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Roy K. Sedge

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ABSTRACT

AN INVESTIGATION OF THE DIFFERENCE BETWEEN AUDITORY AND AUDITORY-VISUAL ARTICULATION CURVES

by Roy K. Sedge

The purpose of the present study was to investigate the differences between auditory and auditory-visual articulation curves. An auditory articulation curve is defined as that curve utilizing an auditory stimulus plotted as a function of intensity. The auditory-visual articulation curve is plotted in the same manner utilizing a combined auditory-visual stimulus.

Thirty-two subjects and one talker were used in the investigation. The subjects consisted of students selected at random from speech and hearing classes at Michigan State University. The talker was a male graduate student also enrolled at Michigan State University. All subjects reported normal vision and had a normal level of hearing as determined by routine screening tests.

The test consisted of two parts, both parts being identical except during the presentation of the second part, the talker's face was visible, while during the first part of the test the talker's face was obscured. Each test consisted of twenty sentences presented sound field

at increasing intensity levels. The subjects responded by recording on paper the words they thought they heard or saw from the sensory cues they observed. Their responses were corrected, and the score for each lipreader was determined as the mean percentage of correct word identifications within each sentence.

The scores for auditory (A) versus auditory-visual scores (AV) were analyzed for different intensity levels using the Wilcoxon matched-pairs, signed ranks statistical analysis. The results indicated a significant difference in the articulation curves at the lower levels of intensity. The mean score of the total subjects was graphed separately for A and AV presentations at each of ten intensity levels. A study of the graph indicated that the visual modality had its greatest significance below the sensation level of two decibels. (re:HL)

On the basis of this analysis of the data, the following conclusion was made: Auditory-Visual and Visual articulation curves differ significantly as a result of the addition of the visual modality. Attenuation of the sound source results in greater contributions by the visual stimulus.

Implications for further research were suggested and discussed.

AN INVESTIGATION OF THE DIFFERENCE
BETWEEN AUDITORY AND AUDITORY-VISUAL
ARTICULATION CURVES

By

Roy K. Sedge

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CHAPTER I

STATEMENT OF THE PROBLEM

Introduction

Clinical research and practical experience indicate that speech audiometry is a substantial interest area in the field of audiology. The basis for selection or rejection of hearing aids is in most part determined by how well the user will benefit from amplified speech. Numerous studies indicate that speech-reception testing is a standardized part of hearing-evaluations. Newby, and Davis and Silverman, report that speech-reception testing methods are commonly used in the United States.^{1,2} The methods cited are:

1. Speech-reception threshold.
2. Discrimination score.
3. Comfort level.
4. Tolerance level.
5. Detection level.

In order to give the reader some insight into the magnitude of the problem, some of the more prominent

¹Hayes A. Newby, Audiology (New York: Appleton-Century-Crofts, 1963).

²Hallowell Davis and Richard Silverman, Hearing and Deafness (New York: Holt, Rinehart and Winston, Inc., 1963).

methods of speech-reception testing have been included. Hirsh reported that many writers preferred such terms as articulation tests, speech perception tests, or speech-hearing tests.¹ This study will bow to tradition and use the term articulation tests.

An articulation test is a method of measuring the intelligibility of a particular speech sample as a function of some variable such as intensity. If the listener can repeat 45 out of 50 items on a given list his articulation score will be 90 per cent. The articulation scores obtained for one set of physical parameters will be different for various test materials.²

Test materials that appear to be used most frequently include nonsense syllables, monosyllabic words, disyllabic words, sentences, and continuous discourse. The advantage of using nonsense syllables lies in the fact that it uses an analytic approach when the interest is focused on the intelligibility of specific phonetic units. Nonsense syllables have limitations to a testing program because of the difficulty encountered in eliciting correct responses from untrained observers. In this light, the convenience of using words rather than nonsense

¹Ira Hirsh, The Measurement of Hearing (New York: McGraw-Hill Book Company, 1952), pp. 132.

²Ibid., pp. 152-156.

syllables is probably responsible for the more general use of words.¹

The next least analytic unit of speech is the monosyllabic word or the one-syllable word.² Such words seem to be more easily repeated than nonsense syllables, particularly by untrained observers. Egan constructed lists of monosyllabic words.³ Each list contains a representative sample of the different phonetic units in the same relative frequency that they occur in the English language. These lists are called Phonetically Balanced or PB lists.

The unit that is even less analytic than the monosyllabic word list is the disyllabic word. These word lists contain two syllables of equal stress. They are constructed in the same manner as the monosyllabic word lists. The listener must hear both syllables and report what he heard. In order to construct words of this nature, the syllables must follow in logical order to give an acceptable word used in the English language. This, of course, cuts down on the number of possibilities that are available to the listener, making this method less analytic. In other words, this method adds additional

¹Ibid.

²J. P. Egan, "Articulation Testing Methods," Laryngoscope (1948), pp. 955-991.

³Ibid.

cues for intelligibility. Hudgins constructed lists of words that were homogeneous in respect to intelligibility.¹ These lists became known as Spondees or Spondaic word lists.

One of the more reliable procedures used today, is the use of groups of words that may appear in general conversation. The type of grouping discussed is the sentence. Pioneering in work with sentences were Fletcher and Steinberg.² The sentences used were interrogative in nature and were not repeated by the listener but answered. The main drawback of the sentences was that the use of them demanded that the listener not only hear the sentences, but answer them as well. Among other things, the sentences demanded a knowledge of New York City and surrounding areas. This group of sentences was discarded for something more suitable. Hudgins constructed a simpler list of sentences at the Psycho-Acoustic Laboratory.³ Since this time, many sentence lists have been devised.

¹C. V. Hudgins et al., "The Development of Recorded Auditory Tests for Measuring Hearing Loss for Speech," Laryngoscope, 57 (1947), pp. 57-89.

²Harvey Fletcher and J. C. Steinberg, "Articulation Testing Methods," Bell System Technical Journal, 8 (1929), pp. 1-5.

³C. V. Hudgins, "A Progress Report of an Acoustic Training Experiment for Profoundly Deaf Children," Journal of Acoustical Society of America, 22 (1950), p. 676.

Hirsh states that the most valid sample of speech is continuous discourse.¹ The drawbacks are many. It is difficult for the listener to respond, and the level of intensity fluctuates. If the intensity level is controlled, the continuous speech becomes so monotonous and uninteresting that it becomes of little value as a clinical tool.

If the researcher controls the intensity and presents the subject matter at specified intensity levels, he may plot the percentage of correct responses and then plot an articulation curve. An articulation curve is the result of articulation scores plotted as a function of intensity. As stated before, articulation curves vary in regard to the test material used.

Test materials influence the gain function of articulation curves. The gain function of an articulation curve may be defined as the relative steepness of the average slope of the curve.² The gain function of Spondaic word lists is steeper than that of PB lists and of monosyllabic words. The gain function of Spondaic word lists is ten per cent per decibel (dB), while unselected disyllables is five per cent per dB.

Monosyllables increase four per cent for each dB of increased gain function.³ Miller states that if the unit

¹Hirsh, op. cit., pp. 152-156.

²George A. Miller, Language and Communication (New York: McGraw-Hill Book Company, 1951), pp. 47-79.

³Hirsh, op. cit., pp. 134-136.

of material is the sentence, the gain function should be as steep or steeper than that of spondees.¹

In order to determine the quality of lipreading, one must compare the curves of intelligibility with and without lipreading. In the United States, audiologists do not trace the curve of intelligibility. The two main characteristics studied are the speech-reception threshold and the discrimination score.²

With much emphasis and interest in the problems of the hard-of-hearing, audiologists have been faced with many difficulties. They have been thrust into situations where judgments must be made concerning whether or not a client is deriving benefit from a well-designed program of lipreading instruction. For the above reason, this project was set forth as a contribution for the audiologist who is faced with the solution of these problems.

