THE EFFECTS OF CUTANEOUS STIMULATION BY SPEECH ON LIPREADING PERFORMANCE

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ABSTRACT

THE EFFECTS OF CUTANEOUS STIMULATION BY SPEECH ON LIPREADING PERFORMANCE

by Gerald Franklin Johnson

The purpose of this research was to investigate the effect of combining cutaneous stimulation by speech with lipreading on a subject's lipreading performance. Cutaneous stimulation by speech, as used in this study, means the transmission of a verbal speech signal via a Cutaneous Speech Transmission System to the dorsal portion of the forearm, on a subject's nondominant side. The Cutaneous Speech Transmission System consisted of four loud-speakers, two inches in diameter. Over the face of the loud-speakers a Pellon fabric membrane was glued so that the membrane made direct contact with the arm of the subject. The resulting vibrations, produced by the speech signal, activated the center of the membrane and made an elliptical vibratory pattern. Thus, the loud-speakers became efficient vibrators.

The loud-speaker-vibrators were then attached to the ends of metal rods. The speaker-rods were then suspended from an overhead bar and placed inside a metal container,

lined with sponge rubber. The subject placed his arm inside the container, and the speaker-rods were then lowered to the subject's arm. To prevent the subject from hearing the speech, the whole apparatus was acoustically insulated, and the subject also received a masking noise via earphones.

The speech stimuli that were employed in testing the subjects in the experimental conditions consisted of twenty-five phonetically balanced words and twenty-five Spondaic words. Two motion picture films employing these fifty words were produced. A silent motion picture film was made for presentation of Condition I (lipreading only) and a sound motion picture film for presentation of Condition II (lipreading combined with cutaneous stimulation by speech).

The subject's lipreading performance was tested under the two experimental conditions in both pre-test (before training in cutaneous stimulation by speech) and post-test (after training in cutaneous stimulation by speech) positions. The subjects, after being tested in the pre-test situation, on Conditions I and II, were trained in the utilization of cutaneous stimulation by speech only. This training consisted of ten half-hour sessions that were devoted to the perception of cutaneous stimulation by speech.

After a subject had completed the pre-test situation and the training sessions, he was again tested on the experimental Conditions I and II. Thus, each subject produced a total of four scores: (1) Pre-test Condition I (lipreading only, before training in cutaneous stimulation by speech), (2) Pre-test Condition II (lipreading combined with cutaneous stimulation by speech, before training in cutaneous stimulation by speech), (3) Post-test Condition I (lipreading only, after training in cutaneous stimulation by speech), and (4) Post-test Condition II (lipreading combined with cutaneous stimulation by speech, after training in cutaneous stimulation by speech). Each of the subject's scores was based upon the total number of words perceived correctly out of a total list of 50 words. This comprised the total experiment.

On the basis of the analysis of the data obtained within the experimental conditions of this investigation, the following conclusions appear to be warranted:

1. After the subject has had the benefit of a brief training period in the utilization of cutaneous stimulation by speech and when cutaneous stimulation by speech is combined with lipreading, the subjects'

lipreading scores are significantly higher than by lipreading alone.

2. Combining cutaneous stimulation by speech with lipreading without the benefit of training in cutaneous stimulation by speech does not improve a subject's usual lipreading performance.

3. Words with spondaic stress patterns accounted for higher performance scores and more significant differences between the different experimental conditions than did the phonetically balanced monosyllabic words.

4. This experiment has shown that an efficient and uncomplicated aid to lipreading has been developed. Subject to further modification and research, the Cutaneous Speech Transmission System could be a useful adjunct to the lipreading process.

THE EFFECTS OF CUTANEOUS STIMULATION BY SPEECH ON LIPREADING PERFORMANCE

By

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CHAPTER I

STATEMENT OF THE PROBLEM

Introduction

Several approaches are utilized in assisting the aurally handicapped with their problems of communication. One of these approaches is the teaching of lipreading. As one becomes more proficient in the art of lipreading, his dependence upon the auditory channel for understanding speech is lessened. Thus, lipreading functions as a compensatory measure for the loss of hearing. Some lipreaders have become quite proficient in their ability to receive verbal messages, and can discriminate these messages as well as persons who are hearing. Many others, however, are not as proficient, and some fail altogether in their attempt to read lips.

Another approach that has been employed experimentally involves the utilization of the tactile channel. Experimental studies have been carried on in both the United States and Sweden that have as their objectives the development of a cutaneous communications system. However, the results of these experiments have been inconsistent.

The optimum result of a cutaneous communications system would be one that would closely approximate the efficiency

of a normal functioning aural system. The greatest single problem in cutaneous communication is the human receiver, and more specifically, the human integument. Because man's cutaneous sensibility is not good it is thought that "cutaneous communication can take place only through the symbolic encoding of language.[1]

> That is to say, there will have to be some sort of mediation whereby a cutaneous stimulus ('signal' or 'symbol' might be a more appropriate term) is interpreted as a symbol for some literate or linguistic form which, in turn, is taken to represent some element of language or speech.[2]

Some other experimenters also prefer the coding of speech signals.[3]

Geldard succeeded in transmitting speech into the somethetic decoding systems of the central nervous system by transforming information into special stimuli optimally adapted to skin receptors. This coded language he calls "vibratese language." His system is based on work accomplished

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[1]F. A. Geldard, "Adventures in Tactile Literacy," American Psychologist, 12(1957), pp. 115-124.

[2]E. A. Alluisi, "Conditions Affecting the Amount of Information in Absolute Judgements," Psychological Review, 64(1957), pp. 97-103.

[3]B. von Haller Gilmer and L. W. Gregg, "The Skin as a Channel of Communication," ETC.: A Review of General Semantics, 18(1961), pp. 199-209.

by Howell[4] and is founded upon three parameters for each symbol corresponding to a letter of a word. The three parameters are: (1) intensity, (2) duration of a sinusoidal vibration, and (3) locus of the stimulus. One of Howell's subjects was able to decode thirty-eight words per minute. This exceeds the expert military standard for a receiver of Morse Code, which is twenty-four words per minute.[5]

Geldard,[6] Gilmer,[7] and Alluisi,[8] et. al., base their rationale for coding the cutaneous signal on Geldard's statement that the skin does not hear with the competency of the ear. However, an experiment by Gault[9] and experiments most recently completed by investigators in Sweden,[10] have shown

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[4]W. C. Howell, "Training on a Vibratory Communication System," (unpublished Master's thesis, Department of Psychology, University of Virginia, 1956).

[5]F. A. Geldard, "Some Neglected Possibilities of Communication," Science, 131(1960), pp. 1583-1588.

[6]Geldard, American Psychologist, 12(1957), pp. 115-124.

[7]Gilmer, ETC, 18(1961), pp. 199-209.

[8]Alluisi, Psychological Review, 64(1957), pp. 97-103.

[9]R. H. Gault, "On the Identification of Spoken Words by Their Tactual Qualities," Journal of Applied Psychology, 10(1926), pp. 75-88.

[10]Speech Transmission Laboratory Quarterly Progress and Status Report, October 15, 1961. Speech Transmission Laboratory, Division of Telegraphy-Telephony, Royal Institute of

that persons receiving cutaneous stimulation by speech can discriminate words and other speech components through the skin well enough to comprehend them. It is doubtful that the proponents of cutaneous stimulation by speech expect the skin to hear with the competency of the ear.

The discrimination of cutaneous stimulation by speech is similar to deciphering a specialized vibratory code. Normal speech can be discriminated aurally by its inherent characteristics of duration, intensity, pitch, and quality. Successful utilization of cutaneous stimulation by speech relies most heavily upon discrimination of two parameters, viz duration and intensity. Frequency might well be a third parameter, the importance of which could possibly be determined through experimentation that would involve leading a filtered speech signal to the skin of subjects.

Statement of Problem and Purpose of Study

The problem involved in this study was the development and testing of a Cutaneous Speech Transmission System[11] that could efficiently stimulate the integument. Because it was

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Technology, Stockholm, Sweden, STL-QPSR-3/1961, (July - September).

[11]For a complete description of this Cutaneous Speech Transmission System (C.S.T.S.) the reader is directed to Chapter III.

thought that coded linguistic cutaneous units would not be feasible to test in conjunction with lipreading, therefore, speech was the stimulus of choice that was delivered to the experimental subjects. In this way the receiver is given the advantage of utilization of two stimuli simultaneously presented to two channels.

The purpose of this research was to investigate the effect that cutaneous stimulation by speech has on a subject's lipreading performance. An attempt will be made to answer the following general questions: (1) Does combining cutaneous stimulation by speech with lipreading improve a subject's lipreading score? (2) What effect does training in cutaneous stimulation by speech have on a subject's combined cutaneous stimulation by speech and lipreading performance? (3) Will there be any difference between a person's lipreading performance and his combined lipreading-cutaneous stimulation by speech performance? (4) Will the PB words, the Spondaic words, or both types of words account for any significance discovered in the investigation?

Hypotheses

In order to answer the previously stated questions in greater detail, the following null hypotheses are proposed and will be statistically analyzed.

1. There is no significant difference among the subject's performance scores obtained under the following experimental conditions: (1) lipreading only before training in cutaneous stimulation by speech,[12] (2) lipreading combined with cutaneous stimulation by speech before training in cutaneous stimulation by speech, (3) lipreading only after training in cutaneous stimulation by speech, and (4) lipreading combined with cutaneous stimulation by speech after training in cutaneous stimulation by speech.

2. There is no significant difference between the subject's performance scores obtained under the following experimental conditions: (1) lipreading only before training in cutaneous stimulation by speech, and (2) lipreading combined with cutaneous stimulation by speech before training in cutaneous stimulation by speech.

3. There is no significant difference between the subject's performance scores obtained under the following experimental conditions: (1) lipreading only after training in cutaneous stimulation by speech, and (2) lipreading combined with cutaneous stimulation by speech after training in cutaneous stimulation by speech.

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[12] For a more explicit discussion of this and other terminology the reader is directed to the Definition of Terms on pages 11-17.

4. There is no significant difference between the subject's performance scores obtained under the following experimental conditions: (1) lipreading only before training in cutaneous stimulation by speech, and (2) lipreading only after training in cutaneous stimulation by speech.

5. There is no significant difference between the subject's performance scores obtained under the following experimental conditions: (1) lipreading only before training in cutaneous stimulation by speech, and (2) lipreading combined with cutaneous stimulation by speech after training in cutaneous stimulation by speech.

6. There is no significant difference between the subject's performance scores obtained under the following experimental conditions: (1) lipreading combined with cutaneous stimulation by speech before training in cutaneous stimulation by speech, and (2) lipreading only after training in cutaneous stimulation by speech.

7. There is no significant difference between the subject's performance scores obtained under the following experimental conditions: (1) lipreading combined with cutaneous stimulation by speech before training in cutaneous stimulation by speech, and (2) lipreading combined with cultaneous stimulation by speech after training in cutaneous stimulation by speech.

Importance of the Study

Basically, the initial consideration for teaching lipreading is to help the deaf or hard of hearing person maintain his communicative relationship with other people. One important aspect of man's daily functioning is his ability to communicate. Becoming deaf or incurring a serious loss of hearing greatly affects this aspect of social behavior. If the loss of hearing cannot be surgically repaired, other rehabilitative measures can be suggested to these people. Training in lipreading is usually suggested because it can often compensate for the loss of the auditory channel. Once the person becomes proficient in lipreading it tends to counterbalance his inability to hear and comprehend speech.

Little is known about the lipreading process, and there is very little evidence concerning the factors that contribute to one's being a skilled lipreader. It is for this reason that the more information that is available to the lipreader the easier the task will be and the greater his discrimination score will be. Residual hearing and knowledge of the subject being talked about all give the lipreader more information and therefore presumably make the lipreading task easier.

Residual hearing is possibly the greatest single aid to the lipreading process and is also one of the biggest deterrents to serious psychological manifestations. Ramsdell writes:

> Anyone who has closely observed an adult soon after he has lost his hearing has noted that he becomes discouraged and struggles with feelings of depression. Sometimes he even becomes suspicious of friends and family.[13]

Ramsdell believes this is because the deaf person is cutoff from the primitive or affective level of hearing. The primitive level of hearing is the auditory background of all daily living.

> At this level we react to such sounds as the tick of a clock, the distant roar of traffic, vague echoes of people moving in other rooms in the house, without being aware that we do hear them . . . Impairment or loss at the primitive 'affective' level is almost fundamentally and intimately connected with the emotional difficulties of the deaf.[14]

If the loss of this primitive level of hearing can be compensated for in some way through vibrations applied to the skin in some region of the body, the deaf adult might

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[13]D. A. Ramsdell, "The Psychology of the Hard-of-Hearing and the Deafened Adult," in Hallowell Davis and S. Richard Silverman, Hearing and Deafness (New York: Holt, Rinehart and Winston, Inc., 1960) pp. 459-473.

[14]Ramsdell, in Davis and Silverman, Hearing and Deafness, pp. 459-473.

not feel so isolated, and the concomitant psychological manifestations will probably be diminished or modified.

The possibility of the deaf's receiving and discriminating vibratory signals, and especially verbal communication, is very intriguing. However, this study is interested only in determining if the extra cue of cutaneous stimulation by speech will increase a person's lipreading performance.

Limitations of the Study

Sixteen subjects will be utilized in the investigation, and will be randomly selected from a stratified population of college students who are speech majors. This experimental population necessarily presents a limitation in relation to projecting the results of this study to a normal population.

The Cutaneous Speech Transmission System, and the vibratory stimuli, present other limitations because of their uniqueness. One vibrator might produce results significantly different from the use of four vibrators, and menaingful sentences, rather than isolated words, could conceivably contribute to higher performance scores throughout the experiment.

The portion of the integument stimulated also presents some limitations upon the investigation, recognizing that there is differential sensitivity as a function of placement. The choice of vibrators could also affect the ultimate outcome of this type of experiment.

In view of these limitations however, the experiment was rigorously controlled.

Definition of Terms

Experimental Conditions: There will be two experimental conditions employed in this study. Condition I will be lipreading only. The subjects will be asked to lipread a series of fifty words, that will be presented on film.

Condition II will be lipreading combined with cutaneous stimulation by speech. In this condition the subjects will be utilizing vision and tactual sensibility simultaneously while perceiving the series of fifty words in randomized order on another film. All of the experimental subjects will be exposed to both conditions in the pre-test and post-test positions.

Pre-test: Pre-test simply means testing the subjects, in both experimental condtions, before they receive training in cutaneous stimulation by speech. Testing the subjects before they receive this training is necessary so that

effects of the training in cutaneous stimulation by speech can be ascertained.

Post-test: Post-test means testing the subjects, in both experimental conditions, after training in cutaneous stimulation by speech. The test scores the subjects receive on the two experimental conditions in the post-test will be compared with their scores on the pre-test to determine the effect of training in cutaneous stimulation by speech.

Training: All of the subjects will be trained in the perception of cutaneous stimulation by speech. The training sessions will last for one half an hour per day for a total of 10 half-hour sessions. After this period of training the subjects will be designated as trained. Thus, training implies having participated in the 10 half-hour sessions. The subjects will receive training only after having completed the pre-test Conditions I and II and before they receive the post-test Conditions I and II.

Cutaneous Stimulation by Speech: Cutaneous stimulation by speech, as used in this study, will mean the transmission of a verbal speech signal via the Cutaneous Speech Transmission System that will be presented to the dorsal part of the forearm on the subject's nondominant side. The

arm was chosen so that ultimately the subject's hands could remain free to perform their usual manipulative functions.

The speech signal to be vibrated will be taken from the sound track of a sound motion picture film that will be used in the presentation of Condition II. Cutaneous stimulation by speech will also be produced from the series of training tapes.

Speech Stimuli: Two different types of words will be chosen for this study. The two types combined will comprise a total list of 50 words. Twenty-five of these words will be phonetically balanced (PB) words that were developed by Egan.[15] Items in the PB word lists satisfy the following criteria: (1) The words are monosyllabic in structure, (2) They have an equal range of difficulty, (3) They are of equal average difficulty, (4) They are of equal phonetic composition, (5) They are representative of English speech, and (6) They are words in common usage.

The other twenty-five words will be chosen from the Spondee word lists. These Spondaic words were developed at the Central Institute for the Deaf as modifications of words

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[15] J. P. Egan, "Articulation Testing Methods," Laryngoscope, 58(1948), pp. 955-991.

developed at the Psycho-Acoustic Laboratory of Harvard University. Each of the thirty-six Spondee words is composed of two syllables that are equally stressed. The words were chosen on the basis of familiarity and intelligibility.[16]

Masking: Masking will mean the application of white noise via earphones to the subjects' ears. Masking is needed to eliminate the possibility that the subjects could hear the speech produced by the Cutaneous Speech Transmission System, thus rendering the study invalid. White noise was chosen because it is "one of the best masking noises yet devised . . . . White noise contains a wide band of frequencies at intervals of 1 cycle per second or less, at approximately the same intensity."[17]

Lipreading: The term lipreading, as used in this study, will mean that process whereby one person (the receiver or

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[16]Hallowell Davis and S. Richard Silverman, Hearing and Deafness (New York: Holt, Rinehart and Winston, Inc., 1960) pp. 535-536.

For additional information about these words the reader is directed to: R. W. Benson, et. al., "C.I.D. Auditory Tests W-1 and W-2," The Journal of the Acoustical Society of America, 23(1951), p. 719.

And:

I. J. Hirsh, et. al., "Development of Materials for Speech Audiometry," Journal of Speech and Hearing Disorders, 17(1952) pp. 321-337.

[17]Hayes A. Newby, Audiology (New York: Appleton-Century-Crofts, Inc., 1958), p. 15.

lipreader) can discriminate and understand a verbal message that is being sent by another person (the sender or communicator) without the aid of hearing. The receiver must then rely on his visual analyzer to be able to comprehend the verbal message. This can be accomplished by the receiver by close observation of the sender's lips, facial and body movements and expressions, and by extra cues that are not clearly defined.

Other persons interested in the process of lipreading have offered their own definitions and have also developed their own terminology. Bulwer, in 1648, defined lipreading as "the subtle art which may enable one with an observant eye to hear what any man speaks by the moving of his lips."[18] Bunger uses the term speech reading which she defines as understanding spoken language while watching the speaker with little or no utilization of hearing.[19] English and English also prefer the term speech reading to lipreading. They define speech reading as "the comprehension of another's speech, without the use of hearing, by observing his facial movements

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[18]Elizabeth H. Nitchie, New Lessons in Lipreading (Philadelphia: J. B. Lippincott Co., 1950), p. 25.

[19]Anna M. Bunger, Speech Reading -- Jena Method (Danville, Illinois: The Interstate Press, 1944).

and other visual cues." They classify lipreading as the "common" word but state that it is "inadequately descriptive."[20] Visual hearing, the term advanced by Mason,[21] is listed as a synonym, but English and English mention that the use of this term is somewhat ambiguous.

Mason's visual hearing terminology was suggested to her by G. Oscar Russell. In defense of this terminology Mason writes:

> The term 'Visual Hearing,' seems more comprehensive in scope than etiher 'Lip-Reading' or 'Speech-Reading.' It does not tend to suggest a focus of attention on the lips as does the former, since it is possible for some skilled students to understand what is said when the speaker's lips are covered. Nor does it convey the idea of oral 'reading' of a speech as does the term 'Speech-Reading.' It does, however, carry the implication of a functional substituion of the 'eye' for the 'ear' in comprehending spoken language.[22]

Further terminology change is proposed by O'Neill and Oyer, who offer "visual thought comprehension" as a possible

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[20]Horace English and Ava English, A Comprehensive Dictionary of Psychological and Psychoanalytical Terms (New York: Longmans, Green and Co., 1958), p. 517.

[21]Marie K. Mason, "A Cinematographic Technique for Testing More Objectively the Visual Speech Comprehension of Young Deaf and Hard of Hearing Children" (unpublished Doctoral Dissertation, The Ohio State University Department of Speech, 1942), p.56.

[22]M. Mason, Doctoral Dissertation, p. 56.

substitute for the word lipreading. Visual thought comprehension is defined as "the correct identification of thoughts transmitted via the visual components of oral discourse . . . . It is a form of learned linguistic behavior."[23]

The use of the word lipreading is largely a matter of semantics. When lipreading and other descriptive names for lipreading are operationally defined, the words often become synonomous. Thus, the term lipreading and lipreader will be used in this study and will mean the ability of a receiver or lipreader to convert a lip code produced by a visual word message of a communicator back into a meaningful message that closely approximates or completely duplicates the message sent by the communicator without the aid of hearing.

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[23]J. J. O'Neill and H. J. Oyer, Visual Communication for the Hard of Hearing (New Jersey: Prentice Hall, 1961), pp. 2-3.

