FACIAL MOVEMENTS OF MALES AND FEMALES WHILE PRODUCING COMMON EXPRESSIONS AND SENTENCES BY VOICE AND BY WHISPER

Thesis for the Degree of Ph. D.

MICHIGAN STATE UNIVERSITY

RALPH LEONARD

1968

This is to certify that the

thesis entitled

FACIAL MOVEMENTS OF MALES AND
FEMALES WHILE PRODUCING COMMON
EXPRESSIONS AND SENTENCES BY
VOICE AND BY WHISPER

presented by

RALPH LEONARD

has been accepted towards fulfillment
of the requirements for

Ph. D. degree in Audiology and
Speech Sciences

Herbert J. Oyer
Major professor

Date 8/1/68

O-169

281

ABSTRACT

FACIAL MOVEMENTS OF MALES AND
FEMALES WHILE PRODUCING COMMON EXPRESSIONS
AND SENTENCES BY VOICE AND BY WHISPER

by Ralph Leonard

There are many teachers of lipreading who believe that the speaker must voice stimulus materials in the lipreading situation, and that the speaker who whispers or mouths stimulus material will tend to change his facial movements and; therefore, provide an unreal lipreading situation for the receiver. However, there seems to be very little evidence concerning the factors that contribute to a person's being a skilled speaker in the lipreading situation.

The purpose of this investigation was to determine whether any appreciable differences of three measures of facial movement existed, when common expressions and sentences were voiced and then whispered, between males and females. It was also the purpose of this study to demonstrate a means of measuring certain facial movements.

The measurements of facial movements were obtained on each speaker by the attachment of a mercury strain gauge to the speaker's face. The mercury strain gauge detects minute changes in movement and was attached at six different

points around the lip region of the speaker, one attachment on the tip of the nose, and one on the point of the chin.

Once the strain gauge attachments were made on the speaker's face, leads from each end of the gauge were connected to the strain gauge input of the plethysmograph. The output from the plethysmograph was fed into one of the D. C. preamplifiers on a polygraph. The movements detected by the strain gauge were intensified by the plethysmograph, and were recorded on the polygraph strip chart recording paper in millimeters.

The stimulus material used in this study was the list of thirty-one common expressions and sentences from Form A of Utley's lipreading test. Twenty separate randomizations of the list were used by ten different speakers. Each speaker voiced one list and whispered a second list. Ten speaker-subjects were used in this investigation, five females and five males.

Measurements made from the recorded movements secured on the chart paper included a measure of a total duration of movement, amount of maximum movement, and time to amount of maximum movement. These three measures were made for each sentence and common expression produced by each speaker. Therefore, there was a total of 93 voiced measures and 93 whispered measures for each speaker over the stimulus material.

One mean score was obtained for each male speaker for each of the three measures voiced, and each of the three measures whispered. Grand means were computed for the male group for the three voiced and three whispered measures. The same procedure was followed for the female group. These means and grand means served as the score values used in the analysis of the data.

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

1. There is no significant difference in the amount of time taken for maximum movement to occur, for certain facial movements, between males and females when voicing and then whispering common expressions and sentences.

2. There is no significant difference between males and females in the amount of maximum movements occurring, for certain facial movements, when producing common expressions and sentences by voice and then by whisper.

3. There is no significant difference between males and females in the duration of certain facial movements when producing common expressions and sentences by voice and then by whisper.

4. There is no significant difference in the amount of time taken for maximum movement to occur, the amount of maximum movement, and the duration of certain facial

movements, between voicing and whispering common expressions and sentences, when produced by males.

5. There is no significant difference in the amount of time taken for maximum movement to occur, the amount of maximum movement, and the duration of certain facial movements, between voicing and whispering common expressions and sentences, when produced by females.

6. This experiment has developed and demonstrated an effective means for measuring, quantifying, and amplifying speaker's facial movements.

The present study was exploratory in nature. The data collected suggest areas for further study.

FACIAL MOVEMENTS OF MALES AND FEMALES WHILE PRODUCING COMMON EXPRESSIONS AND SENTENCES BY VOICE AND BY WHISPER

By

Ralph Leonard

A THESIS

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

DOCTOR OF PHILOSOPHY

Department of Speech

1968

ACKNOWLEDGMENTS

This research was supported in part by a fellowship from the Vocational Rehabilitation Administration.

This writer wishes to thank the following members of his guidance committee for reading, advising, and constructively criticising the thesis:

Dr. Kenneth J. Hance, Professor of Speech

Dr. Edward Hardick, Associate Professor of Speech

Dr. Gregory Miller, Professor of Education

I am most grateful and appreciative to Dr. Herbert J. Oyer, Professor of Speech, who was my major advisor.

A special note of thanks to Dr. W. Bradford Lashbrook, Assistant Professor of Speech, for his advice and assistance concerning the statistical analysis and computer programing for this study.

I am indebted to the students who served as subjects for this study.

My mother, Mrs. J. D. Leonard, was a constant source of encouragement when it was needed most.

To my wife, Carol, and my children, Sharon and Dennis, my deepest gratitude is given. Their understanding and support during the writing of this study was greatly appreciated.

TABLE OF CONTENTS

TABLE OF CONTENTS - Continued

LIST OF TABLES

LIST OF ILLUSTRATIONS

CHAPTER I

STATEMENT OF THE PROBLEM

Introduction

The ability to perceive oral communication is achieved by a combination of sensory modalities. It is generally accepted that visual and auditory skills are vital factors in the channel of communication, and we have knowledge that indicates that these two factors are closely related to one another. Harris points out that the similarities of these two senses are often striking:

> Both organs serve to collect and to sort out stimuli impinging on the organism. Thanks partly to the organization of the two sensory systems these essentially random stimuli are given spatial and temporal organization and become for us the basis for our meaningful experimental world.[1]

Visual as well as auditory skills are important in the communication of hard of hearing individuals, and it has been demonstrated in past years that hard of hearing people can learn to use visual clues to help them in the communication process. One approach used to assist the hard of hearing, to learn to use visual clues, is the teaching of lipreading. As a person attains greater skill in the art of

---

[1] J. Donald Harris, Some Relations Between Vision and Audition (Springfield, Illinois: Charles C. Thomas, Publisher, 1950), p. 3.

lipreading, his dependence upon the auditory channel for understanding speech is reduced. Therefore, lipreading functions as a compensatory measure for the loss of hearing acuity.

There are many factors necessary to produce a good lipreading situation. The lipreading process involves many variables concerning the speaker, code, environment, and receiver. In discussing a logical way to approach the experimental study of the lipreading process, O'Neill and Oyer presented the possible variables that exist in the lipreading process (see Figure 1).