Statement of Purpose of Study

The purpose of the study is to investigate the hypothesis that articulation curves of sentences will increase if the visual modality is used as well as the auditory modality. It is an attempt to determine the difference between articulation curves; one employing the auditory

¹Miller, op. cit., pp. 75.

²Michel Portmann and Claudine Portmann, Clinical Audiometry (English edition) (Springfield, Illinois: Charles C. Thomas, 1961), pp. 86-91.

stimulus, and the other employing the visual modality in conjunction with the auditory stimulus.

Hypothesis

Within the confines of this study, the question to be investigated and the corresponding null hypothesis are as follows:

Do articulation curves treated with identical test materials differ when one test utilizes lipreading and the other does not?

Null Hypothesis: There is no significant difference in auditory articulation curves as compared to auditory-visual articulation curves.

Importance of Study

For the deaf or hard-of-hearing, lipreading is of vital importance. Lipreading, in effect, supplements that part of hearing which may be impaired. In order to give a graphic picture of the benefits extending from lipreading, means must be sought that are different from the conventional methods of speech audiometry employed in the United States.

It is the purpose of this study to provide information on the feasibility of using articulation curves in the evaluation of performances of lipreaders.

Limitations

This study utilized 32 subjects drawn at random from undergraduate speech classes from Michigan State University. The age range of the subjects was limited to include only those persons between the ages of eighteen and twenty-five.

The subjects were further limited in that no person having a hearing problem or reporting gross visual difficulties was selected. Subjects with corrective lenses were allowed to participate. Each subject passed a hearing screening test. The procedure consisted of testing the subject at four frequencies; 500, 1000, 2000 and 4000 cps. A subject's hearing level could not be more than ten dB (re: 1951 ASA standards) at any level.

Definition of Terms

Lipreading--The term lipreading is used to refer to the process employed by an individual to tell what another is saying by utilizing visual cues.

Lipreader--The term lipreader refers to the person employing the use of lipreading.

Articulation test--This term refers to the test materials that are administered at specified levels of intensity in order to obtain an articulation score.

Articulation score--An articulation score is defined as the percentage of correct responses at a specified intensity level.

Articulation curve--That curve which is drawn by plotting each articulation score as a function of intensity is defined as an articulation curve.

Auditory articulation curve (A)--The auditory articulation curve is made with articulation scores derived by hearing alone.

Auditory-Visual articulation curve (A-V)--That curve which is derived with articulation scores determined by the simultaneous use of the auditory and visual modalities is described as auditory-visual articulation curve.

Talker--The person administering the test material is referred to as the talker.

Listener--The person listening to the talker is referred to as the listener.

Organization of Thesis

This thesis is divided into five chapters. The first chapter includes an introduction, statement of problem, purpose of the study and the null hypothesis to be tested. Chapter II is a review of the pertinent literature related to this thesis. The third chapter contains a description of the subjects, materials, and procedures utilized in the study. The analysis of the data and a discussion of the results comprise Chapter IV; and the summary, conclusions and implications are included in Chapter V.

CHAPTER II

REVIEW OF THE LITERATURE

Studies Related to Visual Cues As Aids to Lipreading

A review of the literature indicates that several studies have been devoted to the development of tests and measurements of lipreading ability.

According to O'Neill and Oyer, the first experimental investigation of lipreading was attempted in 1914 by Kitson.^{1,2} His research involved a study of the various factors assumed to be related to lipreading skill. The investigation utilized tachistoscopic techniques to evaluate visual awareness and visual attention span. The results of the study indicated that subjects who had high scores on visual skills also rated high on lipreading tests.

Sumby and Pollack investigated the contributions of visual cues to speech intelligibility as a function of

¹John O'Neill and Herbert Oyer, Visual Communication for the Hard of Hearing (Englewood Cliffs, New Jersey: Prentice Hall, Inc., 1961), pp. 41.

²H. D. Kitson, "Psychological Tests for Lipreading Ability," Volta Review, 17 (1915), pp. 471-476.

the speech-to-noise ratio and the size of the vocabulary presented. Results revealed that the visual contributions to speech intelligibility increased as the speech-to-noise ratio was reduced. Visual contributions also occurred when the vocabulary was increased.¹

Neely, in 1956, conducted a similar study.² When additional visual cues were added to an auditory stimulus of a constant intensity, the intelligibility of the received speech was raised twenty per cent. The investigation also measured lipreading as a function of distance. Lists of sentences were read at varying distance intervals. It was found that the distance from the listener to the talker did not have a significant effect on the listener's intelligibility score if the distance was within a three- to nine-foot radius.

Reams, in a study investigating the relationship between the experiences of identifying words through visual sensory stimulation, found that the obtained correlation coefficients were not high enough to indicate any positive relationship between auditory intelligibility and visual identification of the same stimulus materials. The test was conducted with normally hearing college students who

¹W. H. Sumby and I. Pollack, "Visual Contributions to Speech Intelligibility in Noise," Journal of the Acoustical Society of America, 26 (1954), pp. 212-215.

²Keith K. Neely, "Effect of Visual Factors on the Intelligibility of Speech," Journal of the Acoustical Society of America, 28 (1956), pp. 1275-1277.

served as experimental subjects. A silent motion picture test was prepared using the Waco multiple-choice intelligibility test as a stimulus. The same test was recorded on tape, using the speakers who appeared on the test film. The subjects then listened to the tape as one section of the test and viewed the film as the later part of the test.¹

Numbers and Hudgins proposed a study to assess the relative contribution that lipreading serves to person-to-person communication.² Word lists were spoken to the listener in the presence of noise. The lists were spoken via the auditory channel of communication in one instance and in another instance via the auditory-visual channel. It was found that if the auditory channel of communication was employed alone, a high level of noise tended to make communication more difficult. When the visual channel supplemented the auditory channel, there was an increase of understandability of vowels, consonants, and phrases that were transmitted.

¹Mary K. Reams, "An Experimental Study Comparing the Visual Accompaniments of Word Identification and the Auditory Experience of Word Intelligibility," (Unpublished Master's Thesis, the Ohio State University, Department of Speech, 1950).

²M. Numbers and C. V. Hudgins, "Speech Perception in Present Day Education for Deaf Children," Volta Review, 50 (1948), pp. 449-456.

The visibility of vowels, consonants, words, and phrases was statistically evaluated by O'Neill.¹ It was found that vision contributed 29.5 per cent to the recognition of vowels, 57 per cent for consonants, 38.6 per cent for words, and 17.4 per cent for phrases. Vision had the greatest effect in the identification of consonants; and lesser effects, in order, on the recognition of vowels, words, and phrases.

O'Neill regards speech as an oral-auditory process.² The deaf and hard-of-hearing employ the visual characteristics of oral discourse in the understanding of speech through lipreading. He further states, "Since most verbal communication is direct face-to-face, oral sending-receiving, the perception of speech might be regarded as a bi-sensory phenomenon."

In 1928, Day and Fusfeld constructed two lipreading tests and administered them face to face to 8,300 deaf pupils.³ Test materials consisted of two separate matched sets of ten sentences. One set was read by a field agent,

¹John O'Neill, Contributions of the Visual Components of Oral Symbols to Speech Comprehension," Journal of Speech and Hearing Disorders, 19 (1954), pp. 429-439.