CHAPTER II

REVIEW OF THE LITERATURE

Introduction

Very little research is to be found that encompasses both lipreading and cutaneous experimentation. That which is available is associated with the early work of Gault and is reviewed in Part I of this chapter. It is of interest to note that the literature pertaining to cutaneous perception is to be found mostly in technical books and journals, whereas the literature pertaining to lipreading is found largely in non-technical books and journals.

Because the pertinent literature pertaining to lipreading and cutaneous studies is so diverse, the review of this literature is divided into two parts. In Part I is reviewed the cutaneous literature and in Part II the literature related to lipreading.

PART I:
REVIEW OF CUTANEOUS LITERATURE

"Despite the fact that the skin is, from the evolutionary standpoint, the oldest of the sensitive tissues of

the body, it has yielded up its secrets reluctantly."[1] In this review some of the better known facts about the skin's capabilities will be discussed. This part is divided according to topics because of the diversity of the material presented.

Cutaneous Sensitivity of Bodily Areas

The human body is a multi-modality, highly variable, sensitive machine. One part of this machine, the human integument, is highly variable, i.e. different portions of the skin react differently to external stimulation. For example,

> It is well known that the skin on the arm is less sensitive than the skin on the thumb. To some extent, this difference is a consequence of the fact that the area on the sensory cortex corresponding to a unit of surface on the thumb is much larger than that corresponding to a unit of surface on the arm.[2]

Not only the thumb but also the rest of the fingers are more sensitive than the arm. In fact, "one of the most important external senses is the touch . . . its most delicate seat is in the points of the fingers."[3] By the use of

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[1]Frank A. Geldard, The Human Senses (New York: John Wiley and Sons, Inc., 1953), p. 159.

[2]Georg von Békésy, Experiments in Hearing (New York: McGraw-Hill Book Co., 1960), pp. 564-565.

[3]J. Bostock, An Elementary System of Physiology (Boston: Wells and Lilly, 1825). Cited by A. E. Taft, "On Touch as a Special Sense," Journal of Nervous and Mental Disorders, 122 (1955), pp. 386-398.

the fingers, "we more accurately distinguish the tangible qualities of things than by other parts of the body."[4] Possibly the reason why the fingers are so sensitive is because "the pulps of man's fingers have highly developed patterns (papillary ridges) and these are more variable and complex than those of any other parts in any of the primates . . ."[5]

Many studies support the belief that the finger-tips are the most sensitive part of the human integument. When different areas of the body were stimulated with vibration and the sensitivity of the skin was measured, it was found that sensitivity is highest at the finger-tips and zero over the eyelids.[6] In another vibratory sensitivity study, Gilmer found that of the different regions of the hand and forearm tested, the most sensitive areas were on the fatty portions of the palmer side of the hand and the finger-tips.[7]

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[4]H. Haller, The First Lines of Physiology (Edinburgh: Chas. Eliot, 1779). Cited by Taft, Journal of Nervous and Mental Disorders, 122 (1955), pp. 386-389.

[5]W. A. Kidd, Sense of Touch in Mammals (London: Adam & Chas. Black, 1907), Cited by Taft, Journal of Nervous and Mental Disorders, 122 (1955), pp. 386-389.

[6]A. Roth, "Measurement of Vibration Sense," War Medicine, 4(1943), pp. 280-282.

[7]B. V. H. Gilmer, "The Measurement of the Sensitivity of the Skin to Mechanical Vibration," Journal of General Psychology, 13(1935), pp. 42-61.

Using a fine stream of air, DeCillis found that the finger-tip was more sensitive than either the arm or the leg.[8] Schewchuk and Zubek also used an air stream that stimulated the tongue, lip, cheek, forehead, neck, tip of the index finger, thumb, back of the hand, forearm, and upper arm. For each of these locations a critical frequency of percussion (cfp) was determined. The relationship between cfp and pressure was the same for all 10 skin areas tested. The cfp for the lip, tongue, and thumb was higher than that of the arms, neck and cheek.[9]

The skin can also localize the impression of external stimuli. The results of a study by Mookherjee reveal that localizations of this kind go together with the delicacy of the skin. "At the highly sensitive parts of the skin such as the tips of the finger, of the lips, of the nose, etc., localization was made in all cases . . . ."[10] Not only are the fingers good at localizing but they also can make fine

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[8] O. E. DeCillis, "Absolute Thresholds for the Perception of Tactile Movements," Archives of Psychology, 52(1944), p. 294.

[9] L. A. Shewchuk and John P. Zubek, "Discriminatory Ability of Various Skin Areas as Measured by a Technique of Intermittent Stimulation," Canadian Journal of Psychology, 14(1960), pp. 244-248.

[10] K. C. Mookherjee, "The Cyclopean Point in Touch," Journal of Experimental Psychology, 17(1934), pp. 600-603.

kinaesthetic discriminations. The results of a study by Dietz, who had subjects judge lengths of aluminum rods that were grasped between the thumb and forefinger, were that the fingers showed remarkable accuracy in kinaesthetic discrimination.[11]

A study by Ahrens has shown that the upper extremities are significantly more sensitive than the lower extremities,[12] and it would appear that the end portion of the extremity is the most sensitive.

In the testing of the sensitivity of the skin "a distinction is frequently made between sensations of touch, relating to light contact, and of pressure, relating to increased application of force."[13] Gilmer found that the regions of the skin most sensitive to mechanical vibration were those spots which were also highly sensitive to pressure.[14] Geldard suggests that sensitivity to "vibration

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[11]Alfred G. Dietze, "Kinaesthetic Discrimination: The Difference Timer for Finger Span," Journal of Psychology, 51(1961), pp. 165-168.

[12]R. S. Ahrens, "A Study of the Vibratory Sensation," Archives of Neurology and Psychiatry, 14(1925), p. 793.

[13]Russell E. Mason, Internal Perception and Bodily Functioning (New York: International Universities Press, Inc., (1961), p. 344.

[14]B. H. Gilmer, "The Relation of Vibratory Sensitivity to Pressure," Journal of Experimental Psychology, 21(1937), pp. 456-463.

involves a mode of operation of the pressure sense."[15] The pressure of the tactile stimulation" . . . is a form of energy that distorts the shape of the tissue out of its usual resting form. Stimulation seems to come about by reason of this distortion."[16] Tactile stimulation also depends upon the magnitude of the stimulated area. An increase of stimulated area leads to a decrease of the threshold.[17]

Sensitivity of the integument is further complicated because the skin has a tendency to adapt itself to the stimulation. Buskirk and Callaway describe three forms of adaptation of the skin to vibration: (1) absolute adaptation to a weak supra-threshold stimulus, (2) elevation threshold at the site of a previous strong supra-threshold stimulation, (3) absolute adaptation to a weak supra-threshold stimulus induced by a strong contra-lateral stimulation. They further state that all three of these phonemena are considered to be

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[15]F. A. Geldard, "The Perception of Mechanical Vibration: I. History of a Controversy," Journal of General Psychology, 22(1940), pp. 243-269.

[16]S. Howard Bartley, Principles of Perception (New York: Harper & Brothers, 1958), p. 356.

[17]V. P. Babkin, O. M. Rozen, L. N. Turmarkina, and R. I. Cherniak, "The Study of Vibrational Sensitivity and the Factors Influencing it," Biofizika, 6(1961), pp. 61-67.

mediated by the central nervous system.[18]

The skin is also subject to fatigue. Kampie found decreased sensitivity due to fatigue,[19] but Katz presents evidence to the contrary. Katz found that while the sense of touch tires very readily the vibratory sense is minimally affected by fatigue.[20] Wedell and Cummings found that sensitivity to vibratory stimulation applied to the palm of the hand is reduced 5 to 15 decibels after three minutes of continuous stimulation. The loss of sensitivity is greater the higher the frequency and the greater the intensity of the fatiguing tone. After stimulation for three minutes at a certain frequency, the loss of sensitivity is the same whether measured at a frequency equal to or higher than the fatiguing frequency, but it is less if measured at a lower frequency.[21]

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[18]Charles Van Buskirk and Enoch Callaway, "Observations on Vibratory Thresholds," Confina Neurologica, 16(1956), pp. 301-308.

[19]A. Kampie, "Experimentelle Untersuchungen uber die praktische Leistungsfahigkeit der Vibrationsempfinden," Archiv für die Gesamte Psychologie, 76(1930), pp. 3-70. Cited by Louis D. Goodfellow, "Vibratory Sensitivity: Its Present Status," Psychological Bulletin, 31(1934), p. 560-571.

[20]D. Katz, "The Vibratory Sense and Other Lectures," The Maine Bulletin, 32(1930), p. 10.

[21]C. H. Wedell and S. B. Cummings, Jr., "Fatigue of the Vibratory Sense," Journal of Experimental Psychology, 22(1938), pp. 429-438.

The Range of Cutaneous Sensitivity to Vibrations

Experimental data from the laboratory show that all important elements of speech and music can be perceived through the senses of touch and vibration. The limits of sensitivity have been investigated by many different experimenters, and various results are reported. Kampie sets the frequency range which can be perceived by the vibratory sense at 16-1300 cycles per second.[22] While Thiel sets it at 86-528 cycles per second.[23]

Geldard makes note of the maximum sensitivity as being in the region of 250 cycles per second. However, Geldard makes no mention of an upper limit because of the technical difficulties of moving the skin at high frequencies.[24] Wagner found that for deaf persons the range lies between 5 and 1700 Hertz (the European equivalent to cycles per second) with a peak between 200 and 400 Hertz, under and above which

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

[23] F. 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.

[24] Geldard, Journal of General Psychology, 22(1940), pp. 243-308.

perceptive capacity drops and amplification has to be increased sharply.[25]

Goodfellow found that the finger-tip can detect vibrations as high as 8,000 per second[26] while Knudsen found that the lower frequency limit to which the sense of touch responds is about 16 cycles per second and the upper limit is 1600 cycles per second but may be as high as 4000 cycles per second. Knudsen, however, did not investigate the range above 1600 cycles per second in this study, but he did predict that higher frequencies could be felt if the intensity of the stimulation were greater. Knudsen also found that the frequency of a vibrating body must change as much as 15-30 percent before a difference is noticeable by the sense of touch.[27]

Gault reports variously about the upper limit of sensitivity. In one report he places the upper limit at 2,000

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[25] P. 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," Neue Blätter für Taubstummenbildung, 15(1961), pp. 82-109, Cited in dsh Abstracts, 2(1962), pp. 226-227.

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

[27] V. O. Knudsen, "Hearing with the Sense of Touch," Journal of General Psychology, 1(1928), pp. 320-352.

vibrations per second,[28] in another report as high as 2,700,[29] and in a third report as high as 3,000 vibrations per second.[30]

Investigators have also found that the finger-tip can differentiate two pitches when the frequencies concerned differ by as little as 2-1/2 percent of the standard.[31] The finger-tip can also detect difference tones and beats[32] and can detect the individual tones in a chord and discriminate between consonance and disconsonance.[33]

Relationship Between Cutaneous and Auditory Modalities

Because the external stimuli applied to the skin have often had the characteristics of auditory stimuli, the

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[28] R. H. Gault, "Hearing Through the Sense of Touch and Vibration," Journal of the Franklin Institute, 204(1927), pp. 329-358.

[29] R. H. Gault, "Fingers Instead of Ears," Welfare Magazine, 18(1927), pp. 1131-1138.

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

[31] W. 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.

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

[33] L. D. Goodfellow, "The Tactual Perception of Musical Intervals," Journal of the Franklin Institute, 215(1933), pp. 731-736.

cutaneous and auditory modalities have been compared by some writers. For example, Gault, in 1934, believed that there was little division between the auditory and vibro-cutaneous senses. He further stated that the function of hearing may be taken over by the vibratory sense.[34]

The finger-tip has long been utilized in vibratory experiments, and its sensitivity has been compared to the sensitivity of the ear. Knudsen found that the finger-tip is able to discriminate different intensities about as well as the ear.[35] And Goodfellow and Gridley report that the finger-tip can detect differences in short intervals of time with 90 percent of the accuracy of the ear.[36, 37]

In comparing the relationship between cutaneous sensibility and hearing, Békésy offers this comparison:

> When continuous vibratory stimuli are presented on the skin the subject can differentiate several attributes:

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

[35] Knudsen, Journal of General Psychology, 1(1928), pp. 320-352.

[36] L. 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.

[37] Pearl Gridley, "The Discrimination of Short Intervals of Time by Finger-tip and by Ear," American Journal of Psychology, 44(1932), pp. 18-43.

> (1) the frequency of the vibration, which is analogous to pitch in hearing, (2) the subjective magnitude of the sensation, which has many features in common with loudness in hearing, and (3) the sensation of the lateral spread along the surface of the skin, which corresponds to the volume of the sound in hearing.[38]

In another comparison of the cutaneous and auditory modalities Jenkins found that above a frequency of 20 per second the sense of touch melts "into a smooth sense of vibration, which shows characteristics roughly analogous to those of hearing." [39]

Hawkes and Loeb studied subjects' vigilance for both cutaneous and auditory stimuli and found a response latency of longer duration for the cutaneous modality than for the auditory sense and that these differences were significant. Also, the number of failures of detection was greatest for the signals applied cutaneously than for the auditory signals.[40,41]

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[38]Georg von Békésy, "Funneling in the Nervous System," Journal of the Acoustical Society of America, 30(1958), pp. 399-412.

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

[40]Michel Loeb and Glenn R. Hawkes, "Rise and Decay Time in Vigilance for Weak Auditory and Cutaneous Stimuli," Perceptual and Motor Skills, 13(1961), pp. 235-242.

[41]G. R. Hawkes, and M. Loeb, "Vigilance for Cutaneous and Auditory Signals," Journal of Auditory Research, 1(1961), pp. 272-284.

Apparatus Used To Produce Cutaneous Stimulation

Possibly Gault was the first person to investigate the possibilities of transmitting cutaneous messages. The methods he employed were quite unique. As it is with initial efforts, his early equipment was quite crude; but his interest and early significant success led him to develop a more refined vibro-tactile apparatus. His initial equipment consisted of a long speaking tube that extended through several walls. At the end of the tube he positioned a subject whose primary task was to discriminate by touch the differences between a number of tuning forks that were set in vibration at the end opposite the subject.[42]

Another of Gault's early instruments was a disk-shaped receiver, analogous to the ear piece in a telephone system. A high quality transmitter was placed at the mouth of a person speaking in another room 35 feet distant. Between the transmitter and the receiver was a three tube amplifier. The transmitter was operated by three dry cells. In addition, the system required a six volt 'A' battery and a 110 volt 'B' battery. When the experimenter spoke into the transmitter, the

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[42] R. H. Gault, "Progress in Experiments on Tactual Interpretation of Oral Speech," Journal of Abnormal and Social Psychology, 19(1924), pp. 155-159.

subject felt the vibration of the receivers against their hands or against the tip of a finger.[43]

Gradually Gault developed more refined apparatus for communicating speech to the finger-tips of an observer. This latter apparatus was called the teletactor,[44] which consists of five vibrating posts, each responding to a mutually exclusive frequency range, and each affecting a single finger of the subject by way of the finger nail.[45] With the use of Gault's teletactor many vibro-tactile experiments were accomplished. A review of some of these experiments will be presented later in this chapter.

Other experimenters have also developed tactile apparatus. Békésy made a noteable contribution to vibro-tactile experimentation when he developed three different types of vibro-tactile apparatus. These apparatus were actually mechanical models of the cochlea and were employed to investigate

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[43] R. H. Gault, "Control Experiments in Relation to Identification of Speech Sounds by Aid of Tactual Cues," Journal of Abnormal and Social Psychology, 21(1926), pp. 4-13.

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

[45] Gault, Journal of the Franklin Institute, 204 (1927), pp. 329-358.

how the nerves react to different vibratory patterns on the basilar membrane. In the use of these mechanical models the skin of the forearm substituted for the nerve supply of the basilar membrane. The three models were also used to demonstrate three of the theories of hearing: (1) the resonance theory, (2) the telephone theory, and (3) the traveling wave theory.[46]

> The resonance model consisted of a series of tuned steel reeds attached to a metal support that oscillated slightly around its longitudinal axis. The length of the support was equal to the length of the forearm. Thirty-six reeds, tuned in equal intervals over a range of two octaves, were distributed along the whole length. A small pin on each reed, fastened close to the support, touched the surface of the skin of the arm. When the arm was placed carefully along the pins, so that the points just touched the skin, the reed system transformed any change in frequency into an easily observable displacement of the stimulated area on the skin.
>
> The model for the telephone theory was a triangular metal frame made of tubing. The frame vibrated perpendicularly to the axis of the edge in contact with the forearm. The rigidity of the frame ensured that all the stimulating parts touching the skin would vibrate in phase.
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> The model for the traveling waves was a plastic tube case around a brass tube with a slit. The tube was filled with fluid. A vibrating piston set the fluid inside the tube in motion, and forces in the fluid produced waves that traveled from the hand to the elbow.[47]

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[46]George von Békésy, "Current Status of Theories of Hearing," Science, 123(1956), pp. 779-783.

[47]Békésy, Experiments in Hearing, p. 546.

The mechanical model of the cochlea developed by Békésy to demonstrate the traveling wave theory was later employed in studies that attempted to develop a vibro-cutaneous communications system.

Keidel was one investigator who employed the Békésy apparatus. Keidel's procedure was to record speech on magnetic tape at the rate of 15 inches per second. The playback speed was slowed down by a factor of approximately 8 (2 inches per second) which shifted the frequency range from 300-3,000 cps (recording) down to 40-400 cps (playback). The playback signal was then fed into the apparatus that was placed on the subject's forearm. Keidel reports that intelligibility of speech seems possible with this apparatus.[48]

Another rather elaborate vibro-tactile apparatus is one currently being employed in experiments conducted in Sweden. The apparatus is called a "vocoder." In the vocoder, ten frequency channels of speech are transmitted into vibratory stimuli each of which varies in amplitude according to the power in one of the frequency channels.[49] The tactile vocoder operates as follows:

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[48] W. D. Keidel, "Note on a New System for Vibratory Communication," Perceptual and Motor Skills, 8(1958), p. 250.

[49] Speech Transmission Laboratory, Quarterly Progress and Status Report, October 15, 1961.

> The speech signal is first compressed in amplitude and then differentiated to emphasize high frequencies (+4 db/oct.). The resulting signal was divided by overlapping filters into ten channels having center frequencies of 210, 580, 830, 1050, 1800, 2250, 3320, 5800, and 7700 c.p.s. The response curves of the channel filters were triangular with sides having slopes that approaches 12 d.b. per octave. The output signal from each channel was rectified and smoothed to yield a control voltage. Each of the ten control voltages modulated the amplitude of a 300 c.p.s. sinusoidal signal. The varying 300 cycle signals were amplified and transmitted to 10 bone-conduction transducers which served as vibrators for stimulating the ventral tips of the subject's fingers. Preceeding from left to right across the dorsal part of the two hands, the frequency channels were presented to the fingers in order beginning with the lowest channel and proceeding to the highest channel.[50]

The vibratory apparatus used at the University of Virginia employs conventional audio equipment for amplification and transmission of the stimulus. As a transducer a Goodmans V-47 vibration generator is employed which is satisfactory up to about the 1000 cycle region.[51] Myers also used a similar set-up for his experiment. His experimental apparatus consisted of a Goodman "shake table" vibrator which had a specially designed finger transducer to stimulate his subject's three middle fingers and thumb. During testing the

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[50] Speech Transmission Laboratory, Quarterly Progress and Status Report, October 15, 1961.

[51] Letter from John F. Hahn, Ph.D., Associate Professor of Psychology, University of Virginia, October 23, 1962.

subjects were seated in front of the apparatus and asked to rest their fingers gently on the finger transducer. A Bell amplifier was used to transmit the signals to the vibrator from an Ampro two-speed tape recorder.[52]

In teaching speech to the deaf, Crane and Evans combined a Language Master with a tactile-device called the Sonovox, which feeds the speech signal through vibratory means to the hard of hearing subject. The Sonovox vibrator is basically a dynamic transducer with a heavy magnet with an enlarged voice coil that has a large displacement. The authors state that the Sonovox produces a faithful vibratory reproduction of the input signal.[53]

In cutaneous experiments, electrodes and even electric current have been utilized. Anderson and Munson, using electrodes, applied audiofrequency signals of various types (sine waves between 100 and 10,000 cps and speech signals) in the form of electrical potentials directly to the skin of a few observers. They found that the character of the

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[52]Robert D. Myers, "A Study in the Development of a Tactual Communication System," The Symposium on Air Force Human Engineering, Personnel, and Training Research, 1960, National Academy of Sciences--National Research Council, Publication No. 783, pp. 238-243.

