.	pot	21.	pock	41.	pa	61.	pop
2.	rode	22.	robe	42.	robe	62.	rode
3.	roof	23.	rue	43.	rue	63.	roof
4.	lies	24.	lithe	44.	lithe	64.	lie
5.	least	25.	leech	45.	least	65.	lee
6.	pot	26.	pock	46.	pot	66.	pock
7.	row	27.	rogue	47.	rode	67.	robe
8.	ruse	28.	roof	48.	ruse	68.	roof
9.	lithe	29.	lie	49.	lie	69.	lies
10.	leash	30.	lee	50.	leech	70.	least
11.	pa	31.	pop	51.	pa	71.	pock
12.	rogue	32.	rode	52.	rogue	72.	row
13.	ruse	33.	Ruth	53.	ruse	73.	Ruth
14.	live	34.	lie	54.	lithe	74.	live
15.	leech	35.	lee	55.	leash	75.	lee
16.	pop	36.	pa	56.	pop	76.	pot
17.	row	37.	robe	57.	rogue	77.	row
18.	Ruth	38.	rue	58.	rue	78.	Ruth
19.	lies	39.	live	59.	live	79.	lies
20.	least	40.	leash	60.	leash	80.	leech

FINAL CONSONANT TEST

Test Form IV

1. pot
2. rode
3. roof
4. live
5. least
6. pop
7. rogue
8. Ruth
9. live
10. leash
11. pot
12. rogue
13. ruse
14. lie
15. leech
16. pop
17. row
18. roof
19. lie
20. leech
21. pa
22. rode
23. Ruth
24. lithe
25. leash
26. pa
27. row
28. rue
29. lithe
30. lee
31. pock
32. robe
33. ruse
34. lies
35. lee
36. pock
37. robe
38. rue
39. lies
40. least
41. pa
42. robe
43. rue
44. lies
45. least
46. pot
47. rode
48. roof
49. lies
50. least
51. pop
52. robe
53. Ruth
54. live
55. lee
56. pock
57. row
58. roof
59. lithe
60. lee
61. pock
62. rogue
63. rue
64. lithe
65. leech
66. pop
67. rogue
68. ruse
69. live
70. leech
71. pa
72. rode
73. ruse
74. lie
75. leash
76. pot
77. row
78. Ruth
79. lie
80. leash

FINAL CONSONANT TEST

Test Form V

1. pock
2. rogue
3. roof
4. lithe
5. least
6. pa
7. rode
8. rue
9. lies
10. leash
11. pop
12. rogue
13. Ruth
14. lithe
15. least
16. pot
17. rode
18. ruse
19. live
20. leech
21. pock
22. row
23. roof
24. lie
25. lee
26. pa
27. row
28. rue
29. live
30. leech
31. pop
32. robe
33. Ruth
34. lies
35. leash
36. pot
37. robe
38. ruse
39. lie
40. lee
41. pot
42. rogue
43. ruse
44. lithe
45. leash
46. pot
47. rode
48. roof
49. lithe
50. leash
51. pa
52. rogue
53. rue
54. lies
55. leech
56. pop
57. robe
58. roof
59. lie
60. lee
61. pop
62. robe
63. Ruth
64. live
65. least
66. pa
67. row
68. rue
69. lie
70. leech
71. pock
72. rode
73. Ruth
74. lies
75. lee
76. pock
77. row
78. ruse
79. live
80. least

INITIAL CONSONANT TEST

Test Form I

1.	care	21.	tear	41.	pair	61.	air
2.	ale	22.	ale	42.	gale	62.	ale
3.	in	23.	fin	43.	in	63.	thin
4.	thee	24.	vee	44.	vee	64.	thee
5.	shop	25.	hop	45.	hop	65.	chop
6.	pair	26.	tear	46.	tear	66.	care
7.	dale	27.	dale	47.	bale	67.	dale
8.	fin	28.	sin	48.	in	68.	thin
9.	zee	29.	thee	49.	zee	69.	e
10.	stop	30.	shop	50.	hop	70.	chop
11.	air	31.	air	51.	air	71.	pair
12.	bale	32.	bale	52.	gale	72.	bale
13.	thin	33.	in	53.	sin	73.	fin
14.	vee	34.	zee	54.	zee	74.	e
15,	hop	35.	chop	55.	stop	75.	stop
16.	care	36.	pair	56.	tear	76.	care
17.	gale	37.	gale	57.	ale	77.	dale
18.	thin	38.	sin	58.	fin	78.	sin
19.	e	39.	e	59.	vee	79.	thee
20.	stop	40.	chop	60.	shop	80.	shop

INITIAL CONSONANT TEST

Test Form II

1. air
2. dale
3. sin
4. thee
5. shop
6. pair
7. ale
8. in
9. zee
10. shop
11. air
12. dale
13. thin
14. e
15. chop
16. tear
17. ale
18. in
19. vee
20. chop
21. tear
22. bale
23. fin
24. vee
25. stop
26. pair
27. bale
28. fin
29. thee
30. stop
31. care
32. gale
33. sin
34. e
35. hop
36. care
37. gale
38. thin
39. zee
40. hop
41. pair
42. bale
43. sin
44. zee
45. chop
46. care
47. bale
48. thin
49. e
50. stop
51. tear
52. ale
53. sin
54. thee
55. hop
56. care
57. gale
58. fin
59. zee
60. shop
61. pair
62. ale
63. fin
64. e
65. chop
66. air
67. dale
68. thin
69. thee
70. stop
71. tear
72. gale
73. in
74. vee
75. shop
76. air
77. dale
78. in
79. vee
80. hop