The contents within Figure 1 obviously indicates that many variables are present in the lipreading process and that there is much to be learned about these variables. It would appear that each one of the variables mentioned in Figure 1 should be studied thoroughly and that quantitative measures of each variable should be made where possible.

In a seminar dealing with the subject of aural rehabilitation of the acoustically handicapped, Oyer suggested areas in need of research. Concerning the area of reception and perception, Oyer pointed out that much more must be known about the non-verbal aspects of communications, and the manner in which the acoustically handicapped utilize them. Studies should be made in depth of the perception and reception of visual, auditory, auditory-visual, and tactile stimuli. There should be well-controlled studies of the

SPEAKER-SENDER

1. Facial characteristics
2. Articulatory movements
   (a) Rate of speaking
   (b) Distinctness of speaking
3. Gesture activity
4. Amount of foice used
5. Feedback characteristics

LIPREADER-RECEIVER

1. Visual acuity and discrimination
2. Communication "set"
3. Residual hearing
4. Personality
   (a) Intelligence
   (b) Behavior patterns
   (c) Past communicative experience
   (d) Visual feedback

ENVIRONMENT

1. Lighting conditions
2. Physical arrangements
3. Number of senders
4. Physical distractions

CODE OR STIMULUS

1. Visibility
2. Familiarity
3. Structure
4. Rate of transmission
5. Auditory-visual aspects

Figure 1. Schematic of variables involved in the lipreading process.[2]

---

[2]J. J. O'Neill and H. J. Oyer, Visual Communication for the Hard of Hearing (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1961), p. 35.

effects of visual training, auditory training, and the need for and effects of selective amplification and tactile training.[3]

Statement of Problem and Purpose of Study

The purpose of this study was to investigate and analyze three aspects of the speaker variable during the production of code by voice and then by whisper. From this investigation and analysis it was hoped that the following general questions could be answered: (1) Is there any difference in the amount of time taken for maximum movement to occur, for certain facial movements, between males and females when voicing and then whispering common expressions and sentences? (2) Is there any difference between males and females in the amount of maximum movements occurring, for certain facial movements, when producing common expressions and sentences by voice and then by whisper? (3) Is there any difference between males and females in the speed of certain facial movements when producing common expressions and sentences by voice and then by whisper? (4) Is there any difference in the amount of time taken for maximum movement to occur, the amount of maximum movement, and the speed of

---

[3]H. J. Oyer, "Research Needs in Aural Rehabilitation," Aural Rehabilitation of the Acoustically Handicapped, Department of Speech, Michigan State University (East Lansing, Michigan, SHSLR No. 266, 1966), p. 139.

certain facial movements, between voicing and whispering common expressions and sentences, when produced by males? (5) Is there any difference in the amount of time taken for maximum movement to occur, the amount of maximum movement, and the duration of certain facial movements, between voicing and whispering common expressions and sentences, when produced by females?

Importance of the Study

Little is known about the lipreading process, and there seems to be very little evidence concerning the factors that contribute to a persons being a skilled speaker in the lipreading situation. O'Neill and Oyer point out that:

> Few statements can be offered about the attributes of a good lipreader or the effects of environment upon lipreading; however, the nature of the lipreading stimulus and the characteristics of the speaker or sender do have some effect upon lipreading; and in short, there are many interesting possibilities open for research in the area of lipreading.[4]

It was hoped that this project would provide valuable information which could be used in lipreading training. Some teachers of lipreading believe that the speaker must voice stimulus materials in the lipreading situation, and that the speaker who whispers or mouths stimulus material will tend to change his facial movements and therefore

---

[4]J. J. O'Neill and H. J. Oyer, Visual Communication for the Hard of Hearing (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1961), p. 48.

provide an unreal lipreading situation for the receiver. There seems to be very little, if any, experimental research performed concerning differences and similarities between voicing and whispering stimulus materials by speakers. Differences and/or similarities concerning the rate of speed and the amount of maximum movement occurring on speaker's faces, when whispering and voicing stimulus material, could provide valuable information which could be used in lipreading training.

It was also hoped that this project would: (1) demonstrate a means of measuring and quantifying the three aspects of speaker variable mentioned above, in relation to sex, and to measure any differences or similarities between the voiced and whispered common expressions and sentences; (2) provide new knowledge that would stimulate more detailed research in the area of lipreading.

Limitations of the Study

The small sample used in this study was a limitation; however, this limitation existed due to the time factor necessary for each speaker-subject during the experiment, and the difficulty of securing the proper equipment for an unlimited period of time.

This project was limited to three aspects of the speaker variable during the production of code by voice and then by whisper. Common expressions and sentences were utilized as code for this project, but no specific aspect of the code was measured. Therefore; code, environment, and the receiver were not studied as potential variables for study at this time.

The three aspects of the speaker variable examined were: (1) the effect of speaker sex upon the amount of time taken for maximum movement to occur, for certain facial movements, when voicing and then when whispering common expressions and sentences; (2) the effect of speaker sex upon the amount of maximum movement occurring, for certain facial movements, when voicing and then when whispering common expressions and sentences; (3) the effects of speaker sex upon the duration of certain facial movements, for each common expression and sentences when they were voiced and then when they were whispered.

There was no attempt made to control, or examine, the amount of voice or the amount of whisper used. This was allowed to operate freely across the speakers as part of the normal speaker variable. Facial characteristics such as expressiveness, head and neck movement, and many others were not examined. It was the opinion of this writer that many more speaker subjects would be needed, as well as special measuring equipment, to examine these characteristics adequately.

Definition of Terms

For the purpose of this study, the terms used were defined in the following manner:

Facial movement: The facial movement referred to those movements, or changes in movement, on the measured surface of the speaker's face caused by the interplay of various facial muscles during the act of speaking by voice and by whisper. These movements were measured by a mercury-rubber strain gauge in conjunction with a polygraph and plethysmograph.

Common expressions and sentences: The thirty-one common expressions and sentences used for this study will be taken from "How Well Can You Read Lips," by J. Utley,[5] Form A.

Voice: Voice referred to the normal conversational voice of each individual speaker.

Whisper: Whisper referred to sound produced by the outgoing breath stream with the vocal cords not in vibration.

Mentum: The anterior prominence of the lower jaw; the tip of the chin.

Philtrum: The shallow groove in the center of the outer surface of the upper lip.

Lipreading: In this study the term lipreading refers to the communication that takes place where one individual, the

---

[5]Jean Utley, "How Well Can You Read Lips?" Teacher's Lesson Manual and Motion Picture (Chicago: DeVry Corporation, 1946).

lipreader or receiver, can understand the verbal message being sent by another person, the speaker, by use of visual cues and without the aid of hearing.