[53]N. W. Crane and B. B. Evans, "The Talking Dictionary," Volta Review, 64(1962), pp. 125-127.

sensation can usually be separated into at least two distinct parts: (1) a disagreeable "burning" feeling near the surface of the skin, and (2) a more deep seated throbbing whose quality depends upon the frequency of the impressed signal. The relative and absolute magnitudes of these two sensations depend upon the size, spacing, and position of the electrodes.[54] Gilmer has also employed electrodes in his experiments. His apparatus consisted of Tektronex equipment that was capable of generating square-wave pulses with the capacitance coupled to a triode amplifier that utilized a type 24 power triode to stiffen the pulses so that the resistance of the skin did not distort the waveform. The output of the amplifier is applied to the electrodes at the skin. Any data that are received are punched directly on cards and programmed for a computer.[55]

Possibly the most unique apparatus was employed by Hawkes and Warm. They investigated electric current intensity level as a cue for signalling purposes and found that when intensity levels were equally spaced in terms of the subjective magnitude of sensation, two levels could be identified without error. Maximum transmission of information was

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[54]Attell B. Anderson and W. A. Munson, "Electrical Excitation of Nerves in the Skin at Audiofrequencies," Journal of the Acoustical Society of America, 23(1951), pp. 115-159.

[55]B. V. Gilmer, "Toward Cutaneous Electro-Pulse Communication," The Journal of Psychology, 52(1961), pp. 215-216.

achieved using three levels. At 1500 c.p.s. alternating current was more effective in transmitting information than alternating current at 100 c.p.s. They concluded that current intensity level could be useful as a cue in an electrical, cutaneous communication system.[56] In defense of this system Hawkes writes:

> The equipment problems of a cutaneous communication system could be simplified if one avoided the use of mechanical vibrators, which are bulky and require considerable power, and instead used electrical current as the source of stimulation. Either direct or alternating current would be suitable for communication purposes. Electrodes are easily mounted on the body surface, and have less bulk and a lower power requirement than mechanical vibrators.[57]

With the use of viberators it is necessary to mask or block out the resulting sound from the subject's hearing. Two methods are usually employed: (1) acoustically enclose the apparatus, and (2) present a masking noise in the subject's ears. With the use of the teletactor Gault and Goodfellow prevented the reception of sound by the subject by constructing a double concrete box (3 foot cube, outside

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[56]Glenn R. Hawkes and J. S. Warm, Communication by Electrical Stimulation of the Skin: I. Absolute Identification of Stimulus Intensity Level, Fort Knox, Ky: U.S.A. Medical Research Laboratory, 1959, No. 400.

[57]Glenn R. Hawkes, "Potential Answers to Communication Problems," Aerospace Medicine, 33(1962), p. 658.

measurement) lined with sound-absorbing material. The vibrator was suspended from the top of the inside box; and the observer, in order to place his fingers upon it, thrust his arm into the inner box through a small hole in the wall of each box that was made to fit the arm. Each opening was encircled with sponge rubber for the purpose of sound insulation when the arm was in position.[58] In testing the effectiveness of the box, sixteen observers were given 3200 trials to decide whether or not a sound had been produced even when they knew what stimulus might be produced and when to expect it. They were entirely at a loss when they had to decide whether or not a sound had been produced.

> Further more, fourteen naïve observers were entirely unable to identify five vowel qualities more times than chance would allow, indicating that no subliminal auditory cues are operative either by bone conduction to the inner ear or by direct hearing.[59]

Békésy was very careful in his vibratory experiments to prevent the transmission of cues by means of the ear. He acoustically insulated the whole apparatus and closed off the

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[58] R. H. Gault and Louis D. Goodfellow, "Eliminating Hearing in Experiments on Tactual Reception of Speech," Journal of General Psychology, 9(1933), p. 223.

[59] R. H. Gault, "Eliminating Hearing in Experiments on the Tactual Interpretation of Speech and Music," Psychology Bulletin, 30(1933), pp. 575-576, 691-692.

auditory meatus with an earplug that was covered by an earphone case. When the sound insulation was not sufficient, masking was used.[60] Myers also used a masking noise that was generated by a General Radio random noise generator. This was sufficient to mask out any concomitant audio frequencies emanating from the vibrators.[61]

Perception of Cutaneous Stimulation by Speech and Music

Much experimentation has been accomplished using the Gault teletactor. The reports of the research reveal a number of very useful applications of the teletactor in the education of the deaf.[62] The teaching of speech to the deaf is greatly facilitated by the use of the teletactor. It helps the child to learn many of the elements of speech and aids in building a concept of sound.[63] The teletactor also

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[60]Georg von Békésy, "Human Skin Perception of Traveling Waves Similar to Those on the Cochlea," Journal of the Acoustical Society of America, 27(1955), pp. 830-841.

[61]Myers, National Academy of Sciences--National Research Council, Publication No. 783, pp. 238-243.

[62]Louise Ebeling Dean, "Experiments in the Academic Education of Adolescent Deaf Pupils," American Annals of the Deaf, 79(1934), pp. 292-305.

[63]D. T. Cloud, "Some Results From the Use of the Gault-Teletactor," American Annals of the Deaf, 78(1933), pp. 200-204.

helps the child put more rhythm into his own speech.[64] The deaf child is also able to compare his speech with that of his teacher, and thus recognize his own particular difficulties.[65]

With training, deaf individuals learn to enjoy music and speech (particularly poetry) communicated to their fingertips by means of the teletactor.[66] Gault found that a subject, normal or deaf, could recognize by means of the teletactor after considerable practice: (1) vowels, (2) diphthongs, (3) consonants, and (4) short sentences.[67] In fact, a few cases are on record of totally deaf individuals who have interpreted speech by means of the senses of touch and vibration alone.[68]

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[64]R. H. Gault, "Extension of the Uses of Touch for the Deaf," School & Society, 23(1926), pp. 368-370.

[65]R. H. Gault, "Drafting the Sense of Touch in the Cause of Better Speech," Journal of Expression, 1(1927), pp. 126-131.

[66]R. H. Gault, "Pleasurable Reactions to Tactual Stimuli," pp. 247-254, in Feeling and Emotions - A Symposium. Edited by Martin L. Reynert (Worcester, Mass: Clark Univ. Press, 1928).

[67]Gault, Journal of the Franklin Institute, 204(1927), pp. 329-358.

[68]Gault, Journal of Applied Psychology, 10(1926), pp. 75-88.

Cloud experimented with the teletactor using eight deaf subjects. After a year's training with these eight subjects the experimenter concluded:

> (1) The teletactor proved to be an aid in tone production, (2) it offered an easy means of distinguishing between long and short vowels and for drilling on words in which these sounds occur, (3) it affords a convenient means for pointing out silent and unvoiced elements, (4) accent in a combination of syllables is more easily developed by aid of the teletactor than without it, (5) the omission of an element or a syllable when it should be vocalized, or its vocalization when it should be silent, is more easily corrected by use of the instrument than otherwise, (6) the pupils that used the teletactor have a much smoother speech than is usually found in deaf children of their age.[69]

Of course, not all cutaneous speech experimentation has been accomplished with the teletactor. With the use of the vocoder, discrimination and identification tests of various spoken sounds indicates that six vowel sounds could be identified with reasonable accuracy, and that the consonant features of affrication, voicing, place, and nasality could be discriminated to some extent.[70]

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[69]Cloud, American Annals of the Deaf, 78(1933), pp. 200-203.

[70]Speech Transmission Laboratory Quarterly Progress and Status Report, October 15, 1961.

Two other studies applied electrodes to the skin. Anderson reports that his subjects could feel differences between such words as "Joe, toe, sew, how, now, cow, blue" and "new" by electrical stimulation of the skin.[71] And lastly, Nelson, using a one and two-electrode system, found that after some training his subjects appeared to be able to distinguish between pairs of contrasting vowels. With one electrode the scores were about 60-70 out of 90 and with the two electrodes about 80 out of 90. However, he found large individual differences between subjects.[72, 73]

Combined Cutaneous Stimulation by Speech and Lipreading

Cutaneous stimulation by speech has been combined with lipreading with noteable success. Gault found that deaf pupils were able to increase their lipreading score on an average of 20 percent when lipreading was combined with

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[71] A. B. Anderson, "Electrical Stimulation of the Skin, Case 38138," A Report to Bell Telephone Laboratory, 1947, pp. 6-7.

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

[73] M. 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).

cutaneous stimulation by speech presented via the teletactor.[74] In another study, Gault found that a deaf lipreader could understand about twice as many words when he combined cutaneous stimulation by speech with lipreading than by lipreading alone.[75]

Gault also reports that when deaf subjects feel speech on their fingers through the teletactor and, at the same time, see it upon the face of a speaker, the combined tactual-visual impressions enable them to interpret speech more fully and accurately than did the visual impression alone, as in ordinary lipreading. The median advantage afforded by the combined stimulation alone was 30 percent when the stimuli were isolated monosyllabic words and scoring was made on the basis of the number of words correctly reported by the subject. When whole sentences were presented as stimuli and scoring is upon the basis of the number of whole sentences

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

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

literally reported, the medium advantage of combined stimulation was 100 percent.[76]

Ilieva studied the relative ability of the eye alone, of the finger-tip alone, and of both together to detect differences in the tempo of speech within spoken sentences. When subjects felt speech on their finger-tips through the teletactor and at the same time saw it upon the face of the experimenter, the combined impressions enabled them to detect the quickly spoken words in a sentence more accurately than did the visual impression alone, as it is found in unassisted lipreading. The percentage of correct judgments increases from 66.0 in the visual situation to 77.2 percent in the visual-tactual situation.[77]

Thus it would appear that a tactual aid for the deaf would be of considerable value if it is operated as a complement to lipreading. In this role a tactual speech apparatus should provide indications of some of the features of speech that are most difficult to identify by lipreading alone.

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[76] R. 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.

[77] M. L. Ilieva, "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.

PART II:

REVIEW OF PERTINENT LIPREADING LITERATURE

> It is conservatively estimated that three million children in the United States have hearing problems. Between two and one-half and three percent have a loss sufficient to warrant special medical care and educational help, and about one-tenth of one percent have a degree of hearing so slight that they may be classified as deaf. Among the adult population, 12 million are estimated to have hearing loss varying from slight to total. About 175,000 of this number were born without functional hearing or lost their hearing before they acquired speech.[78]

Lipreading is one of the important rehabilitative measures available to these deaf and hard of hearing persons. Montague suggests that "lipreading is a prime necessity for every person with any degree of hearing loss."[79] Guilder and Schall agree with Montague's suggestion by recommending lipreading for all patients with a hearing loss, while a hearing aid should be prescribed only in those cases where a sufficient amount of serviceable residual hearing has been ascertained.[80]

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[78] Hearing Loss . . . A Community Loss (Washington, D. C.: American Hearing Society, 1958), p. 5.

[79] H. Montague, "Lipreading . . . A Continuing Necessity," Journal of Speech Disorders, 8(1943), p. 259.

[80] Ruth Guilder and LeRoy Schall, "Rehabilitation of the Child Who Is Handicapped by Deafness," Laryngoscope, 54 (1944), pp. 511-530.

Newhart and the Ewings qualify their statements about the need for lipreading. Newhart advocates lipreading for those patients in whom there remains only a slight residue of hearing within the speech range.[81] Ewing and Ewing state that lipreading is regarded as essential for patients who are deaf to sound above the fequency of 1,000 cycles.[82] While slight disagreement may appear to exist among different authors as to the criterion to be used in selecting persons for lipreading training, the fact remains that lipreading is an essential rehabilitative measure to apply to the hard of hearing population.

Part II will concern itself with a review of the history of lipreading and some features of the lipreader as a person, and the lipreading process.

History of Lipreading in Europe

The actual teaching of the deaf was possibly delayed by the Greek philosopher Aristotle, who theorized that even though the deaf had voice, they were speechless. This brief

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[81]Horace Newhart, "Hearing Problems in Education," Journal of the American Medical Association, 109(1937), pp. 839-841.

[82]Irene Ewing and Alex Ewing, The Handicap of Deafness (London: Longmans, Green and Co., 1938).

statement was thought to mean that the deaf were mentally deficient or in terms of a popular statement: "deaf and dumb." Thus, "Aristotle was saddled with the responsibility of having kept the deaf in ignorance for nearly two thousand years."[83]

The Italian Cardan was able to demonstrate that the organs of speech of the deaf could be made effective, thus disproving Aristotle's claim. Ponce de Leon, A Spanish Contemporary of the Italian Cardan, is considered to be the first teacher of the deaf.[84] The registry of his monastery contains this statement:

> Slept in the Lord, Brother Pedro Ponce, benefactor of this house, who amongst other virtues, which he possessed in high degree, excelled chiefly in this, which is held in the greatest estimation by the whole world, to wit, teaching the dumb to speak.[85]

Bonet, in 1620, published what is thought to be the first book dealing with the oral method.[86] He thought that

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[83]Fred DeLand, The Story of Lip-Reading (Washington, D. C.: The Volta Bureau, 1931), p.3.

[84]DeLand, The Story of Lipreading, pp. 19-22.

[85]Introduction to Lipreading (Elmsford, New York: Sonotone Corporation, 1958), p. 18.

[86]Juan Pablo Bonet, Simplification of the Letters of the Alphabet, and Method of Teaching Deaf Mutes To Speak. Published in Madrid in 1620. Translated from the original Spanish by H. N. Dixon with Historical Introduction by A. Farrar, London, 1890. Cited by DeLand, The Story of Lip-reading, pp. 28, 39.

the deaf had a limited ability and would be largely ineffectual in life situations even with training.[87] Twenty-eight years later, Bulwer, an English physician, published a book concerning the deaf and thought that lipreading afforded the deaf an avenue for learning to speak.[88] Amman, a Swiss physician, published a book in 1692 in which he also desribes a course in teaching the deaf to speak and to lipread. He also advocated mirror practice in the teaching of lipreading and speech.[89]

Baker, an English naturalist, poet, and Fellow of the Royal Society, in 1720 became interested in teaching a deaf girl to read, write, and lipread. He became very successful in his methods but did not divulge his techniques.[90]

In France, due to the efforts of l'Epee, the teaching of the deaf was accomplished by the manual method.[91] In

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[87]Fred DeLand, "Ponce De Leon and Bonet," Volta Review, 22(1920), pp. 391-420.

[88]DeLand, The Story of Lipreading, pp. 41-46.

[89]John C. Amman, A Dissertation on Speech (London: Sampson Low, Marston, Low and Searle, 1873), p. 154. The notice and description of this English translation of Surdus Loquens by Dr. Charles Baker, Doncaster, England, appears in the American Annals of the Deaf, 19(1874), pp. 31-34.

[90]DeLand, The Story of Lipreading, pp. 68-69.

[91]Rae Luzerne, "The Abbe De l'Epee," American Annals of the Deaf, 1(1848), pp. 69-76.

Germany, however, the oral method was paramount because of the fine work of Heinicke, who believed that the deaf could become useful members of society only if they learned how to speak. It was only after the death of Heinicke that Germany turned to the manual method largely due to the influence of Heinicke's sons-in-law.[92] It took another century before the oral method was again taught in Germany. The reintroduction of the oral method was due to the efforts of F. M. Hill.[93]

> To Frederick Moritz Hill (1805-1874) may be accredited what is distinctively called the 'German System.' Historians consider him one of the greatest of all educators of the deaf. He based his philosophy of education on the concept that a deaf child must be taught to speak in the same manner as nature develops speech in a hearing child.[94]

In England, Thomas Braidwood (1715-1806) was one of the most important figures in the development of lipreading. His later years were spent exclusively with teaching the deaf.[95]

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[92]Rae Luzerne, "A Monument to Heinicke," American Annals of the Deaf, 1(1848), pp. 166-170.

[93]O'Neill and Oyer, Visual Communication, p. 13.

[94]M. Mason, Doctoral Dissertation, pp. 15-16.

[95]Rae Luzerne, "Thomas Braidwood," American Annals of the Deaf, 3 (1851), pp. 255-256.

History of Lipreading in America

The earliest publication on the education of the deaf that was written by an American, which appeared in 1785, was written by Francis Green. Green's publication was actually a duplication of Braidwood's methods. However, Green did not consult with the Braidwoods about his book and by not doing so incurred the displeasure of the Braidwoods.[96]

A grandson of Thomas Braidwood, John Braidwood, established a school for teaching the deaf in Virginia in 1815 with the help of Colonel William Bolling, who had three deaf children.[97] About this time (1817) Gallaudet went to England to learn more about the Braidwood method but was discouraged from doing so by the Braidwoods because of their fear of competition. While in England, Gallaudet heard a lecture by Abbe Sicard and was persuaded by him to go to Paris to learn the manual method. It was this turn of events that was to have an influence on the teaching of deaf persons in America.[98]

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[96] M. Mason, Doctoral Dissertation, pp. 16-17.

[97] DeLand, The Story of Lipreading, pp. 93-97.

[98] H. P. Peet, "Tribute to the Memory of the Late Thomas Gallaudet," American Annals of the Deaf, 4(1852), pp. 65-77.

While in France, Gallaudet became friends with a teacher of the deaf, Laurent Clerc, and influenced him to come to America. The two of them started a school for the deaf, now called the American School for the Deaf, that became very successful and is federally subsidized.[99] Other schools for the deaf were established following the success of the Gallaudet-Clerc teaching effort, and they too used the manual method.[100]

The oral method really did not get started again in America until 1843 when Horace Mann returned from Europe with glowing reports of this method. However, in America, lipreading was taught only in small private schools. In 1867, John Clarke, the great philanthropist, donated $50,000 to establish an oral school for the deaf in Northampton, Massachusetts.[101] Following this a school was established in Boston where Bell taught the Visible Speech Symbols that his father had originated. With the establishment of these two schools lipreading finally achieved stature in America.[102]

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[99]W. W. Turner, "Laurent Clerc," American Annals of the Deaf, 15(1870), pp. 16-28.

[100]O'Neill and Oyer, Visual Communication, p. 14.

[101]DeLand, The Story of Lipreading, p. 113.

[102]O'Neill and Oyer, Visual Communication, p. 14.

Alexander Graham Bell, in his early career with teaching the deaf, did not teach his students lipreading. It was not until he began to visit the Horace Mann School for the Deaf that he began to concentrate on teaching lipreading and to recognize its values.[103] A few years later in a speech before the Philosophical Society of Washington, D. C., concerning the advantages of lipreading, Bell said that he had

> made an examination of the visibility of all the words in our language contained in a pocket dictionary, and the result has assured me that there are glorious possibilities in the way of teaching speech reading to the deaf, if the teachers will give special attention to the subject.[104]

In 1894, the Volta Bureau was constructed in Washington, D. C., largely from a gift of $100,000 from A. G. Bell to his father for the creation and maintainance of the Bureau for increasing and diffusing knowledge concerning the deaf.[105]

A number of periodicals were published during these early years that were devoted entirely to the teaching of the

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[103]Convention of Teachers of Visible Speech, Worcester, Mass., January 24, 1874. American Annals of the Deaf, 19 (1874), p. 98.

[104]Alexander Graham Bell, "Fallacies Concerning the Deaf," An address delivered at the 239th meeting of the Philosophical Society of Washington, D. C., October 27, 1883. Printed in the American Annals of the Deaf, 29(1884), p. 32.

[105]DeLand, The Story of Lipreading, p. 124.

deaf. The American Annals of the Deaf was started in 1874 at the Harford School; and in 1899 the Association Review, later known as the Volta Review, was published by the American Association to Promote the Teaching of Speech to the Deaf.[106]

Lillie E. Warren was one of the first to recognize the needs of the hard of hearing child and to attempt the development of residual hearing. On this subject she published an article in 1892[107] and a book in 1894.[108] Warren was also one of the first teachers of adults. She believed that the sounds of English were revealed in sixteen facial configurations and that in training students to lipread they must associate certain numbers with certain sounds. Warren describes her method as follows:

> The object of my system is to teach the learner to associate the elementary or substantially elementary sounds with the special expression of the human face which invariably accompanies the utterance of such sounds. It includes a series of pictures of the human face in which separately substantially every expression is shown which the face assumes in uttering

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[106] DeLand, The Story of Lipreading, pp. 121-126.

[107] Lillie E. Warren, "Teaching Deaf Children to Hear," Medical Record, Oct. 22, 1892. Cited by DeLand, The Story of Lipreading, p. 134.

[108] Lillie E. Warren, Defective Speech and Deafness (New York: Edger Werner, 1895). Cited by DeLand, The Story of Lipreading, p. 134.

> the series of elementary sounds used in speaking the language, and it also includes with this series of pictures a series or schedule of characters, marks, or symbols, one for each picture and expression, each arbitrary character referring to its appropriate picture.[109]

Warren called her lipreading technique the "Warren Method of Expression-Reading and Numerical Cipher" which was copyrighted and patented.

Nitchie, a contemporary of Warren, studied for a time with Warren, but soon left her and opened his own school in 1903 in New York. He devoted many years to teaching adults, and is responsible for creating the New York League for the Hard of Hearing. Nitchie published a book in 1903 which Warren claimed was a plagiarism of her method. But while Nitchie's method did resemble Warren's, it was an improvement because he used a system of symbols instead of numerical ciphers for identification of each consonant position. Nitchie firmly believed in the regenerative possibilities of lipreading, and this belief permeated his writings.[110,111]

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[109] DeLand, The Story of Lipreading, p. 135.