INITIAL CONSONANT TEST

Test Form III

1.	care	21.	tear	41.	air	61.	pair
2.	dale	22.	bale	42.	bale	62.	dale
3.	sin	23.	in	43.	in	63.	sin
4.	e	24.	thee	44.	thee	64.	zee
5.	stop	25.	chop	45.	stop	65.	hop
6.	care	26.	tear	46.	care	66.	tear
7.	ale	27.	gale	47.	dale	67.	bale
8.	thin	28.	sin	48.	thin	68.	sin
9.	thee	29.	zee	49.	zee	69.	e
10.	shop	30.	hop	50.	chop	70.	stop
11.	air	31.	pair	51.	air	71.	tear
12.	gale	32.	dale	52.	gale	72.	ale
13.	thin	33.	fin	53.	thin	73.	fin
14.	vee	34.	zee	54.	thee	74.	vee
15.	chop	35.	hop	55.	shop	75.	hop
16.	pair	36.	air	56.	pair	76.	care
17.	ale	37.	bale	57.	gale	77.	ale
18.	fin	38.	in	58.	in	78.	fin
19.	e	39.	vee	59.	vee	79.	e
20.	stop	40.	shop	60.	shop	80.	chop

INITIAL CONSONANT TEST

Test Form IV

1. care	21. air	41. air	61. tear
2. dale	22. dale	42. bale	62. gale
3. sin	23. fin	43. in	63. in
4. vee	24. thee	44. e	64. thee
5. stop	25. shop	45. stop	65. chop
6. pair	26. air	46. care	66. pair
7. gale	27. ale	47. dale	67. gale
8. fin	28. in	48. sin	68. thin
9. vee	29. thee	49. e	69. vee
10. shop	30. hop	50. stop	70. chop
11. care	31. tear	51. pair	71. air
12. gale	32. bale	52. bale	72. dale
13. thin	33. thin	53. fin	73. thin
14. zee	34. e	54. vee	74. zee
15. chop	35. hop	55. hop	75. shop
16. pair	36. tear	56. tear	76. care
17. ale	37. bale	57. ale	77. ale
18. sin	38. in	58. sin	78. fin
19. zee	39. e	59. thee	79. zee
20. chop	40. stop	60. hop	80. shop

INITIAL CONSONANT TEST

Test From V

1. tear
2. gale
3. sin
4. thee
5. stop
6. air
7. dale
8. in
9. E
10. shop
11. pair
12. gale
13. fin
14. thee
15. stop
16. care
17. dale
18. thin
19. vee
20. chop
21. tear
22. ale
23. sin
24. zee
25. hop
26. air
27. ale
28. in
29. vee
30. chop
31. pair
32. bale
33. fin
34. E
35. shop
36. care
37. bale
38. thin
39. zee
40. hop
41. care
42. gale
43. thin
44. thee
45. shop
46. care
47. dale
48. sin
49. thee
50. shop
51. air
52. gale
53. in
54. E
55. chop
56. pair
57. bale
58. sin
59. zee
60. hop
61. pair
62. bale
63. fin
64. vee
65. stop
66. air
67. ale
68. in
69. zee
70. chop
71. tear
72. dale
73. fin
74. E
75. hop
76. tear
77. ale
78. thin
79. vee
80. stop

VOWEL TEST

<u>Test Form I</u>

1. boot
2. bit
3. boat
4. but
5. beat
6. bait
7. bet
8. bat
9. but
10. boot
11. bait
12. bat
13. boat
14. bet
15. beat
16. bit
17. bit
18. bat
19. beat
20. boot
21. bet
22. boat
23. bait
24. but
25. bait
26. boat
27. bat
28. bet
29. but
30. bit
31. boot
32. beat
33. bat
34. but
35. bet
36. bit
37. bait
38. beat
39. boat
40. boot
41. beat
42. bet
43. boot
44. boat
45. bit
46. but
47. bat
48. bait
49. boat
50. beat
51. but
52. bait
53. boot
54. bat
55. bit
56. bet
57. bet
58. bait
59. bit
60. beat
61. bat
62. boot
63. but
64. boat

VOWEL TEST

Test Form II

1. but
2. bat
3. boat
4. bat
5. boat
6. but
7. bait
8. bet
9. bit
10. but
11. boot
12. bat
13. bat
14. bait
15. boot
16. bait
17. boat
18. bit
19. bit
20. beat
21. boat
22. beat
23. but
24. beat
25. bit
26. bet
27. boot
28. bet
29. bait
30. boot
31. bet
32. beat
33. bit
34. bit
35. but
36. bat
37. boot
38. boat
39. bait
40. bait
41. but
42. bat
43. boot
44. but
45. boot
46. boat
47. bit
48. bit
49. boot
50. bet
51. bait
52. beat
53. bait
54. bet
55. but
56. bat
57. beat
58. beat
59. beat
60. bat
61. bet
62. boat
63. boat
64. bet