Many other persons have offered their own definitions of the process of lipreading. Bunger used the term "speech reading" instead of lipreading. She defined speech reading as understanding spoken language while watching the speaker with little or no use of hearing.[6] Mason used the term "visual hearing" rather than lipreading or speech reading, believing that the term visual hearing carries the implication of a functional substitution of the eye for the ear in comprehending spoken language.[7]

More change in terminology has been proposed by Oyer, who defines the term lipreading as "the act of a receiver in receiving information from the lips, face, and gestures of the speaker and the milieu in which this takes place."[8]

The definitions in terminology mentioned above, concerning the term lipreading, seem quite similar in most cases.

---

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

[7]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 Apeech, 1942), p. 56.

[8]Personal communication with Herbert J. Oyer, Chairman of the Department of Speech, Michigan State University, June 28, 1967.

CHAPTER II

REVIEW OF THE LITERATURE

Introduction

There has been very little research, if any, accomplished concerning lipreading and the physiological measurement of lip movement. However, there have been studies that measured various dimensions of the mouth of speakers during the production of single word units. These measurements were obtained by filming the speakers, and then securing the measurements from the film. Though many statements have been made about the importance of lip movement on the speaker's face, in the lipreading situation, there is very little scientific evidence to support statements concerning lip movement. Lack of evidence, in the past, seems to be due to the absence of adequate equipment and measuring devices to carry out such investigation.

Because so little is known about physiological measurement of lip movement, the review of this literature was divided into two main parts. Part I consists of literature reviewed concerning ways and means measurements have been made on speaker faces. In Part II, literature pertaining to other factors related to lipreading has been reviewed.

Included in Part II were studies related to voiced and whispered speech. Some new procedures that may produce more quantitative measures for lip movement will be reviewed in a later chapter.

PART I

MEASUREMENT OF LIP MOVEMENT

Several individuals have stated the importance the speaker's lip movement plays in the lipreading process. Fusfield believed that the speaker who provided personality and dynamic animation in the lipreading situation certainly promoted an encouraging backdrop for lipreading. In contrast, he pointed out that the cold, mechanical kind of speaker was a handicapping factor for the lipreader, and that exaggerated mouthing by the speaker put the lipreader at a disadvantage. Fusfield discussed and suggested that the following factors all affected the lipreading ability of the speaker: (1) the speaker's bearing, (2) the character of his lip movement, (3) pronunciation, (4) facial features, (5) fullness of lips, (6) size of mouth, (7) sex, and (8) chin and jaw movements.[1]

In their discussion of deaf children Silverman, Lane, and Doehring, state that the deaf child is not able to learn

---

[1]Irving Fusfield, "Factors in Lipreading as Determined by the Lipreader," American Annals of the Deaf, CIII (March, 1958), pp. 229-242.

speechreading by associating visual symbols with auditory language and therefore he is forced directly to his visual speechreading language:

> The extent to which he is able to do this may depend upon a number of factors, some of which are exceedingly complex and difficult to analyze. One group of factors concerns the speaker. These include his distance and position and how well his face is illuminated. They include the character of his speech, his precision of articulation, how fast he talks, his use of sectional expressions, the mobility of his face, and the familiarity of the speechreader with the particular speaker.[2]

In discussing tests of lipreading, O'Neill and Oyer suggest that clinical experience seems to indicate that there are some people much more difficult to lipread than others. They believe that lip movements, mouth openings, eye movements, and other various postures and gestures lend themselves to the ease or difficulty with which the speaker can be understood in the lipreading situation.[3]

Fujimura conducted a study concerning lip movement in relation to code. This study concerned the lip movement that takes place during the pronunciation of bilabial consonants. The movements of the lips while producing bilabial stops and nasals in various context have been studied by means of a stroboscopic technique. For the major

---

[2]S. R. Silverman, H. S. Lane, and D. G. Doehring, "Deaf Children," Hearing and Deafness, Ed. Hallowell Davis and S. R. Silverman (New York: Holt, Rinehart and Winston, Inc., 1960), p. 441.

[3]J. J. O'Neill and H. J. Oyer, *op. cit.*, p. 21.

part of this study a rate of 240 frames per second was used. The results of the measurements made indicated that, for the initial [P], [b], and [M] when not followed by [r], the separation of the lips reached about 30% of the maximum value in the following vowel, and the width of the mouth opening reached about 50% only about 5 milliseconds after the separation began.

The results of Fujimura's study indicated that the speed of motion in the lip region depends on the context. An oscillatory tendency in the motion of the lips generally was seen after the plosion of the stops especially when [P] was followed by [r]. The data in this study suggested that the lips are blown apart by the air pressure behind the occlusion in the case of the initial [P] and [b] but not in the case of the [m].[4]

Fromkin attempted to analyze three different kinds of data to determine the parameters of lip positions in a range of American English Vowels. The three kinds of data included were: (1) standardized simultaneous frontal and lateral photographs; (2) lateral x-rays; (3) plaster casts of a subject's lips. The measurements taken were as follows: (1) the distance between the corners of the mouth (width); (2) height of the opening of the mouth on the midline;

---

[4]Osama Fujimura, "Movements of the Lips in the Generation of Bilabial Consonants," Journal of Acoustical Society of America, 32 (July, 1960), pp. 913.

(3) protrusion; (4) area as measured on a frontal view; (5) and retraction of the corners of the mouth. In order to check on the consistency of performance and measurement, the data mentioned above were used to compare a single subject's production of the set of vowels on several occasions. In addition, comparisons with other subjects were made.[5]

It is interesting to note that Fromkin' study was one of the first attempts to investigate lip positions based on physiological parameters. Fromkin believed that the results of the study were only the first step:

> A description of the vowel lip position based on actual physiological parameters would include height, width, and lower lip protrusion. For the simplest model, one might use only two parameters, height, and width, as the major and minor axes of an ellipse, connected so as to be equivalent to the actual area of the mouth opening of any vowel, protrusion being predicted from the width.[6]

The remaining research concerned primarily with measurement of lip movement, and code, has been dealt with via several unpublished Master's Theses.

In 1962, Joergenson took the physical measurements of the mouths of four speakers as they spoke forty-eight homophenous words. This was accomplished by a frame-by-frame analysis of a moving picture film. It was hoped that

---

[5]Victoria A. Fromkin, "Lip Positions in American English Vowels," Language and Speech, VII (October-December, 1964), pp. 215-225.