[110] Edward B. Nitchie, "The Spiritual Side of Lipreading," Volta Review, 12(1910). Cited by Montague, Journal of Speech Disorders, 8(1943), pp. 257-268.

[111] Edward B. Nitchie, "Synthesis and Intuition in Lipreading," Volta Review, 15(1913). Cited by Montague, Journal of Speech Disorders, 8(1943), pp. 257-268.

Nitchie's last book emphasized the necessity for training the student to grasp whole meanings from the segments of speech that are seen.[112]

Another early contributor to the teaching of lipreading was Martha Bruhn, who is credited with translating the Mueller-Walle method into English. In so doing she had to work consonant by consonant, and vowel by vowel, to find equivalent English words to illustrate the lipreading principles expounded by Mueller-Walle. The teaching method is based on sound educational principles for it works from the known to the unknown, from the simple to the complex, from the easy-to-see to the practically invisible. The first lessons are almost wholly objective. The drills for eye training involve practice on meaningless syllables, which are carefully arranged and graduated, so as to accustom the pupil to recognize the visible movements of speech. As he progresses, the student is given more interesting and more meaningful material, and the psychological aspects of lipreading are emphasized; but the syllable practice and eye drill are continued throughout the course.[113]

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[112]Edward B. Nitchie, Lipreading, Principles and Practice (New York: Frederick A. Stokes Company, 1912).

[113]Martha E. Bruhn, The Mueller-Walle Method of Lipreading for the Deaf (Lynn, Mass.: The Nichols Press, 1929).

Cora Kinzie, who studied with both Bruhn and Nitchie, adapted the methods of her teachers and evolved her own method. Her sister, Rose, later joined her in further developing these teaching techniques which were a series of graded lipreading lessons for children and adults. They found that the graded lessons allowed their students to proceed at their own pace and facilitated their students' progress. In their book they present many lessons that are interesting and purposeful.[114]

Jacob Reighard translated the Jena method of Karl Brauckmann into English and with the assistance of Bessie Whitaker and Anna Bunger introduced it in America. Whitaker was given the task of trying out this method at Michigan Normal College in 1926. The Jena method advances the theory that since speech has three forms, motor, auditory, and sensation, it may be understood equally well by any of the three forms. The pupil begins from the start to recite with the teacher on the theory that when a person makes the same speech movements as a speaker, he will have the same speech sensations, will feel the words as the speaker feels them, and will understand through feeling. The system of practice

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[114]Cora Kinzie and Rose Kinzie, Lipreading for the Deafened Adult (Chicago: The John C. Winston Co., 1931).

enables the hard of hearing person to become aware of his own speech sensations and through them to understand the speech of others.[115]

Until the late twenties these lipreading schools continued to grow and spread, and many of them were prosperous.

> Then two things happened that halted this steady growth of lipreading. The depression caused the lopping off of many educational enterprises; and the great improvement in hearing aids caused many hard of hearing adults to conclude that lipreading was not so necessary as they had been lead to believe.[116]

However, there is currently a general revival in teaching the deaf and hard of hearing lipreading. Courses in lipreading are being offered to students interested in teaching the deaf in many colleges and universities. Teachers of the deaf are able to receive scholarships for their study by the Vocational Rehabilitation Administration. Last year (1962) the Vocational Rehabilitation Administration Program graduated 100 teachers of the deaf while 400 will graduate with professional degrees this year (1963).[117]

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[115]Anna M. Bunger, Speech Reading -- Jena Method.

[116]Montague, Journal of Speech Disorders, 8 (1943), p. 261.

[117]Mary E. Switzer, "Assessment: Capacity for Useful Living," Exceptional Children, 28(1962), p. 463.

Other developments in the teaching of lipreading are the film techniques of Marie Mason and Morkovin and Moore.

Mason's lipreading films are based on exercises designed to demonstrate the various movements of speech. After the student becomes familiar with the theory of lipreading, he views the films and studies them at his leisure. Each of the thirty films is composed of three parts, the first part functioning as a text and announcing the topic to be studied. Sentences are printed on cards so that the student can read these before he is asked to lipread the filmed speaker. The second part of the film presents the remainder of the lesson and the third part presents questions concerning the material covered by the lesson.[118]

Morkovin and Moore's films dramatize "life situations," which they believe make lipreading less of a task and easier to learn. Lipreading, they believe, is most successful when it is taught on the basis of life problems and the necessity for solving them.[119] "In learning speech reading from motion pictures, the plan should be to proceed from the obvious phrases and words, which are easily suggested by the action

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[118] O'Neill and Oyer, Visual Communication, p. 101.

[119] B. V. Morkovin, Through the Barriers of Deafness and Isolation. Oral Communication of the Hearing Impaired Child in Life Situation (New York: Macmillan, 1960), p. 178.

of the film to the more difficult and abstract words."[120] Their method is called the "audio-visual kinaesthetic" method because it utilizes the student's hearing throughout the lessons. There is no attempt on the part of the teacher to mask out her voice when giving lessons. The student is encouraged to make use of whatever hearing he has remaining.[121]

As a summary to this review of the history of lipreading, Montague made a poignant statement in 1943. What she wrote then is applicable today:

> At present, the whole business of imparting lipreading is . . . at a crossroads. The older methods are forty years old; the newer methods are not very radical departures, but are more or less a composite of the old. Can anything new be learned?[122]

Lipreading Training

Training in lipreading is necessary if the person ever hopes to become a proficient lipreader. Kropp believes that aurally handicapped children should be taught lipreading

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[120]Boris V. Morkovin, "Rehabilitation of the Aurally Handiccaped Through the Study of Speech Reading in Life Situations," Journal of Speech Disorders, 12(1947), pp. 363-368.

[121]Lucelia M. Moore, "Life Situation Motion Pictures for Teaching," Volta Review, 44(1942), p. 705.

[122]Montague, Journal of Speech Disorders, 8(1943), p. 267.

early in their life[123] with most children needing a great deal of training in this skill. During their school careers is the most opportune time for this training.[124] Magner thinks that the ideal time to begin lipreading is before the age of two, and hence is home-centered. The longer a child must wait to acquire the skill of lipreading after deafness has been diagnosed, the more difficult it is for him to become proficient in the art.[125]

The training period for lipreading instruction will vary due to individual differences, but Goldstein suggests that for children lipreading instruction requires a period of from one to two years.[126] Mitchell recommends a minimum of two weekly lessons of one hour's duration for maximum benefit from lipreading instruction for children.[127] In

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[123]E. Kropp, "Thoughts about the Hard of Hearing Child and His Education," Neue Blätter für Taubstummenbildung, 15 (1961), pp. 317-325. Cited in dsh Abstracts, 2(1962), p. 213.

[124]K. Jones, "Communication Scales," Volta Review, 63(1961), pp. 72-77, 94.

[125]M. E. Magner, "Parents Can Help Deaf Children Acquire Ability in Speech-Reading," American Annals of the Deaf, 105(1960), pp. 431-433.

[126]Max A. Goldstein, "The Education of the Deaf and Hard-of-Hearing Child," American Journal of Surgery, 42(1938), pp. 151-155.

[127]J. R. Mitchell, "The Education of Deaf Children," Public Health, 52(1939), pp. 271-273.

working with adults, Hughson and Westlake recommend at least one year's study in order to attain any real degree of proficiency. They also mention that even with two years' study the student might still be in need of further instruction.[128]

The effect of lipreading training is dramatically shown in a study by Hofsommer. Seventeen hard of hearing children were given lipreading training for one to three years. In studying these children it was found that 47 percent of the group showed an increase in I.Q., 41 percent showed no change, and 11 percent showed a decrease. In 75 percent of the group a definite improvement in classroom achievement was noted. Among 16 hard of hearing children who refused instruction in lipreading none showed an increase in I.Q. during the same period, but 75 percent showed a decrease. Only 18.7 percent made classroom improvement and all individuals in this group were personality problems.[129]

Teaching lipreading by television has also been studied. Oyer, after training his subjects for ten weeks,

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[128]Walter Hughson and Harold D. Westlake, "Manual for Program Outline for Rehabilitation of Aural Casualties, Both Military and Civilian," Transactions of the American Academy of Ophthalmology, (Supp), 48(1944), pp. 1-15.

[129]A. J. Hofsommer, "Lipreading and the Intelligence Quotient of the Hard of Hearing Child," Journal of the American Medical Association, 107(1936), pp. 648-650.

found that his subjects did improve their lipreading performance. It was also noted that throughout the television training sessions the interest level of the subjects appeared to be high.[130]

Factors Contributing to Lipreading Ability

What makes a good lipreader? If this question could be answered with well defined conclusions, the teaching of lipreading might not be so arduous. A number of conclusions concerning those factors that contribute to a person's lipreading ability have been discovered.

Residual hearing is one factor that contributes to a person's lipreading ability. Results of an investigation by Evans showed that 45 out of 50 deaf children had higher scores when combining listening and lipreading than when lipreading alone.[131] This finding is supported by Heider, who found that the more hearing a child has and the more this hearing has been trained, the better his lipreading ability will be.[132]

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[130] H. J. Oyer, "Teaching Lipreading by Television," Volta Review, 63(1961), pp. 131-132, 141

[131] L. Evans, "Factors Related to Listening and Lipreading," Teacher of the Deaf, 58(1960), pp. 417-423.

[132] Fritz Heider, "Acoustic Training Helps Lipreading," Volta Review, 45(1943), p. 135.

O'Neill and Davidson studied relationships between lipreading ability and five psychological factors. They found no statistically significant relationship between lipreading ability and level of aspiration, intelligence, reading comprehension, and digit memory span. However, they did find a statistically significant relationship between lipreading ability and non-verbal concept formation.[133]

Intellectual level and analytical ability are thought to be of secondary importance by Walter. But he does believe that an individual's vocabulary and the extent of his general knowledge appear to be important for gaining proficiency as a lipreader.[134] According to Connally, the development of a visual memory span is important for those persons who want to increase their lipreading ability.[135]

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[133]John J. O'Neill and John L. Davidson, "Relationship Between Lipreading Ability and Five Psychological Factors," Journal of Speech and Hearing Disorders, 21(1956), pp. 478-481.

[134]M. M. Walter, "Vocational Rehabilitation for the Deaf and Hard of Hearing," Transactions of the American Academy of Ophthalmology and Otolaryngology, 49(1944), pp. 103-111.

[135]E. E. Connally, "Implications of Research for the Classroom Teacher," American Annals of the Deaf, 106 (1961), pp. 397-404.

Another factor that can affect a person's lipreading ability is his age. Farrimond found that a person's lipreading ability improves from the second to the third decade of life with a decline in ability thereafter.[136]

In the research department of the Clarke School for the Deaf it was learned that good lipreaders are apparently more responsive to color than to form, whereas poor lipreaders are more responsive to form.[137]

A person's lipreading proficiency is dependent, to a degree, upon the visibility of the components of the spoken language. It would appear to be a logical assumption that the more visible the language the easier that language would be to lipread. Woodward and Barber tested perceptual differences among English initial consonants. Stimulus materials consisted of pairs of phonemically identical and minimally different nonsense syllables. These nonsense syllables provided a consistent, nonredundant linguistic environment

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[136]T. Farrimond, "Age Differences in the Ability To Use Visual Cues in Auditory Communication," Language and Speech, 2(1959), pp. 179-192.

[137]Clarke School for the Deaf, Northampton, Mass. Reports of the Clarence W. Barron Research Department included in the School Reports for 1933-1934 and 1935-1936. Sections on lipreading.

for the phoneme tested. Results indicate that only four visually-contrastive units are available consistently to the lipreader. They are the bilabial, rounder-labial, labial-dental, and nonlabial.[138]

Kinzie and Kinzie state that more than 50 percent of all speech elements are either invisible or indistinguishable (homophonous).[139] One would assume that the distance between the lipreader and the communicator would improve the visibility of the language. However, Neely found that the distance from three to nine feet was not a significant factor in a person's ability to lipread.[140]

The person communicating the language is also an important variable that can affect a person's lipreading ability. Lott attempted to isolate the role of the communicator. The hypothesis is that the communication skill is more efficient when the interpreter (lipreader) has positive rather

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[138]M. F. Woodward, and C. G. Barber, "Phoneme Perception in Lipreading," Journal of Speech and Hearing Research, 3(1960), pp. 212-222.

[139]Kinzie and Kinzie, Lipreading for the Deafened Adult.

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

than negative feelings about the communicator. Partial support for the hypothesis came from the results of one experiment in which it was found that "most preferred" group members were lipread significantly better than those "least preferred." A second experiment suggests an additional communicator variable important for the prediction of lipreading efficiency. Two communicators who had role-played "agressive" and "moderate" discussion leaders were later lipread most efficiently by subjects who had seen them in that role which was the most natural one for them to play, i.e., the one most like their own typical behavior.[141]

The expressions that the communicator displays on his face while speaking can also affect a person's lipreading ability. Hartman completed a study of the lipreading performance of 87 deaf students who watched two speakers that were filmed under different conditions. Speaker I, who overemphasized his facial expressions, was lipread correctly more often than Speaker II, who concentrated his expressions around the mouth and lower jaw. When the mouth was blacked out, the students correctly lipread 66 percent of the sentences

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[141]Bernice Eisman Lott and Joel Levy, "The Influence of Certain Communicator Characteristics on Lipreading Efficiency," Journal of Social Psychology, 51(1960), pp. 419-425.

spoken by Speaker I and 44 percent by Speaker II. Hartman stresses the importance of facial expressions in conveying both the emotion and sense of a message.[142] Gilliat has found from experience that an expressionless face, immobile lips, and grimaces inhibit a person's lipreading ability.[143] Lastly, Lowell found that an unsmiling face is easier to lipread than a smiling face.[144]

Psychological Aspects Related to Lipreading

Certain psychological factors have to be considered in recommending lipreading training to the deaf or hard-of-hearing person. A reluctance on the part of the patient to admit his hearing loss sometimes can induce an inhibition against the study of lipreading, strong enough to require the

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[142] N. Hartman, Quoted by W. J. Bechinger, "Convention To Further Informing and Educating Teachers of Schools for the Deaf, the Hard of Hearing, and Speech Defectives in Baden-Wurttemberg, Heidelberg, January 9 and 10, 1961," Neue Blätter für Taubstummenbildung, 15(1961), pp. 168-184. Cited in dsh Abstracts 2, No. 3. (1962), pp. 209-210.

[143] M. E. Gilliat, "If I Were Teaching Children Again," Teacher of the Deaf, 59(1961), pp. 55-59.

[144] E. L. Lowell, "New Insight into Lipreading," Rehabilitation Record, 2(1961), pp. 3-5.

assistance of a medical-social worker.[145] It is for this reason that sometimes there is a need for psychological and frequently even psychiatric preparation of the patient before beginning the formal study of lipreading.[146]

Once the person has undertaken training in lipreading, lipreading will often lessen the burden of deafness and will stimulate compensatory factors within the personality [147] and will also remove a false sense of shame and center the attention of the student on achievement.[148] Goldstein writes:

> To the partial or incurably deaf the acquisition of lipreading is a manifold blessing; it releases him from the constant handicap of his aural infirmity; it relieves the constant nervous strain and embarassment of isolation from the rest of his fellows; it restores his social status and his means of communication with his fellow men. To the otologist it offers a consolation for his inability and impotency to cope with certain forms of aural pathology and it places him in a

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[145] Dorothy Sutherland and Maxine Miller, "Rehabilitating the Hard of Hearing Child," The Child, 9(1944), pp. 51-56.

[146] W. E. Grove, "The Role of the Otologist in a Hearing Conservation Program," Annals of Otology, Rhinology and Laryngology, 54(1945), pp. 458-465.

[147] A. B. Stokes, "The Psychological Aspect of Deafness," Journal of Laryngology and Otology, 56(1941), pp. 106-110.

[148] Walter, Transactions of the American Academy of Ophthalmology and Otolaryngology, 49(1944), pp. 103-111.

> position to restore the peace of mind and to instill new hope in his deaf patient.[149]

Lipreading is not a cure-all, nor can it be of benefit to everyone who undertakes training in it. Hughson and Westlake present an interesting observation that hearing aids will fail to produce a beneficial effect in exactly the same group of patients (extreme nervousness, unwillingness to undergo a learning period, and undue consciousness of their disability) in which lipreading instruction faces its greatest obstacles.[150]

Discussion

In the review of the cutaneous literature it was mentioned that the thumb as well as the other fingers were most sensitive to vibratory stimulation. Supposedly, it was for this reason that the fingers were most often utilized in vibratory cutaneous communications experiments. The vibratory signal supplied to the integument of the fingers was generally filtered, with a portion of the signal going to each finger. In the few studies where lipreading was

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[149]Max A. Goldstein, Problems of the Deaf (St. Louis: The Laryngoscope Press, 1933), p. 296.

[150]Hughson and Westlake, Transactions of the American Academy of Ophthalmology and Otolaryngology (Supp.), 48 (1944), pp. 1-15.

combined with the cutaneous stimulation speech was, by necessity, the vibratory cutaneous stimulant.

In the studies cited in the cutaneous review of the literature, two factors became apparent: (1) the cutaneous speech signal was supplied to the fingers, and (2) the speech signal was filtered in the process of transmitting it to the integument.

Both of these points were rejected in this study. The fingers were not utilized in this study for purposes of practicality. If cutaneous stimulation by speech does enhance a person's lipreading performance and the apparatus can be made functional, the speech vibrator should not interfere with the manipulative function of the hands and fingers. It was for this reason that some other portion of the integument was chosen, namely the arm, for the placement of the vibrators.

Filtering of the speech signal, except above 4800 cps in order to filter out the extraneous high frequency noise produced by the lipreading movie and the amplifiers, was also thought unnecessary and cumbersome. Basically then, the speech signal was unaltered. This would ultimately simplify the design of the Cutaneous Speech Transmission System.

The teaching of a cutaneous vibratory linguistic code for the transmission of messages is a very difficult and time consuming task, as is the teaching of lipreading. Teaching a person to become a proficient lipreader has given rise to a number of methodologies that have demonstrated beneficial results. But the need still remains for further increasing the lipreader's performance. It was this need that prompted some investigaters to turn their attention to some other receptive channel, viz. the cutaneous modality. It is the combination of the two sensations, vision and cutaneous perception, that might become the most proficient means for the comprehension of a verbal message by a severely aurally handicapped person.

CHAPTER III

SUBJECTS, EQUIPMENT, AND PROCEDURES

Subjects

The experimental population consisted of sixteen subjects. The subjects were undergraduate and graduate students at Michigan State University and all subjects had normal hearing. Two criteria were employed in the selection of subjects. The first was that they have normal or corrected 20/20 vision, and the second was that they had no formal training in either lipreading or perception of cutaneous stimulation by speech.

Both male and female subjects participated. Of the sixteen subjects twelve were female.

Equipment

Motion Picture Camera: An Aurican 16 mm sound movie camera was used for filming. This camera was equipped with a 50 mm f 1.9 lens. The camera lens was focused at 9 3/4 feet and set at f 3.5 - 4.0.

Film: The film used was a black and white, single-system, plus X, reversal type with A.S.A. 64. The light source that was shown on the speaker was of 250 foot-candle power.

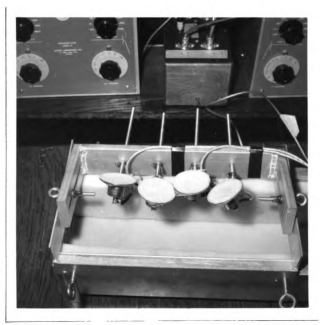
Amplifier: A Newcomb 30 watt amplifier, Model KX-30, amplified the output signal of both the projector and the tape recorder before this signal was sent through the filters and to the vibrators. This additional amplifier was needed because of a significant output loss produced by the passive network filters.

Filters: Four Allison, Model 25, filters were employed in this study. These are audiometric filters having a low cutoff, high cutoff, and band pass functions. The design is a completely passive network with a two-section, constant K circuit in each function. The filters were used only as low pass instruments. The high cutoff selector was set at 4800 on all of the filters while the low cutoff selector was in the "off" position. The operation of these filters, then, was merely to filter out extraneous sound above 4800 cps.

Vibratory Apparatus: The choice of a vibrator to use in this study was a different task. After experimentation with a number of different conventional audiometric bone conduction oscillators, with little success, an unconventional method was tried. This method was the use of miniature loud-speakers of the type usually found in transistor radios. Initially the loud-speakers were used without modification,

but it was subsequently determined that the loud-speaker cone was making little contact with the arm. Only the metal rim of the loud-speaker made the contact. It was then decided to glue a Pellon fabric membrane over the face of the loud-speakers. Figure 1 shows this arrangement.