VOWEL TEST

Test Form III

1. beat
2. boot
3. bit
4. bat
5. bet
6. beat
7. but
8. beat
9. boat
10. boat
11. bait
12. boot
13. but
14. boot
15. bat
16. but
17. boat
18. beat
19. bit
20. boot
21. bet
22. bet
23. bait
24. bait
25. bait
26. bet
27. bat
28. boat
29. but
30. bit
31. bat
32. bit
33. bit
34. beat
35. bit
36. but
37. bet
38. boot
39. bet
40. but
41. boat
42. boat
43. boat
44. boot
45. beat
46. bat
47. beat
48. bet
49. bit
50. boot
51. bait
52. boat
53. beat
54. but
55. bet
56. boot
57. bait
58. bait
59. bat
60. but
61. bat
62. bat
63. bait
64. bit

VOWEL TEST

Test Form IV

1. bet
2. but
3. beat
4. bit
5. bat
6. bat
7. bait
8. bet
9. bet
10. but
11. beat
12. bit
13. bait
14. boot
15. bet
16. bait
17. bat
18. boat
19. bat
20. but
21. bait
22. but
23. boat
24. boot
25. beat
26. beat
27. boot
28. bit
29. boat
30. bit
31. boat
32. boot
33. beat
34. but
35. bait
36. boot
37. bait
38. bet
39. boat
40. beat
41. bit
42. bit
43. bet
44. bat
45. boot
46. boat
47. but
48. boot
49. beat
50. boot
51. boat
52. bet
53. bet
54. but
55. beat
56. bit
57. boat
58. but
59. bit
60. bat
61. bait
62. bat
63. bat
64. bait

VOWEL TEST

Test Form V

1. but	17. bait	33. bait	49. bait
2. bit	18. boot	34. bat	50. beat
3. bait	19. bit	35. boat	51. boot
4. boot	20. bat	36. but	52. beat
5. beat	21. boat	37. bit	53. boot
6. bit	22. bet	38. bet	54. but
7. bait	23. boat	39. but	55. boat
8. beat	24. boot	40. boat	56. bait
9. bat	25. bat	41. beat	57. boot
10. beat	26. bait	42. bat	58. bait
11. but	27. bit	43. but	59. bet
12. boot	28. but	44. bet	60. boot
13. but	29. bet	45. bat	61. bit
14. bet	30. boat	46. bat	62. bit
15. bet	31. boat	47. boat	63. bit
16. beat	32. bat	48. beat	64. bet

APPENDIX B

SUBTEST ANSWER SHEETS

1. Final Consonant Subtest....Answer Sheet 1

   Final Consonant Subtest....Answer Sheet 2

   Final Consonant Subtest....Answer Sheet 3

   Final Consonant Subtest....Answer Sheet 4

2. Initial Consonant Subtest....Answer Sheet 1

   Initial Consonant Subtest....Answer Sheet 2

   Initial Consonant Subtest....Answer Sheet 3

   Initial Consonant Subtest....Answer Sheet 4

3. Vowel Subtest....Answer Sheet 1

   Vowel Subtest....Answer Sheet 2

   Vowel Subtest....Answer Sheet 3

   Vowel Subtest....Answer Sheet 4

FINAL CONSONANT TEST

Answer Sheet I

1.	pop	pot	pock	pa	21.	pop	pot	pock	pa
2.	robe	rode	rogue	row	22.	robe	rode	rogue	row
3.	Ruth	roof	ruse	rue	23.	Ruth	roof	rue	ruse
4.	lithe	lie	live	lies	24.	lithe	lie	live	lies
5.	leash	least	lee	leech	25.	leech	least	leash	lee
6.	pock	pa	pot	pop	26.	pock	pa	pot	pop
7.	row	robe	rode	rogue	27.	row	robe	rode	rogue
8.	ruse	rue	Ruth	roof	28.	ruse	rue	roof	Ruth
9.	lie	lies	lithe	live	29.	lie	lies	lithe	live
10.	least	leech	leash	lee	30.	leash	lee	leech	least
11.	pot	pop	pa	pock	31.	pot	pop	pa	pock
12.	rogue	row	robe	rode	32.	rogue	row	robe	rode
13.	rue	ruse	roof	Ruth	33.	roof	Ruth	ruse	rue
14.	live	lithe	lies	lie	34.	live	lithe	lies	lie
15.	lee	leash	leech	least	35.	least	leech	lee	leash
16.	pa	pock	pop	pot	36.	pa	pock	pop	pot
17.	rode	rogue	row	robe	37.	rode	rogue	row	robe
18.	roof	Ruth	rue	ruse	38.	rue	ruse	Ruth	roof
19.	lies	live	lie	lithe	39.	lies	live	lie	lithe
20.	leech	lee	least	leash	40.	lee	leash	least	leech