²John O'Neill, "Contributions of the Visual Components of Oral Symbols to Speech Comprehension of Listeners With Normal Hearing," (Doctoral Dissertation, Ohio State University Department of Speech, 1951).

³H. E. Day, I. S. Fusfeld, and R. Pinter, "A Survey of American Schools for the Deaf: 1924-1925 (Washington, D. C.: National Research Council, 1928).

the other by the teacher. Analysis of the data showed that the speech reading scores of the set read by the teacher were higher than those read by the field agent. This suggested that familiarity with the speaker has a definite correlation with lipreading scores.

Development of Articulation Test Materials

A review of the literature revealed that articulation test materials were first used at the Bell Telephone laboratories. Intelligibility lists were first developed and used by communication engineers to rate sound transmission systems:¹

A speech sample was presented by a speaker through a transmission system to a trained listener. The listener then wrote down what he heard. The percentage of correct responses served as efficiency ratings of the system. . . the listener's percentage of correct responses was taken as a measure of his ability to discriminate, or hear clearly the sounds of the English Language.

An attempt to construct monosyllabic word lists was conducted by Egan.² Each list contains a representative sample of the various phonetic units, and each unit occurs at the same relative frequency as used in the English language. Each list contains 50 words. The lists are commonly called PB lists or Phonetically Balanced word lists.

¹C. V. Owens, "Intelligibility of Words Varying in Familiarity," Journal of Speech and Hearing Research, 4 (1961), pp. 113-119.

²Egan, op. cit., pp. 955-991.

Heider and Heider constructed three filmed tests of lipreading ability.¹ It was revealed that recognition of vowels were superior to consonant recognition and that no correlation existed between the ability to lipread nonsense syllables and general lipreading ability.

Articulation curves in routine speech audiometry are not determined in the United States. Davis, as early as 1947, emphasized the need for utilizing articulation curves as a standard audiometric procedure. He states:

. . . We can describe quite satisfactorily someone's ability to hear speech by means of a so-called articulation curve which tells us the percentage of a list of chosen words the listener understands as the words are spoken to him louder and louder. . .for quick routine tests, however, the complete articulation curve using PB lists takes too long, it is a research tool. We may hope soon some sufficiently reliable but abbreviated form₂ of the test will be worked out for everyday use.²

Hirsh developed a series of intelligibility lists at the Central Institute for the Deaf in St. Louis, Missouri.³ The CID W-22 word lists are comprised of 50 monosyllabic words with the same characteristics as PB words. One of the main differences between the CID W-22

¹F. K. Heider and G. M. Heider, "Studies in the Psychology of the Deaf," Psychological Monographs, 52 (1940), pp. 124-133.

²Hallowell Davis, Hearing and Deafness (New York, Toronto: Murray Hill Books, Inc., 1947), pp. 146-150.

³Ira J. Hirsh, "Clinical Application of Two Harvard Auditory Tests," Journal of Speech Disorders, 12 (1947), pp. 151-158.

lists and the Harvard PB-50 lists is that the former are comprised of words selected on the basis of having greater familiarity with the general public.

Black reported that sentence intelligibility was much greater than word intelligibility at specified levels of intensity.¹ He states that sentences are more intelligible because they supply a running sequence of symbols that, "follow the rules." This is accomplished by following a pattern of familiar probabilities common to that of the sequential English language.

Egan and O'Neill investigated the relationship between sentence intelligibility scores and individual word intelligibility scores.^{2,3} Both found that at an intensity where the listener could hear a high percentage of the sentence, he could only hear half of a spoken word list. Egan stated that when the listener was able to recognize correctly 80 per cent of a sentence list, he was able to recognize only 50 per cent of monosyllabic words spoken at the same level.

¹John Black, "Systematic Research in Experimental Phonetics: 2. Signal Reception: Intelligibility and Side Tone," Journal of Speech and Hearing Disorders, 19 (1954), pp. 140-145.

²Egan, op. cit., pp. 955-991.

³John O'Neill, "Recognition of Intelligibility of Test Materials in Context and Isolation," Journal of Speech and Hearing Disorders, 22 (1957), pp. 87-90.

Cutaneous Vibratory Research As a
Sensory Modality Aiding
Lipreading

There has been some experimental research that links cutaneous experimentation and lipreading. This section of the review of the literature will discuss the early work of R. H. Gault and those who are associated with his work.

During the period of 1925-1935, it was shown by experimentation that important elements of music and speech can be perceived through the senses of touch and vibration. The limits of sensitivity from these modalities have been investigated by many researchers. Kampie reported that the frequency range of pure tones, which can be perceived by the vibratory senses, is between 16 and 130 cps.¹ Thiel states that the range can extend from 86 to 528 cps.² Wagner claims the range to be slightly different for the deaf, the range being between 5 and 170 cps.³

¹Kampie, *Archiv für die gesamte Psychologie*, 76 (1930), pp. 3-70. Cited by Goodfellow, Psychological Bulletin, 31 (1934), pp. 560-571.

²F. C. Thiel, "Experimental Studies in the Vibratory Sense in Deaf Mutes," Zeitschrift für Psychologie und Physiologie der Sinnesorgane, 119 (1931), pp. 109-178. Cited by Goodfellow, Psychological Bulletin, 31 (1934), pp. 560-571.

³P. Wagner, "Investigations into Tactile Language. On the Perceptive Value of Tactile Sensations and Their Applicability as Linguistic Symbols in the Beginning of the Teaching of Speech in the School for the Deaf," Naue Blätter für Taubstummen bildung, 15 (1961), pp. 82-109, Cited in dsh Abstracts, 2 (1962), pp. 226-227.

Goodfellow reported that the finger tips can detect vibrations that are high in frequency. He states that the finger tips are sensitive to vibrations as high as 8,000 cps.¹ Knudsen reports the lower limitation of cutaneous stimulation by vibration can be as low as 16 cps with the upper limit being around 1600 cps. He did predict, however, that high frequencies could be felt through cutaneous stimulation if the stimulation was more intense. Knudsen also found that the frequency of the vibrating apparatus must change from 15 to 30 per cent before a difference can be noted by the sense of touch.²

Gault, in early experimentation, reported various studies concerned with the upper limit of vibratory sensation.³ In his first report, he places the upper limit of sensation at 2,000 cps. Gault reported two other studies which tend to conflict with his earlier work. A second study reported the upper limit of sensation at

¹L. D. Goodfellow, "The Sensitivity of the Finger Tip to Vibrations of Various Frequency Levels," Journal of the Franklin Institute, 216 (1933), pp. 387-392.

²V. O. Knudsen, "Hearing with the Sense of Touch," Journal of General Psychology, 1 (1925), pp. 320-352.

³R. H. Gault, "An Interpretation of Vibrotactile Phenomena," Journal of the Acoustical Society of America, 5 (1934), pp. 252-254.

2,700 cps, and a third report stated that this limit was as high as 3,000 cps.^{1,2}

Johnson cites Roberts, Dunlap, and Goodfellow as finding that the vibratory stimulation of the finger tips at different frequencies can be readily perceived.^{3,4,5,6} It was found that the frequencies concerned differ by as little as two and one-half per cent of the standard. The finger tip can also follow beats, can detect the individual tones in a chord, and can discriminate between consonance and disconsonance.

Because the studies above indicate that external stimuli applied to the skin had many characteristics of auditory stimuli, the cutaneous and auditory modalities have been compared by some experimenters. Gault felt that

¹H. H. Gault, "Fingers Instead of Ears," Welfare Magazine, 18 (1927), pp. 1131-1138.

²R. H. Gault, "On the Upper Limit of Vibrational Frequency That Can be Recognized by Touch," Science, 65 (1927), pp. 403-404.