[6]Ibid.

this analysis would determine the variables, if any, that exist in mouth openings, mouth widths, and teeth visibility during the production of homophenous words. Joergenson believed that there might be visible measurable differences in lip patterns when uttering homophenous words. This study produced the following results: (1) the size of the mouth opening at the philtrum was first measured, and results revealed visible differences in mouth openings during the production of homophenous words; (2) there were very minute differences in mouth widths during the utterance of homophenous words. Mouth widths were measured from corner to corner; (3) difference in time required for saying the homophenous words in this study was not statistically significant; (4) the difference in time during which the teeth were visible or not visible was not statistically significant for the words studied, but Joergenson believed further critical analysis needed to be done in relation to the visibility of the teeth to all homophenous words uttered by speakers in this study.[7]

Fulton, in 1964, made a comparative assessment of certain visible differences between voiced and unvoiced words of six different speakers. This was accomplished, as was Joergenson's study, with a frame-by-frame analysis of

---

[7]Ann Marie Joergenson, "The Measurement of Homophenous Words." (Unpublished Master's Thesis, Department of Speech, Michigan State University, 1962.)

a motion picture film. Each speaker said four words both with voice and without voice. The variables of lip opening, mouth width, jaw movement, eyebrow movement, mouth, teech, and tongue area, and the visibility of the tongue and teeth were analyzed. The data pertaining to lip opening, width of mouth, jaw movement, and mouth and teeth area were plotted on graphs illustrating distance in either measures of millimeters or fractions of square inches. Time was shown by the number of frames of film needed to complete the word.

The results from Fulton's study indicated visible differences in the size and amount of lip openings, mouth widths, jaw movements, and mouth and teeth areas in subjects between voiced and unvoiced-words. Calculations for both eyebrow movement and tongue area could not be measured.[8]

In summarizing the research of Joergenson and Fulton it must be pointed out that measurements were made with a frame-by-frame analysis of motion picture film, and that the code used in each study was of the single word unit type. However, each study was a new attempt to make finer measurements. Joergenson's study was confined primarily to measurement of specific code, whereas Fulton's study was

---

[8]Richard M. Fulton, "Comparative Assessment of Visible Differences Between Voiced and Unvoiced Words." (Unpublished Master's Thesis, Department of Speech, Michigan State University, 1964.)

primarily related to speaker variables when voicing and not voicing words. It is the opinion of this writer that the results obtained and methods used by Joergenson and Fulton suggest new avenues for further research and the need for greater attention to be focused on securing finer measurements of the variables involved in the lipreading process.

PART II

FACTORS RELATED TO LIPREADING

In this study the primary interest was concerned with the speaker and lip movement. However, it seemed appropriate that certain other areas related to lipreading should be reviewed. Therefore, literature pertaining to the following three general areas was discussed; (1) code and stimulus material; (2) speaker characteristics; (3) voiced speech and whispered speech. The literature reviewed, concerning these three general areas, was confined to those studies that pertained in some was to the speaker and/or lip movement, and the type of stimulus material used by the speaker.

Code and Stimulus Material

Research concerned with the ease of difficulty in which certain units of code are lipread is certainly of importance in the lipreading process. Much study has been accomplished with homophenous words, sentence length, visibility of consonants vs. vowels, etc. In 1943 it was suggested that both synthesis and intuition are necessary to solve the problem of one movement representing more than one sound. This indicated that it is impossible to distinguish visually between words that have different meanings, sound different, but look the same. These words, known as homophenous words, are otherwise impossible to distinguish on a visual basis alone. "However, when found in a sentence, the factors of context, time, place, topic of conversation, etc., invariable indicate the only word acceptable."[9]

In relation to homophenous words, Samuelson presented a paper before the section on Otolarynogology to the Academy of Medicine in 1937. She reported that 40% of the speech elements are homophenous. She also showed a method of lip-reading instruction using the audience as subjects. She reported that it takes 1/13 of a second to articulate a speech element and that about 50% of the speech elements are either obscure or invisible. This leaves approximately 50% of the sound visible.[10] Keaster stated that only about 30% of the sounds of English speech are visible and all of the other sounds are hidden in the mouth or look like one or two other

---

[9]American Hearing Society, <u>New Aids and Materials for Lipreading</u> (Washington, D. C.: American Hearing Society, 1943), pp. 2-3.

[10]Estelle Samuelson, "Fundamentals of Lip-Reading, Including Demonstrations with Audience as Subjects," <u>Larynogoscope</u>, XXXXVII (April, 1937), pp. 237-238.

cognate sounds.[11]

These two studies were attempts to classify sounds into percentages visible and invisible categories. It would be interesting to find out if the percentage of visible sounds in English speech would agree with Samuelson or Keaster's study if many speakers were used of both sexes.

Woodward attempted to apply principles of structural linguistics to the study of lipreading stimulus materials. The basic theory under consideration was that absolute visibility of phonation was a function of the area of articulation. Normal hearing subjects judged stimulus pairs, which consisted of syllables pairs made-up of consonant-vowel combinations, determining whether the pairs were the same or different. The sets of stimuli were filmed while spoken by one female speaker. Results indicated that the following sets of initial English consonants were classified in homophenous clusters: P-b-m; f-v; wh-w-r; ch-dz-sh-zh-y; t-d-n-l-s-z-o; K-g-h. It was pointed out by Woodward that if lipreaders were to differentiate among the members of these sets, it must be on the basis of phonetics, lexical, or grammatical redundancy, because articulatory differences

---

[11]Jacqueline Keaster, "An Inquiry into Current Concepts of Visual Speech Reception (Lipreading)," Larynoqoscope, LXV (January, 1955), pp. 80-84.

among them are not noticeable during visual observation.[12]

In 1961 Roback attempted to determine the ability of viewers to identify homophenous words. Homophenous words were presented by four different speakers on silent film, and these films were viewed by college students not formally trained in lipreading. Results of this indicated that viewers were able to select correctly the homophenous words more frequently than would be expected by chance alone. Results also showed that there were some observable differences in speaker preformance and that even though homophenous words are highly similar, they are not produced exactly alike on the lips.[13]

Joergenson, as mentioned earlier in this chapter, found that there were visible differences in mouth openings, and mouth widths, during utterance of homophenous words.[14]

The possibility of word length and word frequency has been investigated as a possible contributor to visual recognition. McGinnies, Conner, and Lacey studied the thresholds of recognition for words varying in length and

---

[12]Mary E. Woodward, "Linguistic Methodology in Lip Reading Research," John Tracy Clinic Research Papers, IV (December 1957), cited in O'Neill and Oyer, op. cit., p. 46.

[13]Ila Mae Roback, "Homophenous Words." (Unpublished Master's Thesis, Department of Speech, Michigan State University, 1961.)