FINAL CONSONANT TEST

Answer Sheet I

41.	pop	pot	pock	pa	61.	pot	pop	pa	pock
42.	robe	rode	rogue	row	62.	rode	rogue	row	robe
43.	ruse	Ruth	roof	rue	63.	Ruth	rue	roof	ruse
44.	lithe	lie	live	lies	64.	lies	live	lie	lithe
45.	least	leash	leech	lee	65.	lee	leash	leech	least
46.	pock	pa	pot	pop	66.	pa	pot	pock	pop
47.	row	robe	rode	rogue	67.	rogue	robe	rode	row
48.	roof	ruse	rue	Ruth	68.	roof	Ruth	ruse	rue
49.	lie	lies	lithe	live	69.	live	lithe	lies	lie
50.	leech	least	lee	leash	70.	least	leech	leash	lee
51.	pa	pock	pop	pot	71.	pock	pa	pop	pot
52.	rogue	row	robe	rode	72.	robe	row	rogue	rode
53.	rue	roof	Ruth	ruse	73.	ruse	roof	rue	Ruth
54.	live	lithe	lies	lie	74.	lie	lies	lithe	live
55.	leash	lee	least	leech	75.	leech	lee	least	leash
56.	pot	pop	pa	pock	76.	pop	pock	pot	pa
57.	rode	rogue	row	robe	77.	row	rode	robe	rogue
58.	Ruth	rue	ruse	roof	78.	rue	ruse	Ruth	roof
59.	lies	live	lie	lithe	79.	lithe	lie	live	lies
60.	lee	leech	leash	least	80.	leash	least	lee	leech

FINAL CONSONANT TEST

Answer Sheet II

1.	pot	pa	pop	pock	21.	pot	pa	pop	pock
2.	rogue	robe	row	rode	22.	rogue	robe	row	rode
3.	rue	ruse	roof	Ruth	23.	ruse	rue	roof	Ruth
4.	live	lithe	lies	lie	24.	live	lithe	lies	lie
5.	least	leech	leash	lee	25.	least	lee	leech	leash
6.	pa	pop	pock	pot	26.	pa	pop	pock	pot
7.	rode	row	rogue	robe	27.	rode	row	rogue	robe
8.	roof	Ruth	rue	ruse	28.	Ruth	roof	rue	ruse
9.	lithe	lie	live	lies	29.	lithe	lie	live	lies
10.	leech	lee	least	leash	30.	lee	least	leash	leech
11.	pop	pock	pot	pa	31.	pop	pock	pot	pa
12.	robe	rogue	rode	row	32.	robe	rogue	rode	row
13.	Ruth	roof	ruse	rue	33.	rue	ruse	Ruth	roof
14.	lies	live	lie	lithe	34.	lies	live	lie	lithe
15.	leash	least	lee	leech	35.	leech	leash	least	lee
16.	pock	pot	pa	pop	36.	pock	pot	pa	pop
17.	row	rode	robe	rogue	37.	row	rode	robe	rogue
18.	ruse	rue	Ruth	roof	38.	roof	Ruth	ruse	rue
19.	lie	lies	lithe	live	39.	lie	lies	lithe	live
20.	lee	leash	leech	least	40.	leash	leech	lee	least

FINAL CONSONANT TEST

Answer Sheet II

41.	pot	pa	pop	pock	61.	pop	pock	pot	pa
42.	rogue	robe	row	rode	62.	row	rode	robe	rogue
43.	rue	roof	Ruth	ruse	63.	ruse	roof	rue	Ruth
44.	live	lithe	lies	lie	64.	lie	lies	lithe	live
45.	leash	lee	least	leech	65.	leash	least	lee	leech
46.	pa	pop	pock	pot	66.	pot	pop	pa	pock
47.	rode	row	rogue	robe	67.	rode	rogue	row	robe
48.	Ruth	rue	ruse	roof	68.	rue	ruse	Ruth	roof
49.	lithe	lie	live	lies	69.	lies	live	lie	lithe
50.	least	leash	leech	lee	70.	leech	lee	least	leash
51.	pock	pot	pa	pop	71.	pa	pot	pock	pop
52.	robe	rogue	rode	row	72.	rogue	robe	rode	row
53.	ruse	Ruth	roof	rue	73.	Ruth	rue	roof	ruse
54.	lies	live	lie	lithe	74.	lithe	lie	live	lies
55.	lee	leech	leash	least	75.	lee	leash	leech	least
56.	pop	pock	pot	pa	76.	pock	pa	pop	pot
57.	row	rode	robe	rogue	77.	robe	row	rogue	rode
58.	roof	ruse	rue	Ruth	78.	roof	Ruth	ruse	rue
59.	lie	lies	lithe	live	79.	live	lithe	lies	lie
60.	leech	least	lee	leash	80.	least	leech	leash	lee

FINAL CONSONANT TEST

Answer Sheet III

1.	pa	pock	pot	pop	21.	pa	pock	pot	pop
2.	rode	row	robe	rogue	22.	rode	row	robe	rogue
3.	ruse	Ruth	rue	roof	23.	rue	Ruth	ruse	roof
4.	lie	lies	lithe	live	24.	lie	lies	lithe	live
5.	leech	lee	least	leash	25.	lee	leash	least	leech
6.	pop	pot	pa	pock	26.	pop	pot	pa	pock
7.	robe	rogue	row	rode	27.	robe	rogue	row	rode
8.	Ruth	ruse	roof	rue	28.	roof	ruse	Ruth	rue
9.	lies	live	lie	lithe	29.	lies	live	lie	lithe
10.	lee	leash	leech	least	30.	least	leech	lee	leash
11.	pock	pa	pop	pot	31.	pock	pa	pop	pot
12.	row	rode	rogue	robe	32.	row	rode	rogue	robe
13.	roof	rue	Ruth	ruse	33.	ruse	roof	rue	Ruth
14.	lithe	lie	live	lies	34.	lithe	lie	live	lies
15.	least	leech	leash	lee	35.	leash	lee	leech	least
16.	pot	pop	pock	pa	36.	pot	pop	pock	pa
17.	rogue	robe	rode	row	37.	rogue	robe	rode	row
18.	rue	roof	ruse	Ruth	38.	Ruth	rue	roof	ruse
19.	live	lithe	lies	lie	39.	live	lithe	lies	lie
20.	leash	least	lee	leech	40.	leech	least	leash	lee