³Gerald F. Johnson, "The Effects of Cutaneous Stimulation by Speech on Lipreading Performance (unpublished Ph.D. Dissertation, Michigan State University Department of Speech, 1963).

⁴W. H. Roberts, "A Two-Dimensional Analysis of Discrimination of Differences in the Frequency of Vibrations by Means of the Sense of Touch," Journal of the Franklin Institute, 213 (1932), pp. 286-312.

⁵K. Dunlap, "Palmesthetic Beats and Difference Tones," Science, 37 (1913), p. 532.

⁶L. D. Goodfellow, "The Tactile Perception of Musical Intervals," Journal of the Franklin Institute, 215 (1933), pp. 731-736.

there was little separation between the auditory and vibro-cutaneous modalities.¹ He felt that the function of hearing may be taken over in total as a vibratory sense.

The finger tips have long been used in vibratory experiments. Experimenters have compared the perceptivity of the finger tips to that of the ear. Knudsen found that finger tips could differentiate different levels of intensity about as well as the ear.² Goodfellow and Gridley reported that by using a vibratory stimulus applied to the finger tips spatial relationships of time can be responded to with a high degree of accuracy. They stated that the finger tips are up to 90 per cent as accurate as the ear in this task.^{3,4}

Johnson cites Bekesy comparing the relationship between cutaneous sensitivity and hearing.^{5,6} Bekesy reported this comparison:

¹Gault, op. cit. (1930), pp. 498-517.

²Knudsen, op. cit. (1928), pp. 320-352.

³L. D. Goodfellow, "Comparison of Audition, Vision, and Touch in the Discrimination of Short Intervals of Time," American Journal of Psychology, 46 (1934), pp. 243-258.

⁴P. Gridley, "The Discrimination of Short Intervals of Time by the Finger Tip and by Ear," American Journal of Psychology, 44 (1932), pp. 18-43.

⁵Johnson, op. cit., pp. 28-29.

⁶George von Bekesy, "Funneling in the Nervous System," Journal of the Acoustical Society of America, 30 (1958), pp. 399-412.

When continuous vibratory stimuli are presented on the skin, the subject can differentiate several attributes: (1) the frequency of vibration, which is analagous to pitch in hearing, (2) the subjective magnitude of the sensation, which has many factors in common with hearing, and (3) the sensation of the lateral surface of the skin, which corresponds to the volume of the sounds in hearing.

Jenkins reported that when a stimulus is presented cutaneously and when the frequency rises 20 cps, the sense of touch fuses into a smooth systematic sense of vibration which is roughly analagous to that of hearing.¹

Cutaneous Stimulation as an Aid to Lipreading

A review of the literature indicates that cutaneous stimulation by speech has been combined with lipreading with notable success. Gault, as early as 1932, developed a highly refined apparatus for communicating speech to the finger tips of the observer.² He called his apparatus a teletactor. Gault found that deaf pupils were able to raise their lipreading score on an average of 20 per cent using lipreading combined with cutaneous stimulation provided via the teletactor.³ In another study Gault

¹W. L. Jenkins, "Somesthesis," in S. S. Stevens, (ed.) Handbook of Experimental Psychology, New York: John Wiley and Sons, Inc., 1951), p. 1177.

²L. D. Goodfellow and A. W. Krause, "Apparatus for Receiving Speech Through the Sense of Touch," Review of Scientific Instruments, 5 (1934), pp. 44-46.

³R. H. Gault, "A Partial Analysis of the Effects of Tactual-Visual Stimulation of Spoken Language," Journal of the Franklin Institute, 209 (1930), pp. 437-458.

found that a deaf lipreader could understand at least twice as many words when the investigator's speech was combined with cutaneous stimulation than by lipreading alone.

Gault also reports that when deaf subjects feel speech on their fingers, and at the same time use their residual hearing plus seeing the investigator's face, the combined stimuli enabled the student to interpret what was said more fully than by visual cues alone. The median advantage of combined stimulation amounted to 30 per cent when the test stimuli were isolated monosyllabic words. Scoring was based on the number of correct words understood by the student. When whole sentences were presented as test stimuli, the median advantage of the combined stimulation resulted in a 100 per cent increase. Scoring was based upon the number of whole sentences correctly reported.^{1,2} Ilevia studied the relative ability of the visual modality, of the cutaneous modality, and of the combination of modalities to detect differences in rhythm of spoken speech in sentences. When the subject felt the speech via a teletactor and at the same time saw the talker's face, the combined stimuli enabled the subject to detect the

¹R. H. Gault, "On the Identification of Certain Vowel and Consonantal Elements in Words by Their Tactual Qualities and as Seen by the Lipreader," Journal of Abnormal and Social Psychology, 22 (1927), pp. 33-39.

²R. H. Gault, "On the Effect of Simultaneous Tactual-Visual Stimulation in Relation to the Interpretation of Speech," Journal of Abnormal and Social Psychology, 25 (1930), pp. 498-517.

speaker's words with much greater accuracy than by lipreading alone. The percentage of correct sentences increased from 66 per cent in the visual presentation to 77.2 per cent in the tactile presentation.¹

Gault reported that by teaching the deaf, using a teletactor, the subject could recognize, after considerable practice, (1) vowels, (2) diphthongs, (3) consonants, and (4) short sentences. A few cases have been recorded of profoundly deaf individuals who gained knowledge of speech by interpreting it solely by means of the senses of touch and vibration alone.²

Anderson applied electrodes to the skin of the subject.³ He reported that his subject could feel the difference between words as, "Joe, sew, how, and blue," by means of electrical stimulation of the skin.

Nelson, using a one and two-electrode apparatus, found that after training and conditioning, some of his subjects appeared to be able to distinguish between pairs of vowels that were contrasting. With a one-electrode setup the scores were about 60 to 70 out of 90

¹M. L. Ilevia, "On the Detection of Variations in Tempo of Speech by Visual, Tactual, and Visual-Tactual Cues," Journal of General Psychology, 7 (1934), pp. 100-109.

²Gault, op. cit. (1927), pp. 33-39.

³A. B. Anderson, "Electrical Stimulation of Speech Sounds," Archives of Otolaryngology, 69 (1959), pp. 445-448.

words. With a two-electrode system the scores increased to 80 out of 90 words. However, he found gross individual differences between the subjects.^{1,2}

It would appear in this review that some method of tactual stimulation for the deaf would be of considerable value if the method were combined with a lipreading program. A tactual speech trainer could aid the teacher of the deaf in teaching those components of oral discourse not readily identifiable on the lips.

¹M. Nelson, "Electrocutaneous Perception of Speech Sounds," Archives of Otolaryngology, 69 (1959), pp. 445-448.

²M. Nelson, "A Comparison of Electro-Cutaneous Differentiation of Vowels Through a 1-Electrode and 2-Electrode System." (unpublished Ph.D. Dissertation, University of Michigan, 1950).

CHAPTER III

SUBJECTS, EQUIPMENT, AND PROCEDURES.

Subjects

The subjects used in this study consisted of students enrolled in undergraduate speech classes at Michigan State University. Thirty-two subjects were drawn for the experiment.

The subjects selected for the study ranged in age from 19 to 26. All subjects reported normal vision. Normal hearing was assumed if the subject passed a screening test. If the subject could correctly respond at a level of 10 dB or less (re: 1951 ASA standard) to all frequencies presented, hearing was considered to be normal. The frequencies presented, hearing was considered to be normal. The frequencies tested were 500, 1000, 2000, and 4000 cps.