Figure 1. Photograph of Loud-speakers with Pellon Fabric Membrane Glued Over the Face of the Loud-speakers.



The Pellon membrane served the purpose of making direct contact with the arm. Secondarily, this membrane gave a bonus factor to the experiment because when the loud-speaker was activated, the resulting air vibrations acting on this membrane were localized near the center of the

membrane in an elliptical pattern. This localization and concentration of the vibrations had a decided influence on the sensations ultimately produced on the arm.

The four loud-speakers chosen to become vibrators were Sanyo brand with an input of 0.2 watts and were eight ohm. The frequency response of these loud-speakers is shown in Figure 2. The diameter of the loud-speakers was two inches. There was a quarter of an inch space between loud-speakers with a total over-all distance of eight and three-quarter inches from one end of the speaker system to the opposite end. Each of the loud-speakers was suspended from a metal rod. The suspension system was a loosely fitting tongue and groove arrangement which allowed the speaker to move so as to fit the contour of the arm. These loud-speakers were then placed in a metal container with an overhead bar to hold the loud-speaker-rods. Figure 3 clearly shows this arrangement. The inside of the metal container was lined with sponge rubber. The sponge rubber served two functions: (1) it made the arm feel comfortable, and (2) it held the arm snugly in place.

The suspension rods could freely move up and down through their holes in the overhead bar. The only pressure exerted on the dorsal part of the forearm was the dead

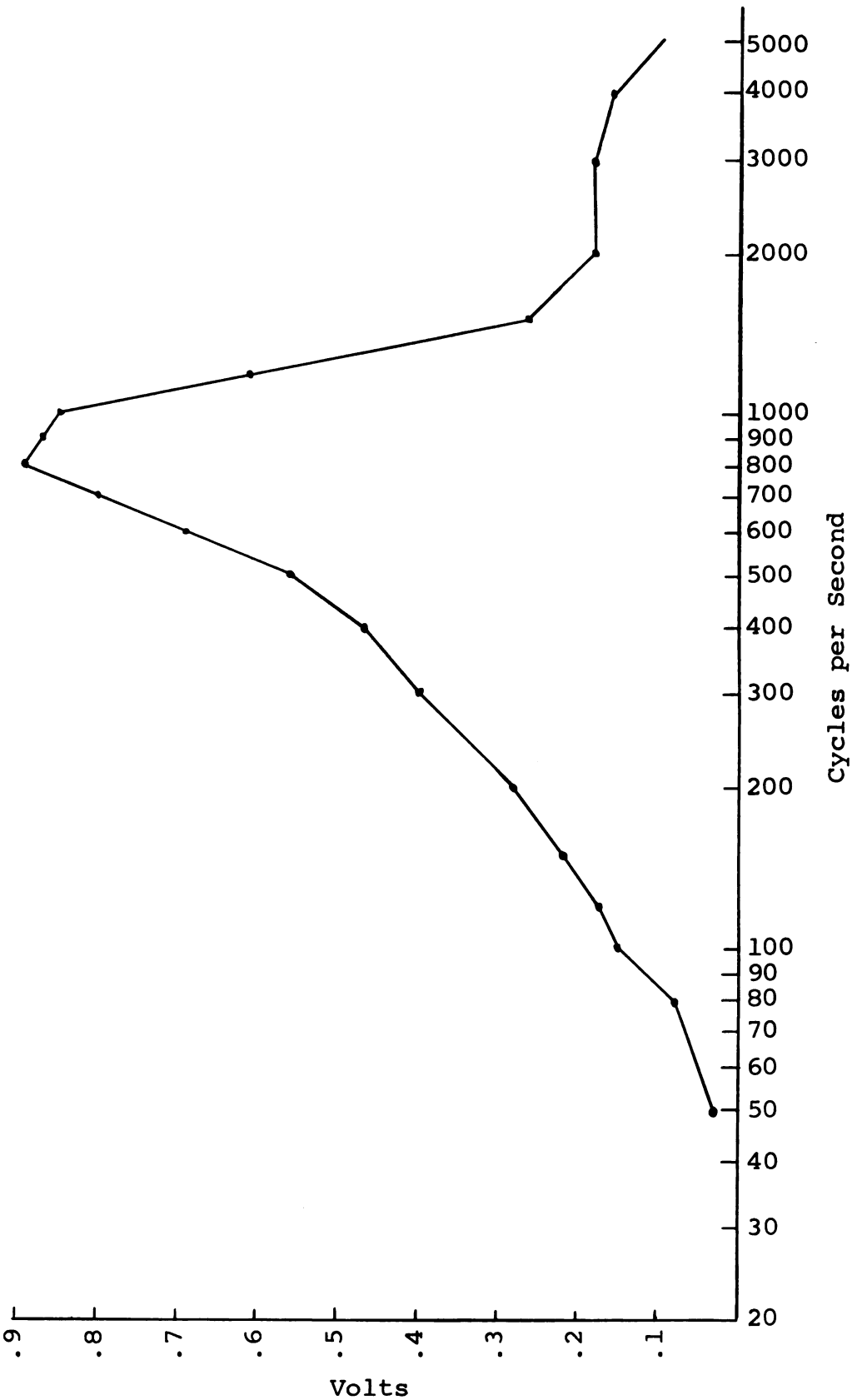
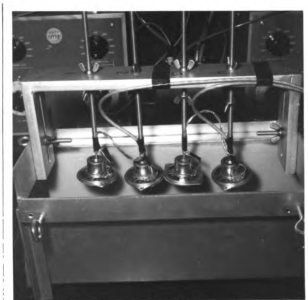


Figure 2. Frequency Characteristics of the Loud-speakers.

Figure 3. Photograph of Loud-speaker Suspension System with the Location of the Loud-speakers in the Metal Container.

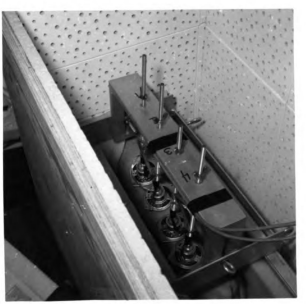


weight of the loud-speaker plus the rod and its connections. This dead weight was measured to be 107 grams.

An acoustically lined box was constructed for this apparatus. This was necessary because of the excessive amount of sound generated by the loud-speakers when in operation. Figure 4 is a top view of the open box with the apparatus inside. Figure 5 is a top-side view showing an arm inside the box with the loud-speaker-vibrators in place. The box was constructed of one-quarter inch plywood and lined with Armstrong, random-hole design, acoustical tile.

Figure 4. Photograph of a Top View of the Acoustically Lined Box with a View Inside Showing the Vibratory Apparatus.

Figure 5. Photograph of a Top-side View of the Acoustically Lined Box with a View Inside Showing the Placement of the Loud-speaker Vibrators on a Subject's Arm.



Underneath the apparatus is a piece of two-inch thick wool insulation. A five and one-quarter inch diameter hole was sawed in one end of the box in order to accommodate the arm. One piece of one inch thick sponge rubber was placed on the outside of the box with a horizontal slit cut in it. Another piece of the same thickness was placed inside the box with a vertical slit cut in it. These two pieces of sponge rubber closely snugged the arm and were an effective acoustical seal for the hole. Figure 6 shows a subject, during a training session, with his arm positioned through the outside sponge rubber seal and into the box.

Figure 6. Photograph of a Subject During Training with His Arm Placed Through the Sponge Rubber Seal of the Acoustically Lined Box.

The acoustically lined box provided quite an attenuation level of the sound coming from the vibrators. The sound pressure level produced by a vibrator, with the microphone of the Soundscope one inch distant, was 113 db (in relation to .0002 dynes/cm^2). The microphone was now removed from the box and placed one-half inch away from the outside sponge rubber seal at its slit. With the microphone in this position the sound pressure level was 88 db. An arm of a subject was now placed in the box. The vibrators were lowered to the arm, and the sound pressure level was again measured. This level was found to be 80 db. With the subject's arm still in position, the sound pressure level was measured at ear level. This reading at the subject's ear was measured to be 62 db.

Figure 7 shows the complete set-up for the experiment except for the acoustically lined box, which was omitted by necessity so that the other pieces of equipment can be seen. As noted below, the separate items are: (1) Sound projector, (2) Tape recorders, (3) Earphones, (4) Amplifier, (5) Filters, and (6) Vibratory apparatus.

Figure 7. Photograph of the Entire Cutaneous Speech Transmission System. (1) Sound Projector, (2) Tape Recorders, (3) Earphones, (4) Amplifier, (5) Filters, (6) Vibratory Apparatus.

Procedures

Filming Procedure: A male speaker was employed in the filming. This person has had experience in teaching lipreading and was so chosen because he would be less prone to exaggerate his mouth movements. The filmed subject has also had radio and televiaion experience. He was therefore an ideal person to use for filming. The filmed subject was given a list of fifty words, twenty-five PB words and twenty-five Spondaic words. He was asked to speak these in as natural a voice as possible. Three seconds were allowed for

filming the word with a 10 second gray-out between words to allow time for the experimental subjects to write down their responses. The filmed person was filmed with a close-mouth position preceding and following the actual word. The picture ultimately taken of the speaker was a top shoulder-full head view. The total film time was almost eleven minutes.

General Testing and Training Procedures: All of the subjects were tested and trained individually throughout the experiment. Each subject had an individually assigned appointment time for a total of fourteen, one-half hour, sessions. Four of the sessions were used to present the experimental conditions; two sessions in the pre-test and two sessions in the post-test situations. The other ten sessions were used for training purposes. Throughout the fourteen periods the subjects received a masking noise in their ears via the earphones. In other words, the masking noise was a constant condition throughout the experiment.

Pre-test: In the pre-test periods both Condition I (lipreading only) and Condition II (combined cutaneous stimulation by speech and lipreading) were presented to the subjects. Condition I preceded Condition II fifty percent of the time in order to control for any order of presentation variable.

In the testing of Condition I the silent motion picture film was shown to the subjects. The subjects were instructed to write down their responses to the filmed words. More specifically the directions for Condition I were:

> You will be shown a movie of a speaker who is saying fifty words. Your task will be to lipread this speaker and write down the word you think he is speaking. The words are not numbered on the film so if you do not know a word be sure to draw a line after that number on your answer sheet. This way you will be sure to follow the words in their correct order. You will also be wearing earphones through which a masking noise will be presented. You will receive this masking noise throughout the experiment so you will not be able to hear any other sound. Remember, write down the words you think the speaker is saying and draw a line after the corresponding number on your answer sheet when you do not think you know the word.

The experimenter kept a close watch on the subjects to make sure they did not lose track of any words.

For Condition II the sound motion picture film was shown to the subjects. Instead of the subjects' hearing the sound portion aurally, the sound was transmitted to the vibrators and then to the dorsal portion of the forearm. The sound motion picture film word list was the same as for the silent film but in randomized order.

Specific instructions given to subjects for Condition II were:

> You will be shown a sound movie of the speaker who is saying fifty words. Your task will be two-fold: First,

to lipread the words and second to make whatever use you can of the vibrations you will be feeling on your arm in order to write down the words you think the speaker is saying. The vibrations you will be perceiving on your arm will be the sound portion of the movie. In other words, instead of your hearing the words aurally you will be feeling their vibrations. The words are not numbered on the film so if you do not know a word be sure to draw a line after that number on your answer sheet. This way you will be sure to follow the words in their correct order. You will also be wearing earphones through which a masking noise will be presented. You will receive this masking noise throughout the experiment so you will not be able to hear any other sound. Remember, write down the words you think the speaker is saying and draw a line after the corresponding number on your answer sheet when you do not think you know the word.

Training: After a subject was tested in the pre-test situation he began the training sessions. Ten tape recordings were made by the person who appeared on the movie films. One hundred and fifty words, including the fifty test words, were tape recorded. Half of the one hundred and fifty words were PB's and the other half Spondee words. On the ten different tape recordings the words were always presented in a different randomized order. For a copy of these training taped word lists see Appendix C.

The tape recordings did vary according to the prescribed training task. On tapes one and two, each word was presented twice with a five second interval between the pair of words.

On tapes three, five, six, seven, nine, and ten, each word was presented once with a five second interval between words. On these eight tapes the subject felt the vibrations of the words on his arm while he followed the words on a typed sheet of paper alongside the acoustically lined box that enclosed the vibratory apparatus. No instructions were given the subjects as to the method he should use in these training exercises. Because there is no one best training procedure, it was believed that each subject should develop his own particular method of training himself.

Training tapes four and eight were different. In these two tapes words were paired either with each other or with another different word. Thus, when the words were presented in pairs, the words were either the same words or different words. The subjects were instructed to determine whether the vibrations they felt on their arm represented two words that were the same or different. Only through the use of these two tapes did the training sessions vary. After completion of the ten training sessions the subjects were classified as trained.

Post-test: After a subject had completed the pre-test and the ten training sessions, he was again tested on

the experimental Conditions I and II. The same directions that were given to the subjects in the pre-test were repeated in the post-test. The only change made between the pre-test and post-test was in the presentation of Condition I and II. If a subject was presented Condition I first in the pre-test, he was presented Condition II first in the post-test.

After completion of the pre-test, the training sessions, and the post-test, the subject was dismissed. This comprised the total experiment.

CHAPTER IV

ANALYSIS AND DISCUSSION

Analysis

The data collected consisted of the number of words lipread correctly by each subject in each experimental condition in both the pre-testing and post-testing. Therefore, there were four scores for each subject: (1) Pre-test Condition I (lipreading only, before training in cutaneous stimulation by speech), (2) Pre-test Condition II (lipreading combined with cutaneous stimulation by speech, before training in cutaneous stimulation by speech), (3) Post-test Condition I (lipreading only, after training in cutaneous stimulation by speech), and (4) Post-test Condition II (lipreading combined with cutaneous stimulation by speech, after training in cutaneous stimulation by speech).

Since it appeared appropriate to utilize analysis of variance in the treatment of the data, a test was made to determine whether there was homogeneity of variance among the scores. A technique described by Walker and Lev[1]: $F_{max} = \frac{s^2max}{s^2min}$ was employed. In the foregoing formula F_{max}

[1]Helen Walker and Joseph Lev, Statistical Inference (New York: Henry Holt & Co., 1953), pp. 191-192.

equals the ratio between the highest mean variance (standard deviation squared), which in this instance is the variance of the pre-test Condition I (lipreading only), divided by the lowest mean variance, which is the variance of post-test Condition II (lipreading combined with cutaneous stimulation by speech). The following values were obtained: $F_{max} = \frac{69.39}{49.00} = 1.42$. The critical region is $P [F_{max} > 5.5] = \alpha .01$ with 15 df and K (number of mean squares) = 4.[2] The observed value $F_{max} = 1.42$ does not fall in the critical region of $F > 5.5$ and so the null hypothesis: There is no significant difference among the before training, lipreading only variance, the before training, lipreading combined with cutaneous stimulation by speech variance, the after training, lipreading only variance, and the after training, lipreading combined with cutaneous stimulation by speech variance, is not rejected. Therefore, it can be assumed that the parametric assumption of homogeneity of variance is met with the data derived from this study.

A treatments by subjects design, as described by Lindquist,[3] was employed. This design is utilized where all

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[2]Walker and Lev, Statistical Inference, Table VII, pp. 462-463.

[3]E. F. Lindquist, Design and Analysis of Experiments in Psychology and Education (Boston: Houghton Mifflin Co., 1953), pp. 156-166.

of the treatments (experimental conditions) are administered to the same subjects. This design also eliminates inter-subject differences as a source of error. Table 1 is the summary table for the treatments by subjects analysis of variance design.

Table 1. Summary Table for the Treatment by Subjects Analysis of Variance.

Source	df	ss	ms	F-ratio
Treatments	3	535.9	178.6	30.8
Subjects	15	3333.5	222.2	38.3
TXS	45	260.6	5.78	
Total	63	4130.0		

The critical region is: $F > 4.26$ which is required for significance at α .01 level of confidence (df = 3.45)[4] for the "treatments" source of variance. Therefore the following null hypothesis is rejected: There is no significant difference between the subject's performance scores obtained under the following experimental conditions: (1) lipreading only, before training in cutaneous stimulation by speech, (2) lipreading combined with cutaneous stimulation by speech,

[4]Walker and Lev, Statistical Inference, Table X, pp. 468-469.

(3) lipreading only, after training in cutaneous stimulation by speech, and (4) lipreading combined with cutaneous stimulation by speech, after training in cutaneous stimulation by speech.

It can be observed further that the inter-subject variance is significantly greater ($F > 2.52$, α .01, df = 15,45)[5] than the treatment by subject interaction. In addition it was helpful to know between which experimental conditions differences occurred.

To determine the extent of the differences a method described by Lindquist:[6] $d = t\sqrt{\frac{2msw}{n}}$ was employed. It is referred to as a critical differences between means. The results were: $d = 2.58\sqrt{\frac{2(5.78)}{16}} = 2.193$. Therefore, the value of d that is needed for significance (α .01, 2 tail) is: $d > 2.193$. Table 2 presents the outcome of the test for critical differences between means.

The data from Table 2 indicate that the following null hypothesis is not rejected: There is no significant difference between the subject's performance scores obtained

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[5]Walker and Lev, Statistical Inference, Table X, pp. 468-469.

[6]Lindquist, Design and Analysis of Experiments, pp. 93-94.

Table 2. Summary Table for the Critical Difference Between Means Analysis. PrI = Pre-test Condition I; PrII = Pre-test Condition II; PoI = Post-test Condition I; PoII = Post-test Condition II.

Means:

PrI = 17.875
PrII = 19.188
PoI = 21.438
PoII = 25.5

	PrII	PoI	PoII
PrI	1.313	3.563*	7.625*
PrII		2.250*	6.312*
PoI			4.062*

*Indicates significant differences.

under the following experimental conditions: (1) lipreading only, before training in cutaneous stimulation by speech (PrI), and (2) lipreading combined with cutaneous stimulation by speech, before training in cutaneous stimulation by speech (PrII).

Also from the data presented in Table 2 the following five null hypotheses were rejected: 1. There is no significant difference between the subject's performance scores obtained under the following experimental conditions: (1) lipreading only after training in cutaneous stimulation by speech (PoI), and (2) lipreading combined with cutaneous stimulation by speech after training in cutaneous stimulation by speech (PoII).

2. There is no significant difference between the subject's performance scores obtained under the following experimental

conditions: (1) lipreading only before training in cutaneous stimulation by speech (PrI), and (2) lipreading only after training in cutaneous stimulation by speech (PoI).

3. There is no significant difference between the subject's performance scores obtained under the following experimental conditions: (1) lipreading only before training in cutaneous stimulation by speech (PrI), and (2) lipreading combined with cutaneous stimulation by speech after training in cutaneous stimulation by speech (PoI).

4. There is no significant difference between the subject's performance scores obtained under the following experimental conditions: (1) lipreading combined with cutaneous stimulation by speech before training in cutaneous stimulation by speech (PrII), and (2) lipreading only after training in cutaneous stimulation by speech (PoI).

5. There is no significant difference between the subject's performance scores obtained under the following experimental conditions: (1) lipreading combined with cutaneous stimulation by speech before training in cutaneous stimulation by speech (PrII), and (2) lipreading combined with cutaneous stimulation by speech after training in cutaneous stimulation by speech (PoII).

In order to test the importance of the roles that the PB and Spondaic words played in this study, two further statistical tests were done. The PB and Spondaic words were statistically analyzed separately by employing the treatments by subjects analysis of variance design with the critical differences between means. This separate analysis was necessary to determine whether the PB words or the Spondaic words were responsible for the variance noted in the major portion of the experiment.

Table 3 presents the summary table for the treatments by subjects analysis of variance for the PB words. The

Table 3. Summary Table for the Treatments by Subjects Analysis of Variance for PB Words.

Source	df	ss	ms	F-ratio
Treatments	3	95.31	31.77	8.47
Subjects	15	452.94	30.20	8.05
TXS	45	168.69	3.75	
Total	63	716.94		

critical region is: $F > 4.26$ which is required for significance at α .01 level of confidence (df = 3, 45) for the "treatment" source of variance. The critical region for the "subjects" is: $F > 2.52$ which is required for significance

at α .01 level of confidence (df = 15, 45).[7, 8]

This significant source of variation produced by the PB words was then statistically analyzed by the critical differences between means test.[9] The d that is required for significance, with α .01 and a two tailed test is: d = 1.765. Table 4 is the summary table for this analysis. The data

Table 4. Summary Table for the Critical Differences Between Means Analysis for PB Words. PrI = Pre-test Condition I; PrII = Pre-test Condition II; PoI = Post-test Condition I; PoII = Post-test Condition II.

Means		PrII	PoI	PoII
PrI = 6.063	PrI	.187	1.375	3.062*
PrII = 6.250	PrII		1.188	2.875*
PoI = 7.438	PoI			1.687
PoII = 9.125				

*Indicates significant differences.

from Table 4 indicate that in only two situations did the PB words produce significant differences between means: (1) Lipreading only, before training in cutaneous stimulation

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[7]Walker and Lev, Statistical Inference, Table X, pp. 468-469.