FINAL CONSONANT TEST

Answer Sheet III

41.	pa	pock	pot	pop	61.	pock	pa	pop	pot
42.	rode	row	robe	rogue	62.	rogue	robe	rode	row
43.	roof	ruse	rue	Ruth	63.	roof	Ruth	ruse	rue
44.	lie	lies	lithe	live	64.	live	lithe	lies	lie
45.	lee	leech	leash	least	65.	least	leech	leash	lee
46.	pop	pot	pa	pock	66.	pop	pock	pot	pa
47.	robe	rogue	row	rode	67.	robe	row	rogue	rode
48.	rue	roof	Ruth	ruse	68.	ruse	roof	rue	Ruth
49.	lies	live	lie	lithe	69.	lithe	lie	live	lies
50.	leash	lee	least	leech	70.	lee	leash	leech	least
51.	pot	pop	pock	pa	71.	pot	pop	pa	pock
52.	row	rode	rogue	robe	72.	row	rode	robe	rogue
53.	Ruth	rue	ruse	roof	73.	rue	ruse	Ruth	roof
54.	lithe	lie	live	lies	74.	lies	live	lie	lithe
55.	leech	least	lee	leash	75.	leash	least	lee	leech
56.	pock	pa	pop	pot	76.	pa	pot	pock	pop
57.	rogue	robe	rode	row	77.	rode	rogue	row	robe
58.	ruse	Ruth	roof	rue	78.	Ruth	rue	roof	ruse
59.	live	lithe	lies	lie	79.	lie	lies	lithe	live
60.	least	leash	leech	lee	80.	leech	lee	least	leash

FINAL CONSONANT TEST

Answer Sheet IV

1.	pock	pop	pa	pot	21.	pock	pop	pa	pot
2.	row	rogue	rode	robe	22.	row	rogue	rode	robe
3.	roof	rue	Ruth	ruse	23.	roof	ruse	Ruth	rue
4.	lies	live	lie	lithe	24.	lies	live	lie	lithe
5.	lee	leash	leech	least	25.	leash	leech	lee	least
6.	pot	pock	pop	pa	26.	pot	pock	pop	pa
7.	rogue	rode	robe	row	27.	rogue	rode	robe	row
8.	rue	roof	ruse	Ruth	28.	rue	Ruth	ruse	roof
9.	live	lithe	lies	lie	29.	live	lithe	lies	lie
10.	leash	least	lee	leech	30.	leech	leash	least	lee
11.	pa	pot	pock	pop	31.	pa	pot	pock	pop
12.	rode	robe	row	rogue	32.	rode	robe	row	rogue
13.	ruse	Ruth	rue	roof	33.	Ruth	rue	roof	ruse
14.	lie	lies	lithe	live	34.	lie	lies	lithe	live
15.	leech	lee	least	leash	35.	lèe	least	leash	leech
16.	pop	pa	pot	pock	36.	pop	pa	pot	pock
17.	robe	row	rogue	rode	37.	robe	row	rogue	rode
18.	Ruth	ruse	roof	rue	38.	ruse	roof	rue	Ruth
19.	lithe	lie	live	lies	39.	lithe	lie	live	lies
20.	least	leech	leash	lee	40.	least	lee	leech	leash

FINAL CONSONANT TEST

Answer Sheet IV

41.	pock	pop	pa	pot	61.	pa	pot	pock	pop
42.	row	rogue	rode	robe	62.	robe	row	rogue	rode
43.	Ruth	rue	ruse	roof	63.	rue	ruse	Ruth	roof
44.	lies	live	lie	lithe	64.	lithe	lie	live	lies
45.	leech	least	lee	leash	65.	leech	lee	least	leash
46.	pot	pock	pop	pa	66.	pock	pa	pop	pot
47.	rogue	rode	robe	row	67.	row	rode	robe	rogue
48.	ruse	Ruth	roof	rue	68.	Ruth	rue	roof	ruse
49.	live	lithe	lies	lie	69.	lie	lies	lithe	live
50.	lee	leech	leash	least	70.	leash	least	lee	leech
51.	pop	pa	pot	pock	71.	pop	pock	pot	pa
52.	rode	robe	row	rogue	72.	rode	rogue	row	robe
53.	roof	ruse	rue	Ruth	73.	roof	Ruth	ruse	rue
54.	lie	lies	lithe	live	74.	live	lithe	lies	lie
55.	least	leash	leech	lee	75.	least	leech	leash	lee
56.	pa	pot	pock	pop	76.	pot	pop	pa	pock
57.	robe	row	rogue	rode	77.	rogue	robe	rode	row
58.	rue	roof	Ruth	ruse	78.	ruse	roof	rue	Ruth
59.	lithe	lie	live	lies	79.	lies	live	lie	lithe
60.	leash	lee	least	leech	80.	lee	leash	leech	least