The talker was a male graduate student enrolled in the Speech and Hearing Science Department at Michigan State University. He had knowledge concerning lipreading gained from courses in audiology and is considered to be a trained talker.

Test Environment

A two-room arrangement used for hearing testing was utilized in conducting the experiment. The test

room was sound treated with acoustical tile and a two-way observation window was located on a common wall.

The aperture of the triple-paned observation window in the control room was 22 x 11½ inches, and 32 x 11½ inches in the test room. Aylesworth¹ reported the attenuation factor for the wall between the control room and the testing room was 50 dB for the frequency range 250 to 1500 cps. Attenuation for frequencies above 1500 cps was in excess of 50 dB, but could not be specified due to ambient noise in the control room. (Appendix A).

The sound equipment employed in the experiment was an Allison, Model 20-A speech audiometer. The test stimulus was presented livevoice, soundfield through an Electro-Voice S-12 speaker. The speaker was located in the left corner of the test room facing the subjects, on the common wall that adjoins the control room.

The subjects were seated in the test room and observed the talker through the observation window. Four chairs were arranged in two rows in the test room. The center point of the four chairs was located seven feet from the middle of the observation window. The talker was seated in the control room 36 inches from the center of the observation window.

¹Donald Aylesworth, "The Talker and the Lipreader as Variables in Face-to-Face Testing of Lipreading Ability," (unpublished Master's Thesis, Michigan State University Department of Speech, 1964), p. 18.

Two clamp-on lamps, with one-hundred watt bulbs were mounted to the upper corners of the observation window created by the overhead lighting system.

Materials

Scoring Sheets--Scoring sheets were utilized with information regarding the subject under test. The information consisted of the test group, chair number, sex, and age of the subjects. The scoring sheets contained two parts, Part A and Part B. Part A used the auditory stimulus while Part B of the experiment used the combined auditory-visual stimulus, both measured as a function of intensity. Both parts consisted of twenty numbers and appropriate lines for responses. (Appendix B).

Audio-Visual stimulus material--Sentences utilized for the study were four lists developed at the Central Institute for the Deaf in St. Louis. These lists are used to represent "everyday American speech." Davis and Silverman list the following important characteristics of the sentences.¹

1. The vocabulary is appropriate for adults.
2. The words appear with high frequency in one or more of the well known word counts of the English language.

¹Hallowell Davis and Richard Silverman, Hearing and Deafness (New York: Holt, Rinehart, and Winston, Inc., 1963), Appendix Nine, pp. 548-552.

3. Proper names and proper nouns were not used.
4. Common non-slang idioms and contractions are used freely.
5. Phonetic loading and tongue-twisting are avoided.
6. Redundancy is high.
7. The level of abstraction is low.
8. Grammatical structure varies freely.
9. Sentence length varies in the following proportions:
 - Two to four words - 1
 - Five to nine words - 2
 - Ten to twelve words - 1
10. Sentence forms are in the following proportions:
 - Declarative - 6
 - Rising interrogative - 1
 - Imperative - 2
 - Falling interrogative - 1

There are ten lists of sentences in the CID "Everyday Speech" lists, each list containing sentences. The first four sentence lists were used in this experiment. Forty sentences were presented to each group tested. (Appendix C)

The talker calibrated his voice through the use of a VU meter on the speech audiometer. The CID everyday speech sentences specify that the sentences should be presented in a normal voice, therefore, the talker allowed his voice to range in a general ten dB pattern. The pattern on the VU meter ranged from a minus eight dB to a plus two dB, thus allowing the talker to speak in a normal conversational voice.

The subjects were brought to the testing room in groups of four. Eight groups were tested in this manner. They were taken into the testing room and seated in chairs that had been arranged beforehand. The talker introduced himself and asked the group to fill in the necessary information on the top of the test form. He positioned himself in the control room and gave instructions of the test via the loudspeaker at an intensity of 40 dB HL.¹ The directions of the test were as follows:

I would like to find out how much you can hear at various sound intensities. I will start at a very low intensity and read a sentence. At each subsequent intensity my voice will get louder as the sentence is read. You probably will not be able to hear the first few sentences. Your hearing and understanding will increase as the intensity increases. At the end of the test you should be able to understand the complete sentence.

On each chair is a pencil and a recording sheet. Each sheet has a set of numbers and space beside the number for you to record what you think you heard. Do not hesitate to guess!

A card will signal you to what sentence is read. Card one will correspond to sentence one, card two for sentence two and so on. The card will be placed in the window facing you. After the card is shown, the lights in the control room will go out and the sentence will be read.

There are two parts of this test, Part A being identical to Part B, except in Part B there will be lights illuminating my face. There are twenty sentences in both sections of the test. Are there any questions?

¹All Hearing Level (HL) references assume that 0 dB HL is equal to 22 dB SPL.

The subject sitting next to the light switch in the test room was instructed to turn out the lights in Part B of the experiment. After each sentence was presented, the lights were turned on so the subjects could transcribe what they heard and saw. In this section of the test, the lights were turned on in the control room for the entire test.

Sentences were presented in a different random order for each group. This method of presentation was followed so that each of the forty sentences would have an equal chance of being presented at any intensity level in either part of the experiment. (Appendix D)

The intensity for both parts of the experiment ranged from no stimulus to 44 dB HL. Sentences were presented at each of the following twenty intensities: No stimulus, -10, -7, -4, -1, 2, 5, 8, 11, 14, 17, 20, 23, 26, 29, 32, 35, 38, 41, and 44 dB HL respectively.

Smaller intensity increments serve to create a more accurate articulation curve. It is for this reason that an intensity increment of three dB was selected for the experiment.

CHAPTER IV

ANALYSIS AND DISCUSSION

Analysis

The data for this study are raw scores obtained on the articulation tests by each subject. These scores were derived by computing the percentage of words correctly identified in each sentence and then taking the mean percentage of correct identifications of all sentences at each specific presentation.

The Wilcoxon matched pairs, signed-ranks statistical analysis was employed to test the following null hypothesis: There is no significant difference in auditory articulation curves as compared to auditory-visual articulation curves.¹

Twenty matched pairs were derived from Part A and B of the experiment. It can be determined by simple inspection of the data (Appendix E and F) that after the ninth intensity level the matched pairs will be equal i.e. the scores will be 100 per cent. For this reason only, the first nine presentations were statistically treated.

The value of Z required for significant difference at the .01 level of confidence is 2.33. In the first

¹Hubert M. Blalock, Social Statistics (New York: McGraw-Hill Book Company, 1960), pp. 206-209.

three lowest intensities the Z was -4.96. In the following five intensity levels the value of Z was -2.71, -2.86, -3.74, -3.34 and -3.81. In each of the statistically treated matched-pairs the value of Z is much smaller than by chance. We may therefore reject the null hypothesis.

Discussion

The analysis of the data indicates that a significant difference exists between audio and audio-visual articulation curves below the level of +2 dB HL.

In order to observe how each curve varies with intensity, mean percentages of all subjects for each test was plotted as a function of intensity for each level (Figure 1). A study of Table I reveals some interesting differences between the articulation curves. First, it may be noted that the greatest variation between the curves occurs at -7 dB where the mean percentage for the A-V curve is 65 per cent and zero per cent for the V curve. This may be accounted for by the large amount of lipreading encountered at this below threshold presentation. Table 1 illustrates the contribution of lipreading at each intensity level. The table was derived by subtracting the matched-pairs of the curves at ten intensity levels.

Presentation one through ten correspond to increasing intensity levels. In the first presentation only lipreading is involved with no auditory stimulus presented.