[14]Joergenson, op. cit.

frequency for twenty subjects. Results of their study revealed a significant interaction effect between frequency and length. This relationship seems to be one in which an increase in frequency lowers visual recognition thresholds more for long words than for short words. However, an increase in word length raises thresholds more strikingly for low-frequency words than for high-frequency words.[15]

In 1944 Morris studied the effects of selected aspects of stimulus materials upon lipreading performance. She examined sentence length, sentence position with a group, and the position of a group within a series of groups. Deaf subjects viewed these stimulus materials in a face-to-face testing situation. Results indicated a definite decline in lipreading scores as sentence length increased. Also a word was harder to understand when it occurred in a longer sentence.[16] This study varies from many other studies by the use of deaf subjects in the testing situation instead of normal hearing individuals.

Taafe and Wong utilized the Iowa Film Test of lipreading to investigate the ease or difficulty with which a certain type of stimulus material could be lipread by

---

[15]E. McGinnies, P. B. Conner, O. L. Lacey, "Visual Recognition Thresholds as a Function of Word Length and Word Frequency," Journal of Experimental Psychology, XLIV (1952), pp. 65-69.

[16]D. M. Morris, "A Study of Some of the Factors Involved in Lipreading." (Unpublished Master's Thesis, Smith College, 1944), cited in O'Neill and Oyer, op. cit., pp. 44-45.

normal hearing college students. The material was examined in terms of sentence order, sentence length, number of words in a sentence, number of syllables in a sentence, and number of vowels and consonants. They found the following results: (1) There was little difference in lipreading ability between sentences of 4, 5, 6, or 7 words in length; (2) An increase in number of syllables in a sentence, an increase in the number vowels of consonants, or an increase in the vowel-consonant ratio, all added to an increased difficulty of the stimulus item; (3) Words consisting of three letters were easiest to lipread, and difficulty increased as the number of letters in a word varied to either side of three.[17]

Research involving the visual components of oral symbols, has been an area that has received more investigation than most in the broad area of visual communications. Numbers, in 1939, found that pupils who score high in recognizing single vowels also have a high score in recognizing meaningful material. In this experiment, Numbers administered a lipreading test to an experimental and a control group, each consisting of eight deaf children. The experimental group had received 20 minutes per day practice in vowel recognition for six months previous to receiving the

---

[17]Gordon Taafe and Wilson Wong, "Studies of Variables in Lipreading Stimulus Material," John Tracy Clinic Research Papers, III (December, 1957).

lipreading test.[18]

Two tests for investigating comparative visibility of English sounds, one for vowels and one for consonants, were developed by Heider and Heider. The vowel test was made-up of 16 syllables, and the consonant test was composed of 40 nonsense syllables, 20 with a diphthong and 20 with a vowel. Lipreading ability was measured by a word-sentence-story test. A total of 81 subjects viewed each test, and the sounds were ranked in terms of per cent of cases in which a sound was correctly recognized. Results of this study indicated: (1) high correlation between the ability to understand vowels on the lips and general lipreading ability; (2) there was a much lower correlation between consonant recognition and general lipreading ability; (3) recognition of vowels was superior to consonant recognition; (4) there was no correlation between lipreading of nonsense syllables and general lipreading ability.[19]

The studies mentioned seem to indicate the importance of the recognition of vowels for good general lipreading ability. However, O'Neill performed a study in 1954 which stresses the importance of visual recognition of consonants. O'Neill assessed the related contribution of lipreading in

---

[18]M. E. Numbers, "An Experiment in Lip Reading," Volta Review, XLI (1939), pp. 261-264.

[19]F. K. Heider and G. H. Heider, "An Experimental Investigation of Lipreading," Psychological Monographs, LII (February, 1940), pp. 124-153.

oral communication. Thirty-two normal hearing subjects listened to each of three speakers under four different noise conditions while viewing the speaker, and four different noise conditions while not viewing the speaker. Visibility of consonants, vowels, words, and phrases was evaluated. Results of this study indicated that vision contributed 57% to the recognition of consonants, 29.5% for vowels, 38.6% for words, and 17.4% for phrases. O'Neill made the interesting observation that if words are more visible than phrases, then context in the sense of the natural order of words is of no great aid in the visual recognition of materials by inexperienced lipreaders.[20] O'Neill's observation could be questioned on the grounds that inexperienced lipreaders may be too analytical. They have not been trained to exercise the synthetic approach when lipreading, and they have not been trained to visualize the "whole."

In 1961, Brannon considered monosyllabic words according to categories of visibility. These categories were based upon the visibility of the consonant sounds within the words. As one would assume, the results indicated that words of lesser visibility were more difficult to lipread. Words of more than one syllable were not identified any more

---

[20]John J. O'Neill, "Contributions of the Visual Components of Oral Symbols to Speech Comprehension," Journal of Speech and Hearing Disorders, XIX (December, 1954), pp. 429-439.

readily than monosyllables. The interesting result found by Brannon was that when words were presented in sentences, the subjects identified nearly 50% of them, but they were able to identify only 30-35% of words when they were in isolation.[21]

Sumby and Pollack attempted to examine the contribution of visual factors to oral speech intelligibility as a function of signal-to-noise ratio. Subjects used in this study had no formal lipreading training. Results indicated that visual perception was an important factor under severe noise conditions and that the visual contribution to intelligibility increased as the signal noise ratio decreased.[22]

These findings indicate that auditory and visual cues together are quite definitely superior to auditory cues alone. This study and O'Neill's study,[23] mentioned above, are unique in that both of these studies were involved with examining stimulus materials and the contribution visual perception had in receiving communication for the lipreader while the auditory stimulus was masked out by noise.

---

[21]J. B. Brannon, "Speech Reading of Various Speech Materials," Journal of Speech and Hearing Disorders, 26 (1961), pp. 348-354.

[22]W. H. Sumby and I. Pollack, "Visual Contribution to Speech Intelligibility in Noise," Journal of the Acoustical Society of America, XXVI (1954), pp. 212-215.

[23]J. J. O'Neill, op. cit.

O'Neill reported that the perception of the phoneme had the greatest effect on the identification of consonants.[24] Simmons stated that the phoneme plays an important role in the comprehension of speech through lipreading.[25]

It appears that most of the research done by the John Tracy Clinic was an attempt to find the basic units of lipreading stimulus material mainly through the principles of structural linguistics. Lowell, Woodward, and Barber in 1960 reported about one of several studies based on a linguistic approach to the study of lipreading. It was their purpose to develop a theoretical model of perception in lipreading. The three general linguistic levels of analysis were: phono-logical, grammatical, and lexical. In this experiment a series of monosyllabic English nouns were used as stimuli. They found that the twenty-two initial consonants of English appeared to fall into seven visually contrastive units.[26]

Lowell, in 1961, found that the structure of the English language seems to influence lipreading scores on a

---

[24]J. J. O'Neill, "An Exploratory Investigation of Lipreading Ability Among Normal Hearing Students," Speech Monographs, XVIII (1951), pp. 309-311.