INITIAL CONSONANT TEST

Answer Sheet I

1.	pair	air	care	tear	21.	pair	care	tear	air
2.	bail	gale	dale	ail	22.	bail	gale	ail	dale
3.	fin	sin	thin	in	23.	thin	fin	in	sin
4.	thee	vee	zee	e	24.	vee	e	zee	thee
5.	shop	stop	hop	chop	25.	hop	stop	chop	shop
6.	tear	care	air	pair	26.	tear	pair	air	care
7.	gale	dale	ail	bail	27.	gale	dale	bail	ail
8.	thin	fin	in	sin	28.	in	thin	sin	fin
9.	e	zee	vee	thee	29.	thee	vee	e	zee
10.	chop	shop	stop	hop	30.	stop	chop	shop	hop
11.	care	pair	tear	air	31.	care	air	pair	tear
12.	ail	bail	gale	dale	32.	ail	bail	dale	gale
13.	in	thin	sin	fin	33.	sin	in	fin	thin
14.	vee	thee	e	zee	34.	e	zee	thee	vee
15.	stop	hop	chop	shop	35.	chop	shop	hop	stop
16.	air	tear	pair	care	36.	air	tear	care	pair
17.	dale	ail	bail	gale	37.	dale	ail	gale	bail
18.	sin	in	fin	thin	38.	fin	sin	thin	in
19.	zee	e	thee	vee	39.	zee	thee	vee	e
20.	hop	chop	shop	stop	40.	shop	hop	stop	chop

INITIAL CONSONANT TEST

Answer Sheet I

41.	pair	tear	air	care	61.	care	air	tear	pair
42.	bail	gale	dale	ail	62.	gale	ail	dale	bail
43.	thin	fin	sin	in	63.	sin	thin	in	fin
44.	vee	zee	thee	e	64.	zee	e	thee	vee
45.	chop	shop	hop	stop	65.	stop	hop	shop	chop
46.	tear	pair	care	air	66.	tear	pair	care	air
47.	dale	ail	bail	gale	67.	bail	dale	gale	ail
48.	in	sin	fin	thin	68.	fin	in	thin	sin
49.	thee	e	vee	zee	69.	thee	vee	e	zee
50.	hop	stop	shop	chop	70.	shop	stop	chop	hop
51.	care	air	pair	tear	71.	air	tear	pair	care
52.	ail	bail	gale	dale	72.	ail	gale	bail	dale
53.	fin	thin	in	sin	73.	thin	fin	sin	in
54.	e	vee	zee	thee	74.	e	zee	vee	thee
55.	shop	chop	stop	hop	75.	hop	chop	stop	shop
56.	air	care	tear	pair	76.	pair	care	air	tear
57.	gale	dale	ail	bail	77.	dale	bail	ail	gale
58.	sin	in	thin	fin	78.	in	sin	fin	thin
59.	zee	thee	e	vee	79.	vee	thee	zee	e
60.	stop	hop	chop	shop	80.	chop	shop	hop	stop

INITIAL CONSONANT TEST

Answer Sheet II

1.	air	tear	pair	care	21.	care	air	pair	tear
2.	dale	bail	ail	gale	22.	ail	bail	dale	gale
3.	in	thin	sin	fin	23.	sin	in	fin	thin
4.	zee	thee	e	vee	24.	zee	vee	thee	e
5.	stop	chop	shop	hop	25.	stop	shop	hop	chop
6.	care	pair	tear	air	26.	pair	care	tear	air
7.	ail	gale	bail	dale	27.	bail	gale	ail	dale
8.	sin	in	fin	thin	28.	fin	sin	thin	in
9.	vee	e	thee	zee	29.	e	thee	zee	vee
10.	shop	hop	chop	stop	30.	chop	hop	stop	shop
11.	pair	air	care	tear	31.	air	tear	care	pair
12.	gale	ail	dale	bail	32.	dale	ail	gale	bail
13.	fin	sin	thin	in	33.	thin	fin	in	sin
14.	e	vee	zee	thee	34.	thee	e	vee	zee
15.	hop	shop	stop	chop	35.	shop	stop	chop	hop
16.	tear	care	air	pair	36.	tear	pair	air	care
17.	bail	dale	gale	ail	37.	gale	dale	bail	ail
18.	thin	fin	in	sin	38.	in	thin	sin	fin
19.	thee	zee	vee	e	39.	vee	zee	e	thee
20.	chop	stop	hop	shop	40.	hop	chop	shop	stop