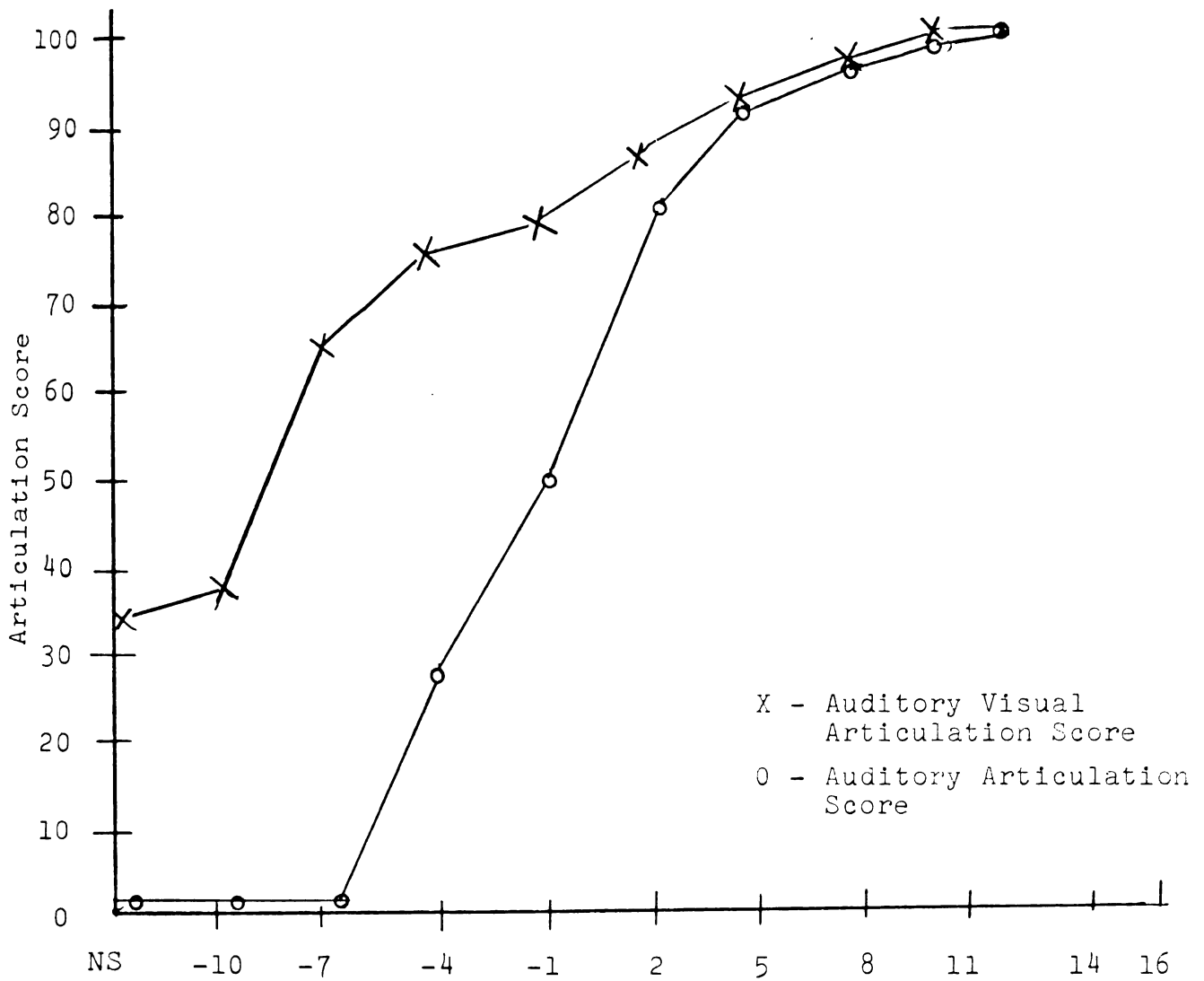


FIGURE 1

MEAN ARTICULATION SCORE PLOTTED AT EACH OF
TEN INTENSITY LEVELS.

TABLE I

MEAN CONTRIBUTION IN PER CENT OF LIPREADING
IN AN AUDIO-VISUAL ARTICULATION CURVE

Stimulus Intensity (dB HL)	Audio %	Audio-Visual %	Contribution Lipreading %
NS	.00	34.64	34.64
-10	.00	37.76	37.76
- 7	.00	65.85	65.85
- 4	29.43	76.63	47.20
- 1	49.16	78.39	29.23
2	78.92	86.92	8.00
5	92.50	97.39	6.11
8	96.92	97.39	.47
11	98.21	100.00	1.79
14	100.00	100.00	.00

Presentation two corresponds to -10 dB, presentation 3 to -7 dB and so on up to +14 dB.

The visual modality plays a less important role at the higher presentations (presentation six through ten). The auditory channel appears to be the largest contributor of the comprehension of speech in the normal vision, normal hearing subject. The point where the two sensory modalities appear to reach equality is during the tenth presentation or +5 dB.

We may conclude that vision appears to have its greatest effect at the lower intensities of the articulation

curve and that the auditory modality contributes more at the higher levels (+5 dB and up).

The data analysis, in conjunction with Figure 1 and Table I indicates that the visual modality serves as a definite aid to the comprehension of speech at the lower intensity levels. The results from this study appear to offer evidence that lipreading ability does not contribute greatly to the comprehension of speech at higher levels of intensity.

CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

The possibility of sensory modalities other than the hearing mechanism, as an aid to the comprehension of speech has been extensively explored by several investigators during the past sixty years. The measurement of cutaneous stimulation, tactile vibration and the visual pathway as alternate methods of comprehending speech have been measured by an assortment of test materials.

An investigation dealing with the visual channel of communication as an aid to the comprehension of speech has not been fully explored. Articulation tests which measure the comprehension of speech both auditorially and visually as a function of intensity, have not been accepted as a clinical tool in the United States. Also, articulation tests generally employ single unrelated words as test stimuli instead of commonly used sentences. These factors have prompted an investigation in this area.

The purpose of this study was to measure the difference between an auditory-visual articulation curve compared to traditional auditory articulation curves.

Both treatments were derived by using normal-hearing subjects and common "everyday" sentences.

Thirty-two subjects and one talker were utilized for the experiment. The subjects consisted of students enrolled in undergraduate speech and hearing classes at Michigan State University.

Subjects were tested in groups of four. The test environment was two adjoining sound treated rooms with an observation window between them, allowing the subjects to observe the talker.

The experiment consisted of two parts, A and B. Each part was conducted identically except that in Part B the subjects were allowed to observe the talker's face. Sentences were given in random order at increasing intensities. Twenty intervals were used with the intensity increasing in 3 dB steps. The intensity range was from no stimulus to 44 dB. The subjects responded to what they heard and observed by recording their answers on a prepared test sheet. The score for each subject was determined by the mean percentage of correct word identifications within each sentence.

The scores were analyzed by using the Wilcoxon matched-pairs, signed rank test. The results indicated a significant difference in test scores obtained at the lower intensity levels of the articulation tests. A study of Figure 1 indicates that combined auditory-visual

scores were significantly higher than the auditory scores at low intensity levels (-10 to +2 dB). This tends to indicate that vision increases articulation scores at lower levels of articulation curves.

Conclusions

From the results obtained by statistical analysis of the data, it was possible to reject the following null hypothesis at the .01 level of confidence at six intensity levels: There is no significant difference in auditory articulation curves compared to auditory-visual articulation curves. Therefore, the following conclusion is appropriate: Articulation curves are increased at their lower levels when the visual modality is employed in obtaining data for that curve.