[25]Audrey Simmons, "Factors Related to Lipreading," Journal of Speech and Hearing Research, II (December, 1959), pp. 340-352.

[26]Edgar Lowell, Mary Woodward, and Carroll Barber, Education of the Aurally Handicapped: A Psycholinguistic Analysis of Visual Communication, Coop. Res. Proj. No. 502, University of Southern California, John Tracy Clinic, (Los Angeles: 1960).

filmed lipreading test. He pointed out that parts of speech progress from the least to most difficult in the following order: pronouns, verbs, nouns, prepositions, adjectives, adverbs, and conjunctions. Questions are easier to lipread than declarative sentences. One and two letter words are about as difficult as four and five letter words, with longer words increasing in difficulty as their length increases. Lowell also suggested that the best vowel-consonant ratio for successful lipreading is an equal number of vowels and consonants. Facial expressions affect lipreading in that an unsmiling face is easier to lipread than a smiling face.[27]

Speaker Characteristics

Research concerned with the speaker's facial characteristics and factors such as speaker rate and expression certainly have their place of importance in the lipreading process. In 1943, Montague stated that the lipreader doesn't watch and lips alone but watches the whole face and body of the speaker. Montague thinks that the speaker with the alive, mobile facial expression, can be understood visually much better than those who have the cultivated or poker-face expression.[28]

---

[27]Edgar Lowell, "New Insights into Lipreading," Rehabilitation Record, II (July-August, 1961), pp. 3-5.

[28]Harriet Montague, "Lipreading--A Continuing Necessity," Journal of Speech and Hearing Disorders.

Lowell, Woodward, and Barber found that a full-face view of the speaker and what they called a profile view, a 45° angle, were equally good for lipreading purposes.[29] Several other experiments have been accomplished which pertain to facial angle of the speaker as well as distance of the speaker for the lipreader. Neely reported that the addition of visual cues to the auditory cues raised the intelligibility of received speech by approximately 20%. The purpose of his study was to attempt to quantify the effects of visual cues on listener-intelligibility scores, for speech in terms of distance and angle, from which the listener observed the speaker. Thirty-five male listeners with normal hearing were used in this study. Results indicated that: (1) the angle at which the listeners observed the speaker influenced their listener intelligibility scores; (2) distance did not seem to make a difference.[30]

Louis Stone, in a study of facial cues pertaining to context in lipreading, examined facial exposure, lip mobility, and facial expression. Stone used colored motion picture films of a trained actor, and these were viewed by normal hearing subjects. The results of this study indicated that a plainly set facial expression was easier to

---

[29]Lowell, Woodward, and Barber, loc. cit.

[30]Keith Neely, "Effects of Visual Factors on the Intelligibility of Speech," Journal of the Acoustical Society of America, XXVII (June, 1956), pp. 1275-1277.

lipread than a smiling expression. Results also showed that normal lip movement contributes to better lipreading performance than tight lip movement. Stone also found that the degree of facial exposure was significant to lipreading performance only when considered along with the two other variables. Full torso exposure was usually preferable to limited mouth exposure. Lip mobility had the most pronounced and consistent effect on the success of lipreading of the variables tested. Facial expression was second to lip mobility in importance.[31] This study was one of the first attempts to experiment with the effects of speaker characteristics on the process of lipreading.

Brannon and Kodman attempted to isolate variables relative to the materials which contributed to visual identifications made by a group of skilled and a group of unskilled lipreaders. They presented these two groups with word and sentence material. They found the following results: (1) little difference existed between the performance of skilled and unskilled lipreaders when viewing individual monosyllabic words; (2) performance of the skilled lipreaders greatly exceeded that of the unskilled when viewing the words presented in sentences; (3) visibility of the total movement form allowed the best cue for visual identification of a word; (4) difference in the size of the vertical mouth

---

[31]Louis Stone, "Facial Cues of Contest in Lip Reading," John Tracy Clinic Research Papers, V (December, 1957), cited in O'Neill and Oyer, op. cit., p. 48.

opening, familiarity of the word, and phonetic length of the one-syllable words were not significant factors in correct identification of words. They also pointed out that the visual identification of words was directly related to place of articulation.[32]

Two experiments have been attempted concerning the size and angle of the speaker's face on the television screen. Alfred Larr's was concerned with: (1) determining the size of image on a television screen for speech reading; (2) finding the facial angle which affords optimum visual perception for speechreading; (3) gaining some indication of the improvement in speechreading proficiency which occurred. Results of this study indicated: (1) The head and neck image and the upper torso image size allowed much better lipreading than when only the head or lips were visible; (2) The 45° angle was found to be the best facial angle for speechreading on television. Larr suggests that this study should be regarded as exploratory and that further research is needed.[33]

Smith pointed out some observations about television production for lipreading purposes. Several people who

---

[32]John B. Brannon, Jr. and Frank Kodman, Jr. "The Perceptual Process in Speech Reading," A. M. A. Archives of Otolaryngology, 70 (1959), p. 118.

[33]Alfred Larr, "Speechreading Through Closed-Circuit Television," Volta Review, LXI (January, 1959), pp. 19-20.

participated in his informal testing program complained that the "head shot" (forehead-to-chin) was unnatural. The "waist shot" (waist-to-head) rendered the face and lips too small to be perceived clearly on a normal television set in a home viewing situation.[34] It must be realized that this information is very subjective in nature, but certainly suggestions from this article are worthy of scientific investigation concerning the speaker image and size on the television screen for lipreading training.

Byers and Lieberman attempted to find out if the lack of uniformity in speakers might be caused by their differences in rate of speech. Four groups of experienced lipreaders were used in this study. Each group consisted of six "good" and six "poor" lipreaders, separated on the basis of a filmed lipreading test. Each group was exposed to a filmed version of the sentence lipreading test adapted from Utley, and each group lipread the filmed material at different rates of speed. Results indicated that lack of uniformity in speakers did not appear to be due to their rate of speaking.[35]

Black, O'Reilly, and Peck in a study pertaining to self-administered lipreading training found that all

---

[34]Robert Smith, "Let's Lipread: Television Production Criteria," American Annals of the Deaf, CX (November, 1965), pp. 571-578.