[8]Lindquist, Design and Analysis of Experiments, pp. 156-166.

[9]Lindquist, Design and Analysis of Experiments, pp. 93-94.

by speech (PrI) and lipreading combined with cutaneous stimulation by speech after training in cutaneous stimulation by speech (PoII), and (2) Lipreading combined with cutaneous stimulation by speech before training in cutaneous stimulation by speech (PrII), and lipreading combined with cutaneous stimulation by speech after training in cutaneous stimulation by speech (PoII). From observation of Table 4 it can readily be observed that PB words did not significantly differ from the lipreading only, after training in cutaneous stimulation by speech (PoI) condition to the lipreading combined with cutaneous stimulation by speech after training in cutaneous stimulation by speech (PoII) condition. This finding tends to diminish the role that the PB words had in the rejection of the most important null hypothesis, viz: There is no significant difference between the subject's performance scores obtained under the following experimental conditions: (1) lipreading only, after training in cutaneous stimulation by speech (PoI), and (2) lipreading combined with cutaneous stimulation by speech after training in cutaneous stimulation by speech (PoII). The rejection of this hypothesis can probably be attributed to the Spondaic words.

To test the assumption that the Spondaic words were largely to account for the significant variation between the post-test Condition I (lipreading only, after training in cutaneous stimulation by speech) and post-test Condition II (lipreading combined with cutaneous stimulation by speech after training in cutaneous stimulation by speech) another treatments by subjects analysis of variance was performed employing the scores obtained on these words. Table 5 is a summary table for this analysis. The critical region for

Table 5. Summary Table for the Treatments by Subjects Analysis of Variance for Spondaic Words.

Source	df	ss	ms	F-ratio
Treatments	3	181.81	60.6	15.578
Subjects	15	1579.94	105.33	27.077
TXS	45	175.19	3.89	
Total	63	1936.94		

significance of the "treatments" source of variance is: $F > 4.26$ at α .01 level of confidence (df = 3, 45). The critical region for significance of the "subjects" source of variance is: $F > 2.52$ at α .01 level of confidence

(df = 15, 45).[10,11] This significant source of variation was further analyzed by the critical differences between means test.[12]

Table 6 is the summary table for the critical differences between means. The d that is required for signif-

Table 6. Summary Table for the Critical Differences Between Means Analysis for Spondaic Words. PrI = Pre-test Condition I; PrII = Pre-test Condition II; PoI = Post-test Condition I; PoII = Post-test Condition II.

Means		PrII	PoI	PoII
PrI = 11.813	PrI	1.125	2.187*	4.562*
PrII = 12.938	PrII		1.062	3.437*
PoI = 14.0	PoI			2.375*
PoII = 16.375				

*Indicates significant differences.

icance, with α .01 and a two tailed test is: d = 1.798. These data indicate that the Spondaic words produced significant results in all but two situations: (1) Pre-test Condition I (lipreading only, before training in cutaneous

[10] Walker and Lev, Statistical Inference, Table X, pp. 468-469.

[11] Lindquist, Design and Analysis of Experiments, pp. 156-166.

[12] Lindquist, Design and Analysis of Experiments, pp. 93-94.

stimulation by speech) did not differ significantly from pre-test Condition II (lipreading combined with cutaneous stimulation by speech, before training in cutaneous stimulation by speech), and (2) Pre-test Condition II (lipreading combined with cutaneous stimulation by speech, before training in cutaneous stimulation by speech), did not differ significantly from post-test Condition I (lipreading only, after training in cutaneous stimulation by speech). It can be observed from Table 6 that the Spondaic words in the post-test Condition II (lipreading combined with cutaneous stimulation by speech, after training in cutaneous stimulation by speech) did differ significantly from all other situations. Therefore, from the foregoing analysis and discussion, it would appear that the Spondaic words were mostly responsible for the significant findings throughout the experiment.

Discussion

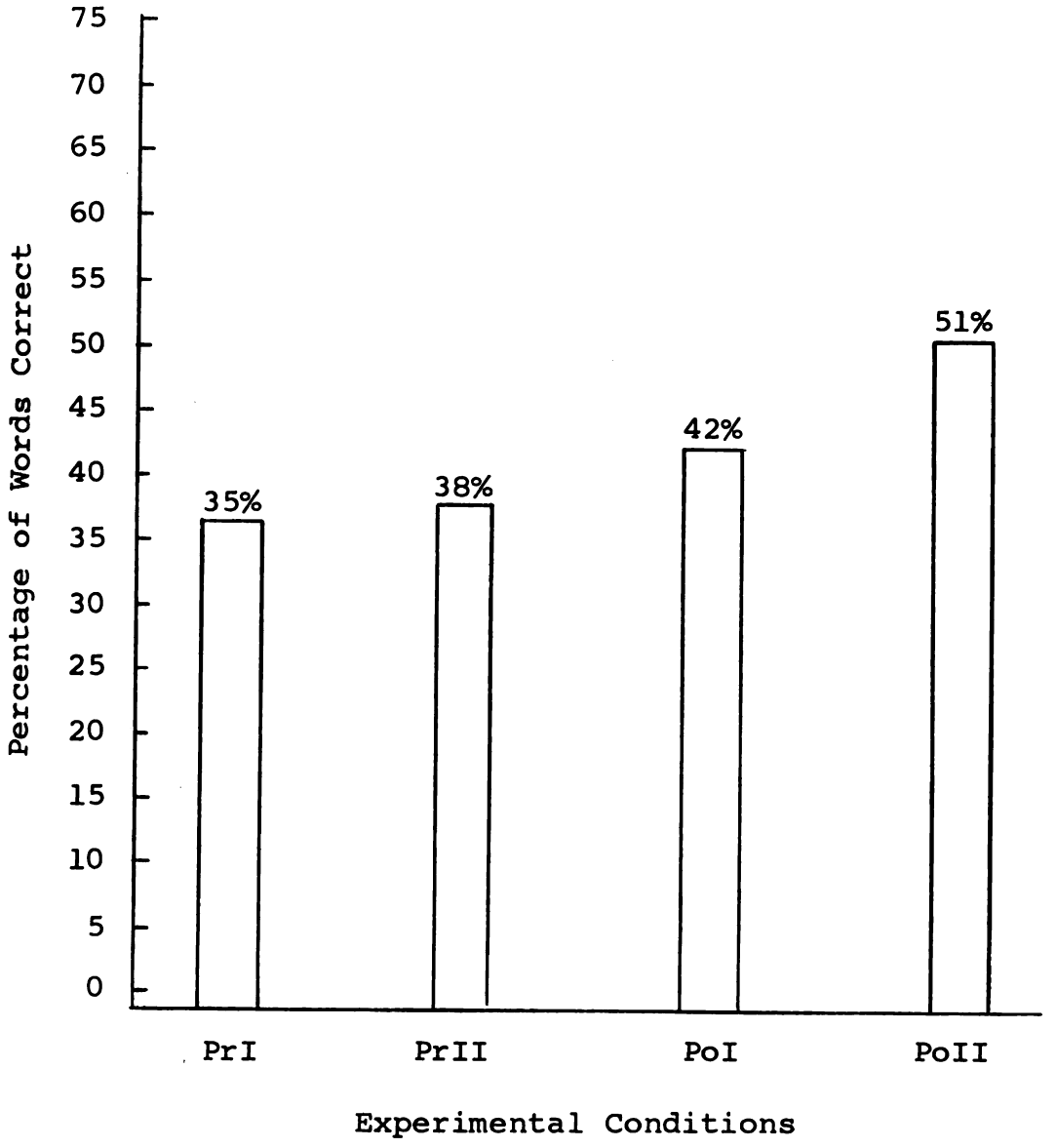
Analyses of the data show that a significant variation exists among the experimental conditions in the pre- and post-test situations. The variance was associated with either the experimental Conditions I and II or with the training procedure in cutaneous stimulation by speech.

It seems evident that the training in cutaneous stimulation by speech was largely to account for the observed

differences because there was no significant difference between Condition I and Condition II on the pre-test. This finding largely rules out variation due only to differences between Condition I and Condition II. It would be expected that if the training in cutaneous stimulation by speech did not affect the variance, there would be no significant differences between Condition I and Condition II on the post-test. Furthermore, there would not have been any significant difference between the pre-test and post-test experimental conditions either. However, there was a significant difference between all but one pair of means. The non-significant difference was that between the pre-test Condition I and the pre-test Condition II. This suggests that before training the combination of cutaneous stimulation by speech and lipreading does not produce significantly greater scores than lipreading alone. However, there was a small difference in scores as shown by percentages in Figure 8.

It was necessary to train the subjects to make use of the subtleties that cutaneous stimulation by speech produced. The subjects were not required to be able to distinguish words only by feeling the vibrations on their arm. Such a task would have required much more extensive training than that which was actually received. Even with

Figure 8. Percentage of Words Correctly Identified by All Subjects Under Each of the Experimental Conditions: PrI = Pre-test Condition I; PrII = Pre-test Condition II; PoI = Post-test Condition I, and PoII = Post-test Condition II.



extensive training, it is doubtful that the discrimination score by vibratory means alone would have produced significant results. In this study it was not believed necessary to try to train the subjects to a definite criterion of proficiency with cutaneous stimulation by speech. Because cutaneous stimulation by speech was to be combined with lipreading, it was thought that the lipreading process would be of primary importance while the cutaneous stimulation by speech would be of secondary importance. Cutaneous stimulation by speech was included with lipreading in order to present "extra" message cues. Some extra cues that cutaneous stimulation by speech presented to the subject may have been: (1) The duration characteristics of individual sounds and words, and (2) the intensity of these sounds and words. All of the subjects reported that throughout the training sessions they were able to distinguish a certain vibratory pattern for some of the sounds and words. Although these sounds and words were not the same from subject to subject, nevertheless, the vibratory patterns produced had meaning for the individual subject.

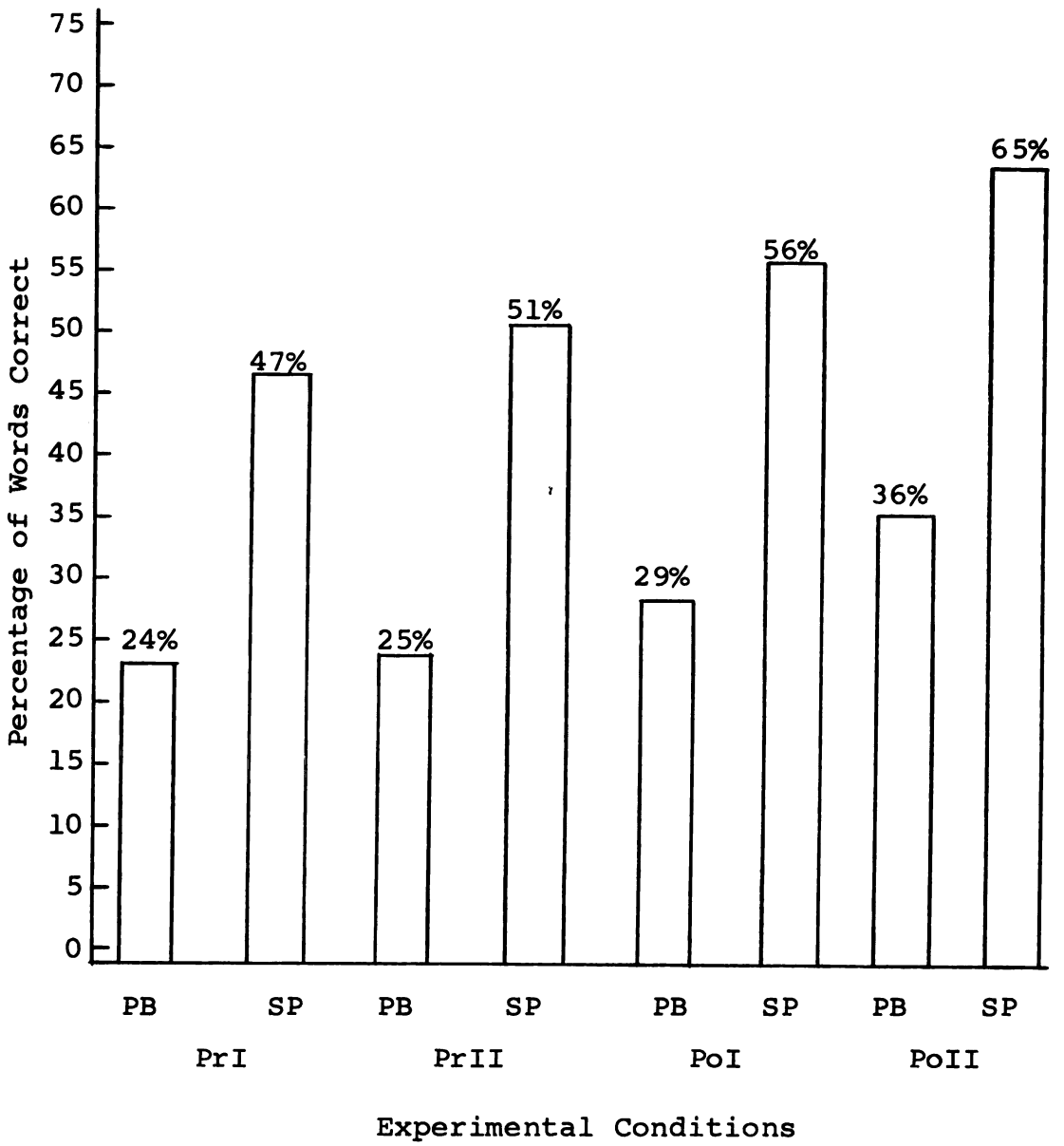
Some subjects were amazed at differences in duration between the individual sounds and words. Visually, the eye perceives a printed word that is composed of four letters.

When this same word is presented through vibratory means to the skin, its duration is much longer--the vibratory sensation does not fit the visually printed pattern. The duration of the vibratory stimulus surely must have been a factor in helping the subjects distinguish between the PB words and the Spondaic words. One would expect that the words of two syllables would produce a different general vibratory pattern on the integument from words of one syllable. Figure 9 presents the percentages of PB words and Spondaic words correctly identified.

The intensity of the individual sounds also gave the subjects extra cues. Some sounds have more power and naturally produced more intense vibrations on the skin than did others.

The combination of the extra cues of duration and intensity helped the subject to delimit his word choice, thus enhancing his lipreading performance. This is verified by the statistical analysis of the data. After the subjects received training in cutaneous stimulation by speech, significant differences between the Conditions I (lipreading only) and II (lipreading combined with cutaneous stimulation by speech) became apparent.

Figure 9. Percentage of Phonetically Balanced (PB) and Spondaic (SP) Words Correctly Identified by All Subjects Under Each of the Experimental Conditions: PrI = Pre-test Condition I; PrII = Pre-test Condition II; PoI = Post-test Condition I, and PoII = Post-test Condition II.



After training in cutaneous stimulation by speech, there were significant differences between the post-test Condition I (lipreading, after training in cutaneous stimulation by speech) and both of the pre-test conditions: (1) lipreading only, before training in cutaneous stimulation by speech, and (2) lipreading combined with cutaneous stimulation by speech, before training in cutaneous stimulation by speech. This finding probably means that the subjects became familiar with the word list during training, which in turn improved their lipreading performance. Even though the training word lists included a total of 150 words, of which 50 were the original test words, this may have been a factor in the final lipreading scores. Had there been no learning effect of the word lists, it would be expected that there should have been no significant differences between the post-test Condition I and the pre-test Conditions.

The test scores produced by the subjects were possibly depressed by the constant presentation of the white masking noise. This depression of lipreading scores by masking has been experimentally investigated by Leonard, who found that when white noise was presented to lipreading subjects, their lipreading scores were depressed 33

percent.[13] Therefore it is quite possible that the same effect was present in the present study.

The most important finding of this study is the significant difference between the post-test Condition I (lipreading only, after training in cutaneous stimulation by speech) and the post-test Condition II (lipreading combined with cutaneous stimulation by speech, after training in cutaneous stimulation by speech). This demonstrates that cutaneous stimulation by speech can and does improve a person's lipreading performance after a brief training period in the use of cutaneous stimulation by speech.

The results of this investigation generally support the findings of Gault.[14] Gault was able to show that the addition of cutaneous stimulation by speech to the lipreading processes produced significantly higher lipreading scores. However, Gault's experimentation and the present investigation differ in important details: (1) This investigation utilized a different portion of the integument. The dorsal part of the forearm was utilized in this study

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[13]Ralph Leonard, "The Effects of Selected Continuous Auditory Distractions on Lipreading Performance" (unpublished Master's thesis, Michigan State University, 1962).

[14]Gault, Journal of Abnormal and Social Psychology, 25(1930), pp. 498-517.

so that ultimately the subject's hands could remain unconstrained for manipulative purposes. (2) The speech signal, for all intents and purposes, was unfiltered. This tended to simplify the entire procedure and will make the modification of the present apparatus more uncomplicated than would otherwise be the case. (3) Experimental procedures and statistical analyses were also quite different. The subjects in the present study were naïve lipreaders and had no formal training in lipreading. They received training only in the perception of cutaneous stimulation by speech. They were also normal hearing subjects. Most of Gault's subjects were taken from hard-of-hearing and deaf populations. While Gault expressed much of his data in percentages, the present study utilized a parametric analysis of variance. (4) Finally, this investigation and Gault's differ in the type of vibrator employed. The vibrators utilized in this investigation were quite efficient, and entirely different from Gault's vibrating posts.[15]

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[15]Gault, Journal of the Franklin Institute, 204 (1927), pp. 329-358.

CHAPTER V

SUMMARY, CONCLUSIONS, AND IMPLICATIONS FOR FUTURE RESEARCH

Summary

An important rehabilitative measure to recommend to a person who has a hearing loss, with a poor medical prognosis, is lipreading. The teaching of lipreading is often a demanding task for both teacher and student; therefore if it were possible to apply some other technique in conjunction with lipreading in order to enhance a person's lipreading performance, it would be worthwhile to do so. Cutaneous perception of oral speech, in the form of cutaneous stimulation by speech, appears to be a technique of some merit.

The purpose of this research has been to investigate the effect of combining cutaneous stimulation by speech with lipreading on subjects' lipreading performance. It has not been the purpose of this study to determine if cutaneous stimulation by speech alone would be satisfactory as a communications system.

The review of the literature was divided into two parts. Part I was concerned with presenting a review of the literature pertaining to cutaneous stimulation. Determining

the sensitivity of bodily areas to cutaneous stimulation (mostly vibration) has been accomplished by many experimenters. It is generally conceded that the part of the integument most sensitive to this stimulation is the palmer side of the fingers, and in particular the thumb. The integument also displays a rather wide range of sensitivity to vibration. The lowest limit reported was 5 Hertz (the European equivalent to cycles per second) while the upper limit was 8,000 c.p.s. However, it is thought the skin is most sensitive to vibrations of 200 c.p.s. to 400 c.p.s. Cutaneous sensitivity, because of the response characteristics of the integument, has been compared with the functioning of the auditory modality. The comparisons range from a belief that there is little division between the auditory and vibro-cutaneous senses to the statement that the skin does not "hear" very well, i.e. the skin is a poor sensory organ and does not compare favorably with the sensitivity of the ear. Many devices have been utilized for the transmission of cutaneous messages. They are either electrical or mechanical stimulators. With the use of these devices it has been possible for subjects to discriminate speech and to decipher coded vibratory messages. Cutaneous stimulation by speech produced by rather elaborate apparatus, has also

been combined with lipreading with significant results.

Part II of the review of literature pertained to lipreading. A review of the history of lipreading in Europe and America was presented. It is evident that a period of training is necessary to develop the skill of lipreading because there are numerous factors that influence a person's lipreading performance. Once lipreading is learned it has a profound effect upon the hearing handicapped person because it tends to help him to relate more meaningfully to those around him.

The subjects employed in this study were undergraduate and graduate students at Michigan State University. All of the subjects had normal vision.

Cutaneous Speech Transmission System was devised for presentation of speech. The Cutaneous Speech Transmission System was simply constructed of four loud-speakers, two inches in diameter, with a Pellon fabric glued over the face of each one. The fabric membrane made each loud-speaker an efficient vibrator. The four vibrators were then placed on the dorsal part of the forearm of each subject. The Cutaneous Speech Transmission System was acoustically insulated, and each subject received a masking noise via earphones to guard against the subject's hearing the speech, thus rendering the experiment invalid.