Implications for Future Research

The significant difference between auditory-visual articulation curves and auditory articulation curves strongly indicate the need for further research in this area. The standardization of testing materials should be explored and the possibility of designing a short articulation test is indicated.

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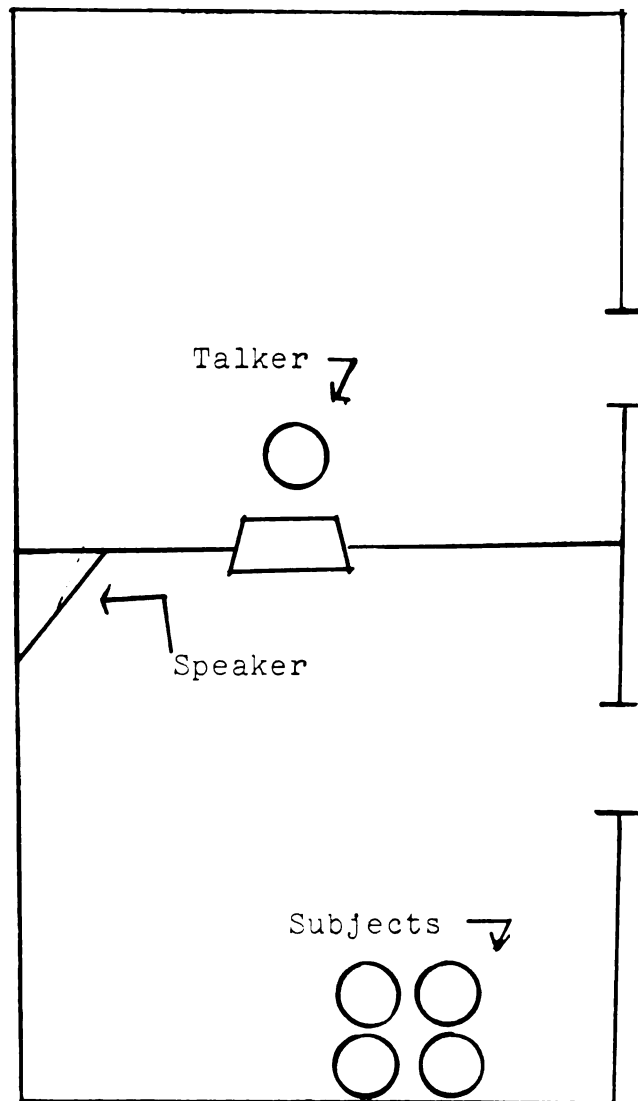
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APPENDICES

APPENDIX A

FLOOR PLAN OF HEARING TESTING ROOM SCALE*



*One inch to three and one-half feet.

APPENDIX B

Answer Sheet

Group: _____

Chair Number: _____

Sex: _____

Age: _____

Test A

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____
11. _____
12. _____
13. _____
14. _____
15. _____
16. _____
17. _____
18. _____
19. _____
20. _____

Test B

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____
11. _____
12. _____
13. _____
14. _____
15. _____
16. _____
17. _____
18. _____
19. _____
20. _____

APPENDIX C

CID "EVERYDAY SPEECH" Lists A to D

1. Walking's my favorite exercise.
2. Here's a nice quiet place to rest.
3. Our janitor sweeps the floors every night.
4. It would be much easier if everyone would help.
5. Good morning.
6. Open your window before you go to bed!
7. Do you think that she should stay out so late?
8. How do you feel about changing the time when we begin to work?
9. Here we go.
10. Move out of the way!
11. The water's too cold for swimming.
12. Why should I get up so early in the morning?
13. Here are your shoes.
14. It's raining.
15. Where are you going?
16. Come here when I call you!
17. Don't try to get out this time!
18. Should we let little children go to the movies by themselves?
19. There isn't enough paint to finish the room.
20. Do you want an egg for breakfast?
21. Everybody should brush his teeth after meals.

22. Everything's all right.
23. Don't use up all the paper when you write you letter.
24. That's right.
25. People ought to see a doctor once a year.
26. Those windows are so dirty I can't see anything outside.
27. Pass the bread and butter please!
28. Don't forget to pay your bill before the first of the month.
29. Don't let the dog out of the house!
30. There's a good ballgame this afternoon.
31. It's time to go.
32. If you don't want these old magazines, throw them out.
33. Do you want to wash up?
34. It's a real dark night so watch your driving.
35. I'll carry the package for you.
36. Did you forget to shut off the water?
37. Fishing in a mountain stream is my idea of a good time.
38. Fathers spend more time with their children than they used to.
39. Be careful not to break your glasses!
40. I'm sorry.

APPENDIX D

RANDOM SENTENCE PRESENTATIONS BY TEST GROUP¹

Order of Presentation (Part A)	1	2	3	4	5	6	7	8
1	1	39	21	37	34	40	19	2
2	11	25	35	10	7	30	3	16
3	25	27	6	14	5	26	6	13
4	20	17	40	12	33	23	4	27
5	5	11	9	38	2	36	7	12
6	10	10	13	20	3	6	40	26
7	12	12	38	36	20	27	32	34
8	36	22	11	29	39	12	15	35
9	23	36	25	25	37	22	23	3
10	15	26	39	28	6	20	36	14
11	4	2	12	16	36	8	8	39
12	24	35	24	7	30	2	31	40
13	18	23	28	9	19	29	2	29
14	22	18	23	32	16	18	12	28
15	19	40	7	23	28	35	10	5
16	14	14	19	40	9	21	1	6
17	17	34	31	34	31	14	5	4
18	29	38	5	31	25	7	20	10
19	30	19	36	3	10	15	25	22
20	16	20	14	8	15	39	35	19

¹Each number in the body corresponds to the sentence number in Appendix C.

Order of Presentation
 (Part B)

	1	2	3	4	5	6	7	8
1	13	32	27	13	38	39	33	23
2	38	15	15	19	18	16	35	18
3	39	30	3	32	21	19	23	32
4	21	7	16	6	26	24	5	11
5	9	9	34	24	35	33	37	21
6	37	37	26	15	40	37	22	17
7	3	33	20	5	17	32	25	37
8	6	16	8	11	11	25	20	30
9	2	24	18	17	29	3	15	31
10	31	28	17	1	23	5	32	36
11	8	4	10	36	4	31	40	7
12	32	3	22	21	1	34	7	18
13	40	5	32	20	8	11	4	24
14	35	29	37	27	14	1	6	15
15	27	21	2	39	32	38	3	38
16	28	8	29	35	29	4	19	20
17	33	13	30	4	13	28	28	1
18	26	1	4	22	22	9	11	33
19	34	31	1	2	12	13	18	25
20	7	6	33	18	27	10	26	6

APPENDIX E
RAW SCORE TOTALS

Test A (Audio)				
Presentation	Total ¹ Words	Total Correct	Mean Per Cent	Intensity
1	240	0	00.00	No Stimulus
2	220	0	00.00	-10
3	192	0	00.00	- 7
4	248	73	29.43	- 4
5	240	118	49.16	- 1
6	204	161	78.92	2
7	280	259	92.50	5
8	228	221	96.92	8
9	224	220	98.21	11
10	216	216	100.00	14
11	252	252	100.00	17
12	212	212	100.00	20
13	208	208	100.00	23
14	280	280	100.00	26
15	236	236	100.00	29
16	156	156	100.00	32
17	220	220	100.00	35
18	212	212	100.00	38
19	198	198	100.00	41
20	168	168	100.00	44 dB

¹Total number of words in the sentences presented at each corresponding intensity level.