[35]V. W. Byers and L. Lieberman, "Lipreading Performance and the Rate of the Speaker," Journal of Speech and Hearing Research, II (September, 1959), pp. 271-276.

speakers are not uniformily readable.[36]

Lipreading ability and speaker characteristics seem to be very interrelated, and it appears that most of the available measures of lipreading ability are centered in the context of the word combinations and the articulatory aspects of speech. Reid suggests that this omits such important stimuli as gestures, bodily tensions, movement, and general situations, all of which go into interpreting of speech by the visual cue. She suggests that a finer test is needed that will measure the more elusive and subtle factors of communication.[37]

Voiced Speech and Whispered Speech

The speaker in the lipreading situation should speak as naturally as possible. Past research indicates that speakers are not uniformly intelligible to the lipreader. Many experts in the area of visual communication believe that the speaker should not whisper or mouth his words but should use his natural voice. However, research in this area of voiced vs. whispered speech is very sparse. Ewing states: "There is another fallacy which modern knowledge about lipreading exposes. Some old-fashioned teachers of

---

[36]John W. Black, Patricia P. O'Reilly, and Linda Peck, "Self-Administered Training in Lipreading," Journal of Speech and Hearing Disorders, 28 (1963), p. 185.

[37]Gladys Reid, "A Preliminary Investigation in the Testing of Lipreading Achievement," Journal of Speech and Hearing Disorders, 12 (1947), p. 82.

lipreading and many other people drop their voices or speak in a whisper whenever they talk to a lipreader."[38] Many times this may occur due to the lack of proper facilities for good lipreading training; however, many times it is quite possible that therapists are unaware that they are whispering in the therapy situation. Ewing goes on to say:

> Never deny this kind of vital stimulation to a partially deaf person. Speak to him at exactly the same level of loudness as when you talk to other people.[39]

Brehman brings up this problem giving a very realistic example:

> More serious perhaps is the fact that the speech therapist cannot easily duplicate the wide variety of lipreading situations encountered by students nor can the teacher simulate the various degrees of poor articulation typical of the outside world. In fact, the teacher-therapist often has very clear lip-movement characteristics but, alas, the world is not like this, and even here the situation is worsened if the teacher mouths the words without sound rather than speaking to the student from another room while being viewed through a window.[40]

The author continues by strongly suggesting that at best the movements are only approximations of the natural lip movements of oral speech when the words are mouthed without any sound.[41]

---

[38]Irene R. Ewing, Lipreading and Hearing Aids, (Manchester: Manchester University Press, 1946).

[39]Ibid.

[40]George E. Brehman, "Programed Discrimination Training for Lipreading," American Annals of the Deaf, CX (November, 1965), pp. 553-562.

[41]Ibid.

Very little scientific research has been attempted concerning the similarities or differences that occur between voiced speech and whispered speech. Moser, Oyer, O'Neill, and Gardner used an objective means of selecting monosyllabic words concerning item difficulty and frequency of occurrence in the language for use in testing the skill in recognition of words. Results indicated that the use of monosyllabic words, in which the words were mouthed using neither whisper or voice, was a reliable measure and correlated highly with a filmed lipreading presentation in which normal speaking, but no sound presentation to the lipreader was used.[42] One may believe, from this study, that there is not a significant difference between voicing and mouthing stimulus materials by the speaker. However, it must be remembered that once again this study used single word units as stimulus materials, there might be quite a different result using sentence materials.

A study by Fulton, mentioned earlier in this chapter, indicated some visible differences in the size and amount of lip openings, jaw movement, and mouth and teeth areas in subjects between voiced and unvoiced words.[43]

---

[42]H. Moser *et al.*, *Selection of Items for Testing Skill in Visual Reception of One-Syllable Words*, Department of Speech, Ohio State University. Development Fund No. 5818 (Columbus, Ohio, 1958).

[43]Fulton, *op. cit.*

One experiment, concerned primarily with speech, should be mentioned before this discussion is concluded. Harbold, in 1958, obtained listener judgments of vowel pitch when these were both voiced and whispered by four speakers. Results of this study indicated that listener judgments of the relative pitch of vowels were not independent of the vowel itself. High correlation between rank order of voiced and whispered speech types was impressive in view of the fact that the latter type does not contain the fundamental frequency ordinarily credited as a physical basis for pitch interpretation. There seems to be much support to further the contention that pitch judgments are not entirely dependent upon the fundamental frequency.[44]

Summary

Conclusions to be drawn from this review seem to indicate that speakers are not uniformily intelligible to the lipreader. This may be due mainly to the variation in preciseness of articulation, flexibility of lip movements, or mobility of facial expression. Very little information is available concerning differences and/or similarities between voiced and whispered stimulus material by speakers in the lipreading situation.

---

[44]George J. Harbold, "Pitch Ratings of Voiced and Whispered Vowels," Journal of the Acoustical Society of America, 30 (July, 1958), pp. 600-601.

It is quite obvious that the majority of current research experiments accomplished, concerning measurement of lip movement, have been exploratory in nature. Most of the measures have been made utilizing frame-by-frame analysis of motion picture film. While certain broad measures can be made off motion-picture film, research is still needed to find measures that quantify actual movement occurring on the lips, as well as on other areas of the speaker's face. Oyer pointed out that the lack of adequate test instruments, and the extreme difficulty of isolation and controlling variables have probably affected the amount of research in the areas of aural rehabilitation.[45]

It would seem quite safe to assume that cooperative efforts from several related professional areas are needed before finer scientific information can be accomplished concerning the factors and variables that exist in the lipreading process. This is also quite evident in the other areas of aural rehabilitation. In discussing the research needs for the general areas of aural rehabilitation, Oyer states his opinion that very little has been done and much remains to be accomplished if we are to progress more scientifically toward the habilitation and the rehabilitation of the

---

[45]H. J. Oyer, "Research Needs in Aural Rehabilitation," Aural Rehabilitation of the Acoustically Handicapped, Department of Speech, Michigan State University (East Lansing, Michigan, SHSLR No. 266, 1966), p. 138.

acoustically handicapped.[46] When offering ideas that can produce improved research in the areas of aural rehabilitation, he suggests:

> We must bring to bear the knowledges and skills of the engineer, the physiologist, the special educator, the psychologist, the speech scientist, etc. For only through concerted efforts can real forward movement occur in garnering of information in this complex area of aural rehabilitation.[47]

---

[46]*Ibid.*, p. 136.

[47]*Ibid.*, pp. 136-137.

CHAPTER III

SUBJECTS, EQUIPMENT, MATERIALS AND PROCEDURES

Subjects

The subject population consisted of five male and five female graduate students selected from the Department of Speech at Michigan State University. The male group of subjects ranged from 24 to 33 years of age. The female group ranged from 24 to 34 years of age. The median age for the male group was 28 years, and for the female group 29 years.

Equipment

The following equipment was employed in this investigation:

A. Polygraph (Grass, Model 5-D).

B. Low-level D. C. Preamplifier (Grass, Model 5PLK).

C. D. C. Drifer Amplifier (Grass, Model 5E).

D. Ink Writing Oscillograph (Grass, Model 5DWC).

E. Recording Chart Paper (Grass type C25-4").

F. Plethysmograph (Parks Electronics Lab., Model 270).

G. Mercury-rubber Strain Gauges (Parks Electronics Lab., inside diameter .015" x outside diameter .04", 14 inch length). Gauges equipped with 48 inch flexible vinyl covered wire leads.