INITIAL CONSONANT TEST

Answer Sheet II

41.	tear	care	pair	air	61.	air	pair	care	tear
42.	dale	bail	ail	gale	62.	dale	gale	bail	ail
43.	in	sin	fin	thin	63.	fin	in	thin	sin
44.	thee	vee	e	zee	64.	thee	zee	vee	e
45.	shop	stop	chop	hop	65.	hop	chop	stop	shop
46.	pair	air	tear	care	66.	pair	air	tear	care
47.	bail	dale	gale	ail	67.	gale	bail	ail	dale
48.	thin	fin	sin	in	68.	sin	thin	in	fin
49.	vee	thee	zee	e	69.	e	thee	zee	vee
50.	stop	chop	hop	shop	70.	stop	hop	shop	chop
51.	air	tear	care	pair	71.	tear	care	air	pair
52.	gale	ail	dale	bail	72.	bail	ail	dale	gale
53.	sin	in	thin	fin	73.	in	sin	fin	thin
54.	zee	e	thee	vee	74.	vee	e	thee	zee
55.	chop	hop	shop	stop	75.	chop	shop	hop	stop
56.	care	pair	air	tear	76.	care	tear	pair	air
57.	ail	gale	bail	dale	77.	ail	dale	gale	bail
58.	fin	thin	in	sin	78.	thin	fin	sin	in
59.	e	zee	vee	thee	79.	zee	vee	e	thee
60.	hop	shop	stop	chop	80.	shop	stop	chop	hop

INITIAL CONSONANT TEST

Answer Sheet III

1.	tear	care	air	pair	21.	air	tear	care	pair
2.	gale	ail	bail	dale	22.	gale	dale	bail	ail
3.	thin	fin	in	sin	23.	in	thin	sin	fin
4.	vee	e	thee	zee	24.	e	thee	vee	zee
5.	chop	hop	stop	shop	25.	shop	chop	stop	hop
6.	pair	air	care	tear	26.	care	air	pair	tear
7.	dale	bail	gale	ail	27.	dale	ail	gale	bail
8.	in	thin	sin	fin	28.	sin	in	fin	thin
9.	zee	thee	e	vee	29.	vee	zee	thee	e
10.	hop	stop	shop	chop	30.	hop	shop	chop	stop
11.	air	tear	pair	care	31.	tear	pair	air	care
12.	bail	dale	ail	gale	32.	bail	gale	ail	dale
13.	sin	in	fin	thin	33.	fin	sin	thin	in
14.	thee	zee	vee	e	34.	zee	vee	e	thee
15.	shop	chop	hop	stop	35.	stop	hop	shop	chop
16.	care	pair	tear	air	36.	pair	care	tear	air
17.	ail	gale	dale	bail	37.	ail	bail	dale	gale
18.	fin	sin	thin	in	38.	thin	fin	in	sin
19.	e	vee	zee	thee	39.	thee	e	zee	vee
20.	stop	shop	chop	hop	40.	chop	stop	hop	shop

INITIAL CONSONANT TEST

Answer Sheet III

41.	care	air	tear	pair	61.	pair	tear	air	care
42.	gale	ail	bail	dale	62.	ail	bail	gale	dale
43.	sin	thin	in	fin	63.	in	sin	fin	thin
44.	zee	e	vee	thee	64.	e	vee	zee	thee
45.	stop	hop	shop	chop	65.	chop	shop	hop	stop
46.	air	care	pair	tear	66.	air	care	pair	tear
47.	ail	gale	dale	bail	67.	dale	ail	bail	gale
48.	fin	in	thin	sin	68.	thin	fin	sin	in
49.	e	zee	thee	vee	69.	vee	zee	thee	e
50.	chop	shop	stop	hop	70.	hop	chop	stop	shop
51.	tear	pair	air	care	71.	care	pair	tear	air
52.	bail	dale	ail	gale	72.	gale	dale	ail	bail
53.	in	fin	sin	thin	73.	sin	thin	in	fin
54.	vee	thee	e	zee	74.	zee	thee	e	vee
55.	hop	stop	chop	shop	75.	shop	stop	chop	hop
56.	pair	tear	care	air	76.	tear	air	care	pair
57.	dale	bail	gale	ail	77.	bail	gale	dale	ail
58.	thin	sin	fin	in	78.	fin	in	thin	sin
59.	thee	vee	zee	e	79.	thee	e	vee	zee
60.	shop	chop	hop	stop	80.	stop	hop	shop	chop

INITIAL CONSONANT TEST

Answer Sheet IV

1.	care	pair	tear	air	21.	tear	pair	air	care
2.	ail	dale	gale	bail	22.	dale	ail	gale	bail
3.	sin	in	fin	thin	23.	fin	sin	thin	in
4.	e	zee	vee	thee	24.	thee	zee	e	vee
5.	hop	shop	chop	stop	25.	chop	hop	shop	stop
6.	air	tear	pair	care	26.	air	tear	care	pair
7.	bail	ail	dale	gale	27.	ail	bail	dale	gale
8.	fin	sin	thin	in	28.	thin	fin	in	sin
9.	thee	vee	zee	e	29.	zee	e	vee	thee
10.	stop	chop	hop	shop	30.	shop	stop	hop	chop
11.	tear	care	air	pair	31.	pair	care	tear	air
12.	dale	gale	bail	ail	32.	gale	dale	bail	ail
13.	thin	fin	in	sin	33.	in	thin	sin	fin
14.	zee	e	thee	vee	34.	vee	thee	zee	e
15.	chop	stop	shop	hop	35.	hop	chop	stop	shop
16.	pair	air	care	tear	36.	care	air	pair	tear
17.	gale	bail	ail	dale	37.	bail	gale	ail	dale
18.	in	thin	sin	fin	38.	sin	in	fin	thin
19.	vee	thee	e	zee	39.	e	vee	thee	zee
20.	shop	hop	stop	chop	40.	stop	shop	chop	hop