Two motion picture films, utilizing a male speaker who was filmed while presenting twenty-five phonetically balanced words and twenty-five Spondaic words, were produced. The presentation of the word order was randomized so that the words were presented in one order on the silent motion picture film and another order on the sound motion picture film. The silent motion picture film was shown to the subjects for presentation of Condition I, which was lipreading only. The sound motion picture film was presented for Condition II, which was lipreading combined with cutaneous stimulation by speech. As was mentioned above, all of the subjects were presented a masking noise in their ears so they could not hear the speech. The subjects were presented both of the experimental conditions twice, once during the pre-test and once during the post-test.

After the subjects were presented pre-test Conditions I and II, they received ten sessions of training in the utilization of cutaneous stimulation by speech.

After a subject had completed the training sessions he was again tested on the experimental Conditions I (lipreading only) and II (lipreading combined with cutaneous stimulation by speech). Thus, each subject produced a total of four scores: (1) Pre-test Condition I (lipreading only,

before training in cutaneous stimulation by speech), (2) Pre-test Condition II (lipreading combined with cutaneous stimulation by speech, before training in cutaneous stimulation by speech), (3) Post-test Condition I (lipreading only, after training in cutaneous stimulation by speech), and (4) Post-test Condition II (lipreading combined with cutaneous stimulation by speech, after training in cutaneous stimulation by speech). Each of the subject's scores was based upon the total number of words perceived correctly out of a total list of 50 words. This comprised the total experiment.

Conclusions

On the basis of the analysis of the data obtained within the experimental conditions of this investigation, the following conclusions appear to be warranted:

1. After the subject has had the benefit of a brief training period in the utilization of cutaneous stimulation by speech and when cutaneous stimulation by speech is combined with lipreading, the subject's lipreading scores are significantly higher than by lipreading alone.

2. Combining cutaneous stimulation by speech with lipreading without the benefit of training in cutaneous

stimulation by speech does not improve a subject's usual lipreading performance.

3. Words with spondaic stress patterns accounted for higher performance scores and more significant differences between the different experimental conditions than did the phonetically balanced monosyllabic words.

4. This experiment has shown that an efficient and uncomplicated aid to lipreading has been developed. Subject to further modification and research, the Cutaneous Speech Transmission System could be a useful adjunct to the lipreading process.

Implications for Future Research

The results of this study have indicated that the addition of cutaneous stimulation by speech to lipreading improves a subject's lipreading performance. However, further research is indicated to investigate the following questions:

1. Will one vibrator, which is placed on some portion of the integument, produce as significant an increase in lipreading performance as did the present apparatus that utilized four vibrators?

2. What portion of the integument should be utilized for the placement of the vibrator?

3. What effect does differing speech stimuli presented by cutaneous stimulation, have on lipreading performance? Is cutaneous stimulation by speech even more efficient when conversational speech is employed rather than individual, isolated words?

4. In what ways can the existing Cutaneous Speech Transmission System be modified and improved?

5. What application does cutaneous stimulation by speech have for the totally deaf? Will deaf subjects show significant improvement in lipreading scores when cutaneous stimulation by speech is combined with lipreading?

6. What application does cutaneous stimulation by speech have for a deaf-blind population?

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APPENDICES

APPENDIX A

WORD LIST FOR PRESENTATION OF EXPERIMENTAL CONDITION I MOTION PICTURE

WORD LIST FOR PRESENTATION OF EXPERIMENTAL
CONDITION I MOTION PICTURE

CONDITION I LIPREADING NAME_____

PRE-TEST_____ POST-TEST_____ DATE_____

NUMBER RIGHT*____ PB_____ SPONDEE_____

BEFORE_____ AFTER_____ CONDITION II

SCHOOLBOY	FLAT	YOUNG
KNEE	TREE	NOW
AIRPLANE	AND	OAK
EARDRUM	HOTDOG	NORTHWEST
WOODWORK	TOOTHBRUSH	MOVE
BASEBALL	GAVE	SIDEWALK
BIRTHDAY	MUSHROOM	HOTHOUSE
NEW	HARDWARE	COWBOY
DUMB	HORSESHOE	STAIRWAY
ARMCHAIR	OATMEAL	SHOW
JAW	STAR	THAT
ICEBERG	WAY	PANCAKE
OWN	EAT	CAP
PADLOCK	MOUSETRAP	SMART
PLAYGROUND	CARS	ROOMS
EASE	GREYHOUND	ONE
LIVE	RAILROAD	

*NUMBER RIGHT IS NUMBER OF
WORDS CROSSED THROUGH

APPENDIX B

WORD LIST FOR PRESENTATION OF EXPERIMENTAL CONDITION II MOTION PICTURE

WORD LIST FOR PRESENTATION OF EXPERIMENTAL
CONDITION II MOTION PICTURE

CONDITION II COMBINED LIPREADING AND VIBRATORY SPEECH

NAME_____

DATE_____

PRE-TEST_____ POST-TEST_____

NUMBER RIGHT*____ PB_____ SPONDEE_____

BEFORE_____ AFTER_____ CONDITION I

HARDWARE	STAIRWAY	TREE
ONE	GREYHOUND	EAT
HOTHOUSE	FLAT	WOODWORK
SHOW	PLAYGROUND	WAY
ARMCHAIR	NOW	PADLOCK
COWBOY	THAT	ROOMS
EARDRUM	YOUNG	SMART
AND	RAILROAD	OATMEAL
BIRTHDAY	KNEE	BASEBALL
NORTHWEST	MOUSETRAP	STAR
TOOTHBRUSH	MUSHROOM	HORSESHOE
SIDEWALK	PANCAKE	CAP
NEW	ICEBERG	HOTDOG
SCHOOLBOY	AIRPLANE	JAW
EASE	CARS	OWN
OAK	DUMB	GAVE
MOVE	LIVE	

*NUMBER OF WORDS RIGHT IS NUMBER OF
WORDS CROSSED THROUGH

APPENDIX C

TRAINING TAPE WORD LISTS, NUMBERS ONE THROUGH TEN

TRAINING TAPE WORD LIST NUMBER ONE

BONBON
AN
ROOMS
STOVE
HOUSEWORK
ICEBERG
LIVE
STAR
THEREFORE
CUPCAKE
OR
SHE
COWBOY
EAT
COOKBOOK
TOE
VAMPIRE
TRUE
UP
OATMEAL
BIRTHDAY
DOVETAIL
LOW
HARDWARE
MUSHROOM
SCHOOLBOY
OWL
DEAF
OWN
LAW
WIRE
THEM
ONE
ARMCHAIR
SIDEWALK
ME
NOT
FELT

YOUNG
DUCKPOND
HORSESHOE
OUTLAW
OAK
THERE
CARVE
GIVE
HEDGEHOG
HUNT
YOU
BACKBONE
SMART
HEADLIGHT
ACE
PLAYGROUND
EGGPLANT
EYEBROW
BLACKOUT
TREE
STAIRWAY
ACHE
DRAWBRIDGE
WOODCHUCK
ISLE
COULD
SUNDOWN
LIFEBOAT
PLAYMATE
KNEES
GREYHOUND
NEW
DOORMAT
AS
BLACKBOARD
EARN
CHEW
THING

MISHAP
BOBWHITE
BUCKWHEAT
POOR
HARDSTICK
SOYBEAN
NORTHWEST
MIDWAY
SKIN
WHAT
SHOW
CARGO
PADLOCK
WAY
ALTHOUGH
AIRPLANE
BATHE
FOOTSTOOL
SEE
HIGH
TOOTHBRUSH
MEW
SCARECROW
JAW
EARDRUM
FIREFLY
EAST
MOVE
GRANDSON
EASE
IT
WATCHWORD
HOTDOG
COUGHDROP
DUMB
DOORSTEP
AND

NONE
CARS
FAREWELL
BEEHIVE
THAT
DAD
EARTHQUAKE
HIM
WOODWORK
GAVE
KNEE
PLATFORM
FLAT
US
BAGPIPE
CAP
BASEBALL
STARLIGHT
HOTHOUSE
RAN
JAM
BELLS
JACKNIFE
WORKSHOP
RAILROAD
NOW
OUTSIDE
DAY
PANCAKE
WET
YARD
DAYBREAK
MOUSETRAP
BLOODHOUND
TWINS
NUTMEG
WIGWAM

TRAINING TAPE WORD LIST NUMBER TWO

NOT
DOORMAT
LIVE
EAT
WIRE
HOTHOUSE
SIDEWALK
SCARECROW
EARN
BEEHIVE
BLACKBOARD
BUCKWHEAT
YOU
YARDSTICK
BAGPIPE
OR
ARMCHAIR
LIFEBOAT
NONE
ISLE
STAIRWAY
BOBWHITE
GREYHOUND
COULD
EYEBROW
WIGWAM
ROOMS
MOVE
MISHAP
EARDRUM
HIM
SCHOOLBOY
EGGPLANT
TOOTHBRUSH
CAP
TWINS
KNEES
CUPCAKE

AS
AND
EARTHQUAKE
OWN
MIDWAY
BIRTHDAY
BLACKOUT
GIVE
DRAWBRIDGE
UP
STOVE
PLATFORM
OAK
TRUE
BONBON
MUSHROOM
BACKBONE
WET
SKIN
ONE
PLAYGROUND
WORKSHOP
SHE
BLOODHOUND
POOR
BATHE
YARD
PADLOCK
WHAT
HORSESHOE
OUTSIDE
DUMB
FAREWELL
CHEW
RAILROAD
HOTDOG
DUCKPOND
LOW

THAT
SEE
WOODWORK
CARVE
DOORSTEP
COWBOY
OATMEAL
BASEBALL
SMART
JACKNIFE
SHOW
FOOTSTOOL
EAST
HARDWARE
DAD
BELLS
NORTHWEST
WATCHWORD
AIRPLANE
COUGHDROP
HUNT
TOE
WOODCHUCK
PANCAKE
JAW
NEW
ACHE
NOW
HIGH
FIREFLY
ACE
DAYBREAK
RAN
SUNDOWN
HOUSEWORK
AN
STAR

THEM
IT
US
MOUSETRAP
JAM
FLAT
YOUNG
NUTMEG
ICEBERG
SOYBEAN
STARLIGHT
KNEE
THING
MEW
OUTLAW
TREE
OWL
GAVE
MAY
HEADLIGHT
COOKBOOK
FELT
LAW
HEDGEHOG
THEREFORE
EASE
DAY
ALTHOUGH
VAMPIRE
CARS
DOVETAIL
DEAF
THERE
GRANDSON
PLAYMATE
CARGO
ME

TRAINING TAPE WORD LIST NUMBER THREE

ME
MUSHROOM
CARVE
CHEW
HORSESHOE
YOUNG
OUTSIDE
BACKBONE
SCARECROW
NOT
WHAT
YARDSTICK
TOOTHBRUSH
ONE
OATMEAL
ROOMS
MEW
HOTDOG
OWL
PLAYMATE
STAR
EASE
THEM
COOKBOOK
GAVE
HOUSEWORK
SIDEWALK
JAM
BLACKBOARD
UP
RAN
DEAF
US
EAT
OR
VAMPIRE
BOBWHITE
SKIN

PADLOCK
FLAT
STARLIGHT
STAIRWAY
PLATFORM
HEADLIGHT
PANCAKE
EAST
DAY
THAT
FAREWELL
DUMB
POOR
DOORMAT
MOUSETRAP
NEW
AIRPLANE
ACE
FOOTSTOOL
AN
MOVE
COWBOY
OWN
SOYBEAN
THING
CARGO
THEREFORE
NOW
BIRTHDAY
ARMCHAIR
FELT
HOTHOUSE
HUNT
DOVETAIL
LAW
PLAYGROUND
THERE
EARN

IT
CAP
OUTLAW
EGGPLANT
HIM
ACHE
ALTHOUGH
HARDWARE
SUNDOWN
YOU
WATCHWORD
GREYHOUND
LOW
MISHAP
GRANDSON
BASEBALL
SMART
WAY
STOVE
DRAWBRIDGE
ISLE
RAILROAD
BEEHIVE
TWINS
LIVE
COUGHDROP
SHOW
GIVE
CARS
KNEES
TREE
OAK
ICEBERG
EYEBROW
DOORSTEP
DAD
COULD

NONE
TOE
AS
SCHOOLBOY
DUCKPOND
WIRE
BATHE
BAGPIPE
WORKSHOP
NORTHWEST
HIGH
MIDWAY
TRUE
WIGWAM
LIFEBOAT
FIREFLY
EARTHQUAKE
BUCKWHEAT
WOODWORK
BLOODHOUND
DAYBREAK
WET
WOODCHUCK
BONBON
EARDRUM
SHE
JACKNIFE
BLACKOUT
AND
BELLS
SEE
CUPCAKE
KNEE
YARD
HEDGEHOG
JAW
NUTMEG

SAME-DIFFERENT TRAINING TAPE WORD LIST NUMBER FOUR

SMART - SMART
EASE - THEREFORE
ICEBERG - ICEBERG
BATHE - EARN
BACKBONE - GAVE
OWL - OWL
AND - AND
IT - MEW
LOW - GREYHOUND
SCHOOLBOY - HORSESHOE
TOOTHBRUSH - TOOTHBRUSH
EAT - JAM
BASEBALL - BASEBALL
THERE - THERE
DOVETAIL - ACHE
DOORSTEP - DOORSTEP
STAR - THING
UP - EGGPLANT
BELLS - VAMPIRE
RAILROAD - RAILROAD
EYEBROW - EYEBROW
JAW - JAW
BLACKOUT - CARVE
THEM - MUSHROOM
NUTMEG - COWBOY
DEAF - DEAF
SUNDOWN - HOTHOUSE
HIM - BIRTHDAY
WIRE - ISLE
FAREWELL - FAREWELL
NOW - RAN
BAGPIPE - SHE
MOUSETRAP - MOUSETRAP
EAST - HUNT
CARS - TREE
CARGO - CARGO
US - US
COOKBOOK - LIFEBOAT
OWN - OWN
BLACKBOARD - SEE
HARDWARE - YOUNG
BONBON - BONBON
CAP - NOT
AIRPLANE - OATMEAL
WIGWAM - PADLOCK
TRUE - TRUE
SCARECROW - EARDRUM
HOUSEWORK - ACE
TWINS - TWINS
NEW - NEW
WATCHWORD - WATCHWORD
YOU - DUCKPOND
HEDGEHOG - HEDGEHOG
AS - AS
FOOTSTOOL - BLOODHOUND
ROOMS - MIDWAY
TOE - YARDSTICK
COUGHDROP - WORKSHOP
DAYBREAK - LIVE
SOYBEAN - EARTHQUAKE
STAIRWAY - NORTHWEST
AN - AN
STARLIGHT - DRAWBRIDGE
WOODCHUCK - WAY
PLATFORM - KNEE
CHEW - OR
MISHAP - MISHAP
ME - MOVE
SKIN - BEEHIVE
COULD - COULD
PLAYGROUND - OAK
HEADLIGHT - HOTDOG
DUMB - YARD
BOBWHITE - BOBWHITE
DOORMAT - BUCKWHEAT
GIVE - KNEES
POOR - OUTLAW
FELT - FELT
PLAYMATE - HIGH
JACKNIFE - JACKNIFE
FLAT - ONE
ARMCHAIR - ARMCHAIR
OUTSIDE - OUTSIDE
STOVE - LAW
SIDEWALK - SIDEWALK
PANCAKE - WET
NONE - SHOW
GRANDSON - DAY
ALTHOUGH - ALTHOUGH
FIREFLY - FIREFLY
CUPCAKE - CUPCAKE
WOODWORK - THAT
DAD - WHAT

TRAINING TAPE WORD LIST NUMBER FIVE

ROOMS	SKIN	TWINS	OUTLAW
BASEBALL	JAW	AS	NEW
HEDGEHOG	DAY	THING	BLACKOUT
CAP	ICEBERG	LOW	BELLS
SHOW	WORKSHOP	MOVE	NUTMEG
EGGPLANT	EAT	NORTHWEST	FIREFLY
STARLIGHT	BATHE	THAT	SCARECROW
DOVETAIL	SMART	COOKBOOK	YARDSTICK
STAIRWAY	MUSHROOM	GIVE	HUNT
EAST	CARVE	RAILROAD	MISHAP
MIDWAY	WIRE	DRAWBRIDGE	BONBON
RAN	US	BLACKBOARD	DOORSTEP
WET	BOBWHITE	MEW	EARN
EYEBROW	TOOTHBRUSH	DEAF	DAD
COUGHDROP	THEREFORE	ALTHOUGH	PLAYMATE
WIGWAM	OR	OWN	ARMCHAIR
COULD	ACE	HIM	HIGH
BAGPIPE	HOUSEWORK	YOU	GRANDSON
KNEE	FELT	DUCKPOND	BIRTHDAY
CARGO	CARS	WOODWORK	SUNDOWN
FLAT	DOORMAT	LIFEBOAT	CUPCAKE
BLOODHOUND	OUTSIDE	PADLOCK	THEM
NOT	EARTHQUAKE	OATMEAL	NONE
SCHOOLBOY	ACHE	NOW	OAK
ME	TOE	DUMB	JACKNIFE
HOTHOUSE	IT	JAM	PLAYGROUND
HORSESHOE	WOODCHUCK	BACKBONE	SOYBEAN
AND	PANCAKE	BUCKWHEAT	SEE
HARDWARE	ONE	VAMPIRE	LIVE
EARDRUM	BEEHIVE	HEADLIGHT	OWL
GAVE	GREYHOUND	ISLE	SHE
FAREWELL	MOUSETRAP	TRUE	DAYBREAK
POOR	LAW	YARD	KNEES
WHAT	EASE	COWBOY	HOTDOG
STAR	AIRPLANE	TREE	AN
YOUNG	STOVE	THERE	WAY
SIDEWALK	PLATFORM	WATCHWORD	FOOTSTOOL
CHEW	UP		

TRAINING TAPE WORD LIST NUMBER SIX

HOTHOUSE
NUTMEG
CARGO
WAY
WORKSHOP
THEM
ME
STAIRWAY
ISLE
MIDWAY
BACKBONE
BAGPIPE
WHAT
AIRPLANE
EARDRUM
MOVE
DOORMAT
DOORSTEP
YARDSTICK
EAT
NORTHWEST
CAP
OUTSIDE
VAMPIRE
ARMCHAIR
ACE
HEADLIGHT
UP
CARVE
MOUSETRAP
HARDWARE
BLACKOUT
EGGPLANT
HUNT
THAT
GIVE
EASE
DOVETAIL

AN
CARS
BLACKBOARD
COUGHDROP
DAYBREAK
TWINS
SUNDOWN
AND
SCHOOLBOY
ICEBERG
KNEES
PLAYGROUND
THERE
RAILROAD
YARD
CHEW
ONE
MEW
TOOTHBRUSH
MISHAP
MUSHROOM
GREYHOUND
FLAT
PADLOCK
NOW
HIGH
WIGWAM
COWBOY
DRAWBRIDGE
BOBWHITE
OATMEAL
JACKNIFE
RAN
BELLS
CUPCAKE
STAR
OAK
BEEHIVE

FOOTSTOOL
BUCKWHEAT
KNEE
GRANDSON
FAREWELL
WOODWORK
EARTHQUAKE
NEW
US
LIVE
BIRTHDAY
SEE
WATCHWORD
SCARECROW
SKIN
EYEBROW
PLATFORM
POOR
OUTLAW
BONBON
WIRE
WET
JAM
HOTDOG
NOT
SHE
DAY
TOE
DAD
COOKBOOK
FELT
YOUNG
PLAYMATE
LIFEBOAT
JAW
HORSESHOE
EAST

DEAF
ACHE
DUCKPOND
THEREFORE
TRUE
BATHE
BASEBALL
SHOW
SMART
OWN
OR
EARN
AS
LOW
LAW
SIDEWALK
OWL
GAVE
COULD
FIREFLY
STARLIGHT
WOODCHUCK
DUMB
BLOODHOUND
PANCAKE
SOYBEAN
ROOMS
TREE
ALTHOUGH
HEDGEHOG
YOU
HOUSEWORK
STOVE
HIM
NONE
IT
THING

TRAINING TAPE WORD LIST NUMBER SEVEN

KNEE
STARLIGHT
THAT
RAILROAD
DAD
DRAWBRIDGE
SHOW
BAGPIPE
PANCAKE
TOOTHBRUSH
ICEBERG
DOORMAT
SHE
OATMEAL
NORTHWEST
TWINS
ONE
OUTSIDE
PADLOCK
OWN
BONBON
FAREWELL
SCHOOLBOY
ME
WORKSHOP
BLOODHOUND
CARVE
MUSHROOM
JAW
THEM
AIRPLANE
DAY
NUTMEG
PLAYGROUND
NONE
COOKBOOK
HORSESHOE
STAIRWAY

MIDWAY
BLACKOUT
BOBWHITE
WIRE
GRANDSON
AN
BACKBONE
YOU
THERE
WOODWORK
HEDGEHOG
UP
YARDSTICK
WATCHWORD
US
NEW
TOE
DOORSTEP
NOW
BUCKWHEAT
SIDEWALK
DAYBREAK
HARDWARE
ROOMS
MEW
BATHE
CARGO
FELT
EARTHQUAKE
JAM
YOUNG
JACKNIFE
DUCKPOND
OUTLAW
EASE
ISLE
SCARECROW
AND