APPENDIX F
RAW SCORE TOTALS

Presentation	Total ¹ Words	Total Correct	Mean Per Cent	Intensity
1	280	97	34.64	No Stimulus
2	196	74	37.76	-10
3	284	187	65.85	- 7
4	184	141	76.63	- 4
5	236	185	78.39	- 1
6	232	201	86.64	2
7	240	223	92.92	5
8	268	261	97.39	8
9	180	180	100.00	11
10	228	228	100.00	14
11	204	204	100.00	17
12	244	244	100.00	20
13	208	208	100.00	23
14	212	212	100.00	26
15	264	264	100.00	29
16	260	260	100.00	32
17	276	276	100.00	35
18	180	180	100.00	38
19	204	204	100.00	41
20	188	188	100.00	44 dB

¹Total number of words in the sentences presented at each corresponding intensity level.

APPENDIX G-1

RAW SCORES--AUDITORY

Group (I-IV) and Subject (1-4)																
Presentation	I				II				III				IV			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	6	6	0	0	11	6	0
5	9	10	9	10	0	0	0	0	6	6	0	6	0	8	5	4
6	2	2	2	2	10	0	10	6	5	7	4	7	8	8	8	8
7	10	10	10	10	7	0	9	9	7	7	7	7	6	6	6	6
8	4	4	4	4	6	5	5	6	7	7	5	7	10	10	10	10
9	11	11	11	11	7	5	7	7	12	12	12	12	3	3	3	3
10	8	8	8	8	2	2	2	2	8	8	8	8	7	7	7	7
11	11	11	11	11	7	7	7	7	8	8	8	8	7	7	7	7
12	4	4	4	4	2	2	2	2	9	9	9	9	11	11	11	11
13	7	7	7	7	8	8	8	8	8	8	8	8	7	7	7	7
14	10	10	10	10	12	12	12	12	6	6	6	6	8	8	8	8
15	5	5	5	5	2	2	2	2	12	12	12	12	11	11	11	11
16	4	4	4	4	8	8	8	8	3	3	3	3	6	6	6	6
17	6	6	6	6	9	9	9	9	4	4	4	4	7	7	7	7
18	7	7	7	7	9	9	9	9	9	9	9	9	2	2	2	2
19	2	2	2	2	5	5	5	5	5	5	5	5	9	9	9	9
20	8	8	8	8	3	3	3	3	3	4	4	4	9	9	9	9

APPENDIX G-2

RAW SCORES--AUDITORY

Presentation	Group (V-VIII) and Subject (5-8)															
	V				VI				VII				VIII			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	4	8	0	9	5	7	0	0	2	0	0	0	0	0	0
5	0	0	2	0	9	8	2	4	3	3	3	1	1	4	0	5
6	8	5	8	7	2	5	5	5	4	4	4	0	0	5	7	3
7	10	10	10	10	7	7	7	7	11	11	10	4	9	9	10	10
8	11	10	10	11	4	3	4	4	7	7	7	5	8	8	8	8
9	3	3	3	3	2	2	2	2	9	9	9	9	9	9	9	9
10	5	5	5	5	5	5	5	5	7	7	7	7	12	12	12	12
11	7	7	7	7	7	7	7	7	10	10	10	10	6	6	6	6
12	10	10	10	10	6	6	6	6	2	2	2	2	9	9	9	9
13	4	4	4	4	11	11	11	11	4	4	4	4	3	3	3	3
14	2	2	2	2	11	11	11	11	11	11	11	11	10	10	10	10
15	4	4	4	4	2	2	2	2	12	12	12	12	11	11	11	11
16	6	6	6	6	2	2	2	2	8	8	8	8	2	2	2	2
17	7	7	7	7	9	9	9	9	4	4	4	4	9	9	9	9
18	11	11	11	11	11	11	11	11	2	2	2	2	2	2	2	2
19	8	8	8	8	8	8	8	8	8	8	8	8	4	4	4	4
20	7	7	7	7	7	7	7	7	2	2	2	2	7	7	7	7

APPENDIX G-3

RAW SCORES AUDITORY--VISUAL

Presentation	Group (I-IV) and Subjects (1-4)															
	I				II				III				IV			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1	3	4	3	5	7	10	6	0	2	2	2	2	0	9	9	6
2	1	3	3	3	4	4	4	3	4	4	4	4	0	1	0	1
3	11	9	11	11	7	9	7	9	0	1	0	0	0	2	2	0
4	2	2	2	2	3	9	9	8	6	6	0	6	9	9	9	9
5	9	5	9	9	3	3	3	3	5	0	3	5	6	8	8	3
6	10	10	10	10	12	12	12	12	10	9	6	10	2	2	2	2
7	6	6	6	6	5	5	5	5	10	10	10	10	4	4	4	4
8	12	12	12	12	6	6	6	6	11	9	11	11	5	4	6	5
9	8	8	8	8	2	2	2	2	11	11	11	11	7	7	7	7
10	9	9	9	9	12	12	12	12	7	7	7	7	4	4	4	4
11	4	4	4	4	9	9	9	9	5	5	5	5	8	8	8	8
12	10	10	10	10	7	7	7	7	3	3	3	3	7	7	7	7
13	6	6	6	6	2	2	2	2	10	10	10	10	5	5	5	5
14	9	9	9	9	8	8	8	8	12	12	12	12	6	6	6	6
15	6	6	6	6	7	7	7	7	7	7	7	7	7	7	7	7
16	8	8	8	8	11	11	11	11	8	8	8	8	6	6	6	6
17	12	12	12	12	4	4	4	4	9	9	9	9	9	9	9	9
18	11	11	11	11	4	4	4	4	9	9	9	9	3	3	3	3
19	7	7	7	7	4	4	4	4	4	4	4	4	3	3	3	3
20	2	2	2	2	8	8	8	8	5	5	5	5	11	11	11	11

APPENDIX G-4

RAW SCORES AUDITORY--VISUAL

Group (V-VIII) and Subjects (5-8)																
Presentation	V				VI				VII				VIII			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1	5	4	6	1	1	0	0	0	5	5	4	3	0	3	0	0
2	2	2	4	0	6	6	1	0	0	1	5	0	0	3	1	0
3	7	7	7	6	8	8	7	7	11	0	11	10	9	7	3	0
4	10	10	0	10	2	2	2	2	2	2	2	2	0	0	1	2
5	2	1	0	6	5	5	5	5	12	12	12	12	7	7	6	6
6	2	2	2	2	12	12	12	11	3	3	3	3	7	7	7	6
7	7	7	7	7	10	6	8	10	9	9	9	9	12	8	11	10
8	7	7	7	7	9	9	9	9	7	7	7	7	9	6	8	9
9	2	2	2	2	7	7	7	7	4	4	4	4	4	4	4	4
10	9	9	9	9	4	4	4	4	10	10	10	10	4	4	4	4
11	9	9	9	9	4	4	4	4	2	2	2	2	10	10	10	10
12	4	4	4	4	9	9	9	9	10	10	10	10	11	11	11	11
13	11	11	11	11	7	7	7	7	9	9	9	9	2	2	2	2
14	2	2	2	2	4	4	4	4	7	7	7	7	4	4	4	4
15	10	10	10	10	11	11	11	11	7	7	7	7	11	11	11	11
16	8	8	8	8	9	9	9	9	8	8	8	8	7	7	7	7
17	4	4	4	4	12	12	12	12	12	12	12	12	7	7	7	7
18	3	3	3	3	3	3	3	3	2	2	2	2	6	6	6	6
19	10	10	10	10	4	4	4	4	6	6	6	6	9	9	9	9
20	6	6	6	6	5	5	5	5	2	2	2	2	8	8	8	8

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