INITIAL CONSONANT TEST

Answer Sheet IV

41.	air	pair	care	tear	61.	tear	care	pair	air
42.	ail	dale	gale	bail	62.	bail	dale	ail	gale
43.	fin	in	thin	sin	63.	thin	fin	sin	in
44.	e	thee	zee	vee	64.	vee	thee	e	zee
45.	hop	chop	stop	shop	65.	shop	stop	chop	hop
46.	care	tear	air	pair	66.	care	tear	air	pair
47.	gale	bail	ail	dale	67.	ail	gale	dale	bail
48.	sin	thin	in	fin	68.	in	sin	fin	thin
49.	zee	vee	e	thee	69.	zee	e	vee	thee
50.	shop	hop	chop	stop	70.	chop	shop	hop	stop
51.	pair	care	tear	air	71.	pair	air	care	tear
52.	dale	gale	bail	ail	72.	dale	bail	gale	ail
53.	thin	sin	fin	in	73.	fin	in	thin	sin
54.	thee	zee	vee	e	74.	thee	vee	zee	e
55.	stop	shop	hop	chop	75.	stop	hop	shop	chop
56.	tear	air	pair	care	76.	air	pair	tear	care
57.	bail	ail	dale	gale	77.	gale	ail	bail	dale
58.	in	fin	sin	thin	78.	sin	thin	in	fin
59.	vee	e	thee	zee	79.	e	zee	thee	vee
60.	chop	stop	shop	hop	80.	hop	chop	stop	shop

VOWEL TEST

Answer Sheet I

Presentation #	beat	bit	bet	bat	bait	but	boat	boot
1.								
2.								
3.								
4.								
5.								
6.								
7.								
8.								
9.								
10.								
11.								
12.								
13.								
14.								
15.								
16.								
17.								
18.								
19.								
20.								
21.								
22.								
23.								
24.								
25.								
26.								
27.								
28.								
29.								
30.								
31.								
32.								

VOWEL TEST

Answer Sheet I

Presentation #	beat	bit	bet	bat	bait	but	boat	boot
33.								
34.								
35.								
36.								
37.								
38.								
39.								
40.								
41.								
42.								
43.								
44.								
45.								
46.								
47.								
48.								
49.								
50.								
51.								
52.								
53.								
54.								
55.								
56.								
57.								
58.								
59.								
60.								
61.								
62.								
63.								
64.								

VOWEL TEST

Answer Sheet II

Presentation #	bat	bet	bit	beat	boot	boat	but	bait
1.								
2.								
3.								
4.								
5.								
6.								
7.								
8.								
9.								
10.								
11.								
12.								
13.								
14.								
15.								
16.								
17.								
18.								
19.								
20.								
21.								
22.								
23.								
24.								
25.								
26.								
27.								
28.								
29.								
30.								
31.								
32.								

VOWEL TEST

Answer Sheet II

Presentation #	bat	bet	bit	beat	boot	boat	but	bait
33.								
34.								
35.								
36.								
37.								
38.								
39.								
40.								
41.								
42.								
43.								
44.								
45.								
46.								
47.								
48.								
49.								
50.								
51.								
52.								
53.								
54.								
55.								
56.								
57.								
58.								
59.								
60.								
61.								
62.								
63.								
64.								

VOWEL TEST

Answer Sheet III

Presentation #	but	bait	boot	boat	bit	beat	bat	bet
1.								
2.								
3.								
4.								
5.								
6.								
7.								
8.								
9.								
10.								
11.								
12.								
13.								
14.								
15.								
16.								
17.								
18.								
19.								
20.								
21.								
22.								
23.								
24.								
25.								
26.								
27.								
28.								
29.								
30.								
31.								
32.								

VOWEL TEST

Answer Sheet III

Presentation #	but	bait	boot	boat	bit	beat	bat	bet
33.								
34.								
35.								
36.								
37.								
38.								
39.								
40.								
41.								
42.								
43.								
44.								
45.								
46.								
47.								
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50.								
51.								
52.								
53.								
54.								
55.								
56.								
57.								
58.								
59.								
60.								
61.								
62.								
63.								
64.								

VOWEL TEST

Answer Sheet IV

Presentation #	boat	boot	bait	but	bet	bat	beat	bit
1.								
2.								
3.								
4.								
5.								
6.								
7.								
8.								
9.								
10.								
11.								
12.								
13.								
14.								
15.								
16.								
17.								
18.								
19.								
20.								
21.								
22.								
23.								
24.								
25.								
26.								
27.								
28.								
29.								
30.								
31.								
32.								

VOWEL TEST

Answer Sheet IV

Presentation #	boat	boot	bait	but	bet	bat	beat	bit
33.								
34.								
35.								
36.								
37.								
38.								
39.								
40.								
41.								
42.								
43.								
44.								
45.								
46.								
47.								
48.								
49.								
50.								
51.								
52.								
53.								
54.								
55.								
56.								
57.								
58.								
59.								
60.								
61.								
62.								
63.								
64.								