STAR
MOVE
HUNT
BASEBALL
HEADLIGHT
OAK
LIFEBOAT
WAY
WET
EAT
EARDRUM
ARMCHAIR
MOUSETRAP
WOODCHUCK
TRUE
PLAYMATE
ACHE
PLATFORM
POOR
KNEES
DOVETAIL
THEREFORE
BELLS
SUNDOWN
AS
HOTHOUSE
OWL
LIVE
ALTHOUGH
FIREFLY
EARN
DUMB
LOW
BIRTHDAY
BLACKBOARD
EAST
THING

FLAT
EYEBROW
COWBOY
GAVE
HIM
SEE
CHEW
IT
RAN
HIGH
BEEHIVE
SKIN
GREYHOUND
WHAT
HOTDOG
DEAF
TREE
CARS
MISHAP
HOUSEWORK
STOVE
SOYBEAN
GIVE
NOT
LAW
COUGHDROP
COULD
WIGWAM
EGGPLANT
FOOTSTOOL
SMART
YARD
CUPCAKE
ACE
VAMPIRE
OR
CAP

SAME-DIFFERENT TRAINING TAPE WORD LIST NUMBER EIGHT

BACKBONE - BACKBONE
JAM - JAM
HORSESHOE - VAMPIRE
JAW - JAW
HEDGEHOG - THING
CARGO - ARMCHAIR
EAST - EAST
GRANDSON - GRANDSON
PANCAKE - WOODWORK
CUPCAKE - STARLIGHT
SHE - SHE
BLACKOUT - ACE
COUGHDROP - GREYHOUND
RAILROAD - TOOTHBRUSH
PLAYMATE - PLAYMATE
OWL - OWL
SEE - SEE
DAD - DAD
EARTHQUAKE - EARTHQUAKE
WAY - NOW
CARS - HOTDOG
SCHOOLBOY - SCHOOLBOY
PLATFORM - DOORSTEP
SIDEWALK - OATMEAL
EASE - FELT
ALTHOUGH - ALTHOUGH
TOE - DUMB
THEM - YOUNG
AND - BASEBALL
AS - PADLOCK
DAY - DAY
WOODCHUCK - LIFEBOAT

DOORMAT - DOORMAT
COOKBOOK - COOKBOOK
OWN - GIVE
GAVE - FLAT
EAT - EAT
YARD - YARD
AN - WHAT
STOVE - STOVE
NONE - OUTSIDE
EARDRUM - MOVE
MIDWAY - MIDWAY
ROOMS - ROOMS
DUCKPOND - DUCKPOND
BLOODHOUND - MOUSETRAP
BAGPIPE - TWINS
DEAF - DEAF
BIRTHDAY - OR
BOBWHITE - BOBWHITE
WORKSHOP - ICEBERG
BONBON - ONE
FIREFLY - FIREFLY
EYEBROW - EYEBROW
HIGH - BEEHIVE
PLAYGROUND - HUNT
ISLE - ISLE
LOW - LOW
HARDWARE - KNEES
YOU - YOU
YARDSTICK - RAN
LAW - LAW
WIRE - SCARECROW
BATHE - BLACKBOARD
STAR - HEADLIGHT
THERE - THERE

CAP - EARN
WATCHWORD - NORTHWEST
SOYBEAN - SOYBEAN
HOTHOUSE - HOTHOUSE
DOVETAIL - DOVETAIL
BUCKWHEAT - WIGWAM
JACKNIFE - THAT
NEW - NEW
NUTMEG - IT
COULD - TRUE
MEW - MEW
HOUSEWORK - DAYBREAK
EGGPLANT - SMART
CHEW - CHEW
KNEE - LIVE
NOT - BELLS
HIM - HIM
FAREWELL - MISHAP
THEREFORE - MUSHROOM
SHOW - SHOW
CARVE - CARVE
UP - UP
STAIRWAY - AIRPLANE
OAK - US
COWBOY - POOR
WET - WET
ME - ME
SUNDOWN - SUNDOWN
FOOTSTOOL - FOOTSTOOL
SKIN - ACHE
DRAWBRIDGE - DRAWBRIDGE
OUTLAW - TREE

TRAINING TAPE WORD LIST NUMBER NINE

NORTHWEST	EARDRUM	BACKBONE	LOW
AS	KNEES	OAK	BLACKOUT
POOR	JAM	COOKBOOK	TRUE
STAIRWAY	DOORSTEP	OR	COULD
COUGHDROP	DUMB	DAD	BLACKBOARD
WOODWORK	NOW	PADLOCK	STOVE
EARTHQUAKE	DAY	LIFEBOAT	NONE
CHEW	AND	BONBON	EASE
FELT	SKIN	THING	YOU
WATCHWORD	NOT	STAR	EGGPLANT
CAP	DEAF	ROOMS	ME
ACHE	ICEBERG	OWL	AN
SHE	IT	SCARECROW	SEE
GREYHOUND	ARMCHAIR	BELLS	YOUNG
ISLE	HIM	BOBWHITE	WORKSHOP
VAMPIRE	NEW	MOVE	US
ONE	HARDWARE	FAREWELL	SUNDOWN
TOOTHBRUSH	DOORMAT	GAVE	CARGO
CARS	FLAT	THEM	DAYBREAK
EAT	AIRPLANE	RAN	HEDGEHOG
SMART	PLATFORM	FIREFLY	JACKNIFE
OUTSIDE	SOYBEAN	OUTLAW	THAT
WAY	MOUSETRAP	LAW	BLOODHOUND
KNEE	LIVE	PANCAKE	RAILROAD
HOTHOUSE	PLAYGROUND	MIDWAY	SCHOOLBOY
YARDSTICK	UP	STARLIGHT	GRANDSON
WET	MEW	BIRTHDAY	JAW
BAGPIPE	HIGH	COWBOY	EYEBROW
DOVETAIL	DRAWBRIDGE	HOUSEWORK	SHOW
WIGWAM	BUCKWHEAT	THERE	BEEHIVE
SIDEWALK	CUPCAKE	MUSHROOM	DUCKPOND
WOODCHUCK	HOTDOG	WIRE	EARN
BATHE	OATMEAL	OWN	ALTHOUGH
TOE	CARVE	ACE	WHAT
FOOTSTOOL	GIVE	MISHAP	EAST
TREE	HORSESHOE	TWINS	NUTMEG
PLAYMATE	BASEBALL	HEADLIGHT	HUNT
YARD	THEREFORE		

TRAINING TAPE WORD LIST NUMBER TEN

AS	ACE	JAM	OR
OUTSIDE	HOUSEWORK	MUSHROOM	COOKBOOK
STAR	WAY	AND	KNEES
UP	PLAYMATE	ROOMS	EGGPLANT
BASEBALL	EARTHQUAKE	PANCAKE	YOU
HOTDOG	FLAT	HIGH	TOE
ARMCHAIR	CHEW	WORKSHOP	STARLIGHT
SIDEWALK	EARDRUM	EAT	WIGWAM
IT	BLACKOUT	GRANDSON	MIDWAY
EYEBROW	THAT	HEADLIGHT	SEE
NOT	PLAYGROUND	PADLOCK	SUNDOWN
DOVETAIL	LIFEBOAT	ACHE	CARVE
EAST	LAW	MEW	LOW
YARD	EASE	BATHE	FELT
BIRTHDAY	THEREFORE	DAY	DAYBREAK
OWL	WHAT	NUTMEG	OUTLAW
BUCKWHEAT	FAREWELL	STAIRWAY	SCARECROW
CAP	AN	RAN	NONE
WOODWORK	OAK	SMART	YARDSTICK
COWBOY	CUPCAKE	TWINS	COUGHDROP
GIVE	TOOTHBRUSH	WIRE	WATCHWORD
BOBWHITE	NOW	DRAWBRIDGE	ALTHOUGH
CARGO	TREE	HUNT	DOORSTEP
RAILROAD	HEDGEHOG	ME	BACKBONE
POOR	DEAF	MOUSETRAP	NEW
BLACKBOARD	BONBON	WOODCHUCK	BEEHIVE
NORTHWEST	STOVE	JAW	SOYBEAN
HOTHOUSE	KNEE	LIVE	VAMPIRE
ONE	FIREFLY	ISLE	US
CARS	PLATFORM	BLOODHOUND	COULD
GREYHOUND	HORSESHOE	SHE	SHOW
BELLS	YOUNG	THERE	OATMEAL
ICEBERG	THEM	MISHAP	DUCKPOND
THING	SCHOOLBOY	WET	SKIN
OWN	HIM	JACKNIFE	HARDWARE
MOVE	FOOTSTOOL	DUMB	DAD
GAVE	EARN	BAGPIPE	AIRPLANE
DOORMAT	TRUE		

APPENDIX D

SUBJECTS' RAW SCORES

RAW SCORES SUBJECT #1

PRE-TEST

PRESENTATION ORDER OF EXPERIMENTAL CONDITIONS I-II

		Number of Words Correct	Percentage of Words Correct
Condition I:	Total Score	22	44
	P B Score	7	14
	Spondee Score	15	30
Condition II:	Total Score	24	48
	P B Score	9	18
	Spondee Score	15	30

POST-TEST

PRESENTATION ORDER OF EXPERIMENTAL CONDITIONS II-I

		Number of Words Correct	Percentage of Words Correct
Condition I:	Total Score	25	50
	P B Score	10	20
	Spondee Score	15	30
Condition II:	Total Score	28	56
	P B Score	8	16
	Spondee Score	20	40

RAW SCORES SUBJECT #2

PRE-TEST

PRESENTATION ORDER OF EXPERIMENTAL CONDITIONS II-I

		Number of Words Correct	Percentage of Words Correct
Condition I:	Total Score	21	42
	P B Score	4	8
	Spondee Score	17	34
Condition II:	Total Score	22	44
	P B Score	6	12
	Spondee Score	16	32

POST-TEST

PRESENTATION ORDER OF EXPERIMENTAL CONDITIONS I-II

		Number of Words Correct	Percentage of Words Correct
Condition I:	Total Score	24	48
	P B Score	6	12
	Spondee Score	18	36
Condition II:	Total Score	27	54
	P B Score	6	12
	Spondee Score	21	42

RAW SCORES SUBJECT #3

PRE-TEST

PRESENTATION ORDER OF EXPERIMENTAL CONDITIONS I-II

		Number of Words Correct	Percentage of Words Correct
Condition I:	Total Score	18	36
	P B Score	6	12
	Spondee Score	12	24
Condition II:	Total Score	20	40
	P B Score	8	16
	Spondee Score	12	24

POST-TEST

PRESENTATION ORDER OF EXPERIMENTAL CONDITIONS II-I

		Number of Words Correct	Percentage of Words Correct
Condition I:	Total Score	25	50
	P B Score	9	18
	Spondee Score	16	32
Condition II:	Total Score	28	56
	P B Score	8	16
	Spondee Score	20	40

RAW SCORES SUBJECT #4

PRE-TEST

PRESENTATION ORDER OF EXPERIMENTAL CONDITIONS II-I

		Number of Words Correct	Percentage of Words Correct
Condition I:	Total Score	28	56
	P B Score	8	16
	Spondee Score	20	40
Condition II:	Total Score	28	56
	P B Score	9	18
	Spondee Score	19	38

POST-TEST

PRESENTATION ORDER OF EXPERIMENTAL CONDITIONS I-II

		Number of Words Correct	Percentage of Words Correct
Condition I:	Total Score	29	58
	P B Score	9	18
	Spondee Score	20	40
Condition II:	Total Score	35	70
	P B Score	13	26
	Spondee Score	22	44

RAW SCORES SUBJECT #5

PRE-TEST

PRESENTATION ORDER OF EXPERIMENTAL CONDITIONS I-II

		Number of Words Correct	Percentage of Words Correct
Condition I:	Total Score	2	4
	P B Score	1	2
	Spondee Score	1	2
Condition II:	Total Score	9	18
	P B Score	3	6
	Spondee Score	6	12

POST-TEST

PRESENTATION ORDER OF EXPERIMENTAL CONDITIONS II-I

		Number of Words Correct	Percentage of Words Correct
Condition I:	Total Score	9	18
	P B Score	2	4
	Spondee Score	7	14
Condition II:	Total Score	17	34
	P B Score	5	10
	Spondee Score	12	24

RAW SCORES SUBJECT #6

PRE-TEST

PRESENTATION ORDER OF EXPERIMENTAL CONDITIONS I-II

		Number of Words Correct	Percentage of Words Correct
Condition I:	Total Score	19	38
	P B Score	10	20
	Spondee Score	9	18
Condition II:	Total Score	23	46
	P B Score	11	22
	Spondee Score	12	24

POST-TEST

PRESENTATION ORDER OF EXPERIMENTAL CONDITIONS II-I

		Number of Words Correct	Percentage of Words Correct
Condition I:	Total Score	22	44
	P B Score	7	14
	Spondee Score	15	30
Condition II:	Total Score	24	48
	P B Score	8	16
	Spondee Score	16	32

RAW SCORES SUBJECT #6

PRE-TEST

PRESENTATION ORDER OF EXPERIMENTAL CONDITIONS I-II

		Number of Words Correct	Percentage of Words Correct
Condition I:	Total Score	19	38
	P B Score	10	20
	Spondee Score	9	18
Condition II:	Total Score	23	46
	P B Score	11	22
	Spondee Score	12	24

POST-TEST

PRESENTATION ORDER OF EXPERIMENTAL CONDITIONS II-I

		Number of Words Correct	Percentage of Words Correct
Condition I:	Total Score	22	44
	P B Score	7	14
	Spondee Score	15	30
Condition II:	Total Score	24	48
	P B Score	8	16
	Spondee Score	16	32

RAW SCORES SUBJECT #7

PRE-TEST

PRESENTATION ORDER OF EXPERIMENTAL CONDITIONS II-I

		Number of Words Correct	Percentage of Words Correct
Condition I:	Total Score	16	32
	P B Score	5	10
	Spondee Score	11	22
Condition II:	Total Score	12	24
	P B Score	5	10
	Spondee Score	7	14

POST-TEST

PRESENTATION ORDER OF EXPERIMENTAL CONDITIONS I-II

		Number of Words Correct	Percentage of Words Correct
Condition I:	Total Score	18	36
	P B Score	8	16
	Spondee Score	10	20
Condition II:	Total Score	19	38
	P B Score	8	16
	Spondee Score	11	22

RAW SCORES SUBJECT #8

PRE-TEST

PRESENTATION ORDER OF EXPERIMENTAL CONDITIONS II-I

		Number of Words Correct	Percentage of Words Correct
Condition I:	Total Score	32	64
	P B Score	11	22
	Spondee Score	21	42
Condition II:	Total Score	33	66
	P B Score	11	22
	Spondee Score	22	44

POST-TEST

PRESENTATION ORDER OF EXPERIMENTAL CONDITIONS I-II

		Number of Words Correct	Percentage of Words Correct
Condition I:	Total Score	38	76
	P B Score	15	30
	Spondee Score	23	46
Condition II:	Total Score	39	78
	P B Score	15	30
	Spondee Score	24	48

RAW SCORES SUBJECT #9

PRE-TEST

PRESENTATION ORDER OF EXPERIMENTAL CONDITIONS I-II

		Number of Words Correct	Percentage of Words Correct
Condition I:	Total Score	9	18
	P B Score	2	4
	Spondee Score	7	14
Condition II:	Total Score	17	34
	P B Score	4	8
	Spondee Score	13	26

POST-TEST

PRESENTATION ORDER OF EXPERIMENTAL CONDITIONS II-I

		Number of Words Correct	Percentage of Words Correct
Condition I:	Total Score	15	30
	P B Score	4	8
	Spondee Score	11	22
Condition II:	Total Score	22	44
	P B Score	7	14
	Spondee Score	15	30

RAW SCORES SUBJECT #10

PRE-TEST

PRESENTATION ORDER OF EXPERIMENTAL CONDITIONS I-II

		Number of Words Correct	Percentage of Words Correct
Condition I:	Total Score	12	24
	P B Score	4	8
	Spondee Score	8	16
Condition II:	Total Score	17	34
	P B Score	4	8
	Spondee Score	13	26

POST-TEST

PRESENTATION ORDER OF EXPERIMENTAL CONDITIONS II-I

		Number of Words Correct	Percentage of Words Correct
Condition I:	Total Score	19	38
	P B Score	7	14
	Spondee Score	12	24
Condition II:	Total Score	20	40
	P B Score	7	14
	Spondee Score	13	26

RAW SCORES SUBJECT #11

PRE-TEST

PRESENTATION ORDER OF EXPERIMENTAL CONDITIONS II-I

		Number of Words Correct	Percentage of Words Correct
Condition I:	Total Score	21	42
	P B Score	8	16
	Spondee Score	13	26
Condition II:	Total Score	15	30
	P B Score	3	6
	Spondee Score	12	24

POST-TEST

PRESENTATION ORDER OF EXPERIMENTAL CONDITIONS I-II

		Number of Words Correct	Percentage of Words Correct
Condition I:	Total Score	21	42
	P B Score	6	12
	Spondee Score	15	30
Condition II:	Total Score	29	58
	P B Score	18	36
	Spondee Score	11	22

RAW SCORES SUBJECT #12

PRE-TEST

PRESENTATION ORDER OF EXPERIMENTAL CONDITIONS II-I

		Number of Words Correct	Percentage of Words Correct
Condition I:	Total Score	10	20
	P B Score	5	10
	Spondee Score	5	10
Condition II:	Total Score	11	22
	P B Score	6	12
	Spondee Score	5	10

POST-TEST

PRESENTATION ORDER OF EXPERIMENTAL CONDITIONS I-II

		Number of Words Correct	Percentage of Words Correct
Condition I:	Total Score	11	22
	P B Score	7	14
	Spondee Score	4	8
Condition II:	Total Score	12	24
	P B Score	7	14
	Spondee Score	5	10

RAW SCORES SUBJECT #13

PRE-TEST

PRESENTATION ORDER OF EXPERIMENTAL CONDITIONS I-II

		Number of Words Correct	Percentage of Words Correct
Condition I:	Total Score	6	12
	P B Score	1	2
	Spondee Score	5	10
Condition II:	Total Score	6	12
	P B Score	1	2
	Spondee Score	5	10

POST-TEST

PRESENTATION ORDER OF EXPERIMENTAL CONDITIONS II-I

		Number of Words Correct	Percentage of Words Correct
Condition I:	Total Score	11	22
	P B Score	3	6
	Spondee Score	8	16
Condition II:	Total Score	17	34
	P B Score	5	10
	Spondee Score	12	24

RAW SCORES SUBJECT #14

PRE-TEST

PRESENTATION ORDER OF EXPERIMENTAL CONDITIONS II-I

		Number of Words Correct	Percentage of Words Correct
Condition I:	Total Score	29	58
	P B Score	10	20
	Spondee Score	19	38
Condition II:	Total Score	25	50
	P B Score	7	14
	Spondee Score	18	36

POST-TEST

PRESENTATION ORDER OF EXPERIMENTAL CONDITIONS I-II

		Number of Words Correct	Percentage of Words Correct
Condition I:	Total Score	29	58
	P B Score	11	22
	Spondee Score	18	36
Condition II:	Total Score	31	62
	P B Score	11	22
	Spondee Score	20	40

RAW SCORES SUBJECT #15

PRE-TEST

PRESENTATION ORDER OF EXPERIMENTAL CONDITIONS I-II

		Number of Words Correct	Percentage of Words Correct
Condition I:	Total Score	15	30
	P B Score	7	14
	Spondee Score	8	16
Condition II:	Total Score	21	42
	P B Score	6	12
	Spondee Score	15	30

POST-TEST

PRESENTATION ORDER OF EXPERIMENTAL CONDITIONS II-I

		Number of Words Correct	Percentage of Words Correct
Condition I:	Total Score	19	38
	P B Score	6	12
	Spondee Score	13	26
Condition II:	Total Score	30	60
	P B Score	11	22
	Spondee Score	19	38

RAW SCORES SUBJECT #16

PRE-TEST

PRESENTATION ORDER OF EXPERIMENTAL CONDITIONS II-I

		Number of Words Correct	Percentage of Words Correct
Condition I:	Total Score	26	52
	P B Score	8	16
	Spondee Score	18	36
Condition II:	Total Score	24	48
	P B Score	7	14
	Spondee Score	17	34

POST-TEST

PRESENTATION ORDER OF EXPERIMENTAL CONDITIONS I-II

		Number of Words Correct	Percentage of Words Correct
Condition I:	Total Score	28	56
	P B Score	9	18
	Spondee Score	19	38
Condition II:	Total Score	30	60
	P B Score	9	18
	Spondee Score	21	42