H. Metal Probe.

I. Metric Ruler.

Materials

The following materials were employed in this study:

A. Aerosol Adherent (Becton, Dickinson, Ace Adherent).

B. Surgical tape, plastic.

C. Towels and Kleenex.

D. Stimulus Material. Form A of the Utley Lip Reading Test[1] was used for the stimulus material in this study. Form A consists of a list of thirty-one common expressions and sentences. The list was a sufficient representation of average American common expressions and sentences.

This list of thirty-one common expressions and sentences was randomized to prevent any effect of word order in this study. Twenty individual randomizations were prepared so that each subject appearing in the project read a separate randomization of the lists of stimulus material. Each subject read two randomizations, voicing one randomized list and whispering another randomized list. The sentences and common expression sequence, for each list were determined by use of

---

[1]Jean Utley, "How Well Can You Read Lips?" Teacher's Lesson Manual and Motion Picture (Chicago: DeVry Corporation, 1946).

a table of random numbers.[2] The list of stimulus material used in this study is presented in Table 1.

Procedures

Before the experimental procedures are explained, recent information shall be reviewed, to suggest a new development of measuring and amplifying fine movements.

Possible New Method for Measuring Fine Movements. The professional fields of physiology and medicine have explored new ways of securing valuable diagnosis and objective measurements during arterial surgery. In 1953 R. J. Whitney first described the use of a simple mercury strain gauge for the study of forearm blood flow. The purpose for using this strain gauge was to aid in the selection of patients inflicted with arteriosclerosis obliterans, or obstruction of the arteries. The gauge consists of a small caliber latex rubber tube filled with mercury. When this is placed about a finger or toe, pulse volume changes in the digit produce a corresponding lengthening of the gauge with its contained mercury column, thereby increasing the electrical resistance of the mercury column. This variable resistance is arranged to form one side of a Wheatstone bridge, an instrument for measuring electric resistance, which is coupled to an alternating current bridge circuit to allow vacuum tube amplification of the resistance changes.

---

[2] H. M. Blalock, Jr., Social Statistics (New York: McGraw-Hill Book Company, Inc., 1960), pp. 437-440.

TABLE I

UTLEY LIP READING TEST

FORM A

1. All right.
2. Where have you been?
3. I have forgotten.
4. That is right.
5. I have nothing.
6. Look out.
7. How have you been?
8. I don't know if I can.
9. How tall are you?
10. It is awfully cold.
11. My folks are home.
12. How much was it?
13. Good night.
14. Where are you going?
15. Excuse me.
16. Did you have a good time?
17. What do you want?
18. How much do you weigh?
19. I can't stand him.
20. She was home last night.
21. Keep your eye on the ball.
22. I can't remember.
23. Of course!
24. I flew to Washington.
25. You look well.
26. The train leaves every hour.
27. You had better go slow.
28. It says that in the book.
29. We got home at six o'clock.
30. We drove to the country.
31. How much rain fell?

The instrument, in the above mentioned form, has a sensitivity such that a change in length of the gauge of only two microns can be amplified to produce a one millimeter deflection on the record. This increase in sensitivity makes it possible to detect and record minute changes in digital blood flow.[3] As early as 1961 this new simple strain gauge plethysmograph had proved to be extremely valuable in selecting patients for reconstructive surgery. According to Strandness, Radke, and Bell, the ease and simplicity of application of this instrument allowed its routine use in evaluating patients with vascular disease. Its primary clinical use was in finding the extent and location of main vessel occlusions.[4]

Improvements were made in the mercury strain gauge plethysmograph in 1963. The latex gauge, which was originally used, was not durable enough to withstand repeated daily use and, in 1963 gauges were constructed with a very elastic synthetic called sialastic. This material proved to be stronger and more durable, without loss of sensitivity, than latex. Also a new plethysmographic matching circuit converted

---

[3] R. J. Whitney, "The Measurement of Volume Changes in Human Limbs," Journal of Physiology, 121 (London, 1953), pp. 1-27.

[4] D. E. Strandness, Jr., M. D., H. M. Radke, M. D., and J. W. Bell, M. D., "Use of a New Stimplified Plethysmograph In the Clinical Evaluation of Patients With Arteriosclerosis Obliterans," Surgery, Gynecology and Obstetrics, 112 (1961), pp. 751-756.

resistance changes of the sialastic mercury strain gauge to a voltage change suitable for the input of any standard electro-cardiograph for further amplification and recording. These improvements have remained since 1963, and have caused this instrument to have widespread use. With the use of the sialastic mercury strain gauge and the plethysmograph, it is possible to: (1) measure segmental leg pressures; (2) study digit pulse contour and volume; (3) study slow wave activity and sympathetic reflexes; and (4) perform venous congestion test and quantitate difital blood flow. There are four major areas in which the use of the plethysmograph is helpful in clinical medicine: (1) as a diagnostic tool; (2) in preoperative evaluation and screening; (3) in operative monitoring of patients selected for reconstructive surgery, and (4) in early and late follow-up examinations.[5]

Recent studies have been undertaken with mercury strain gauge plethysmography concerning ankle pressure responses after reconstructive arterial surgery. Pre-operative information via strain gauge plethysmography and arteriography shows abnormal exercise response indicating the problem of blockage, or reduction of arterial blood flow. If surgery is successful, the surgeon notes return of the pulse movement

---

[5]G. E. Gibbons, M. D., D. E. Strandness, Jr., M. D., and J. W. Bell, M. D., "Improvements in Design of the Mercury Strain Gauge Plethysmograph," Surgery, Gynecology and Obstetrics, 116 (1963), pp. 679-682.

distal to the reconstruction of the artery.[6]

It would appear to this writer that the measurement of lip movement by mercury strain gauge plethysmography could possibly contribute much new information concerning speed and amount of lip movement present on speaker's faces during the lipreading process. Speakers are not uniformly intelligible to the lipreader probably due to the variation in precision of articulation, flexibility of lip movement, and mobility of facial expression.

As early as 1943, Mason observed the lack of objective measurement concerning lipreading, and stressed the need for objective and adequate measurement.[7] Lowell in 1964 stated: "What we need more than anything else at this time is the development of measuring instruments. Until we get the yardsticks comparable to those in the physical sciences we are not going to make the progress that they have."[8]

Pilot Study. Early in the planning for this project, it became evident that much pilot work would be necessary in order to develop a reliable method for the measurement of certain facial movements.

---

[6]D. E. Strandness, Jr., M. D., "Abnormal Exercise Responses after Successful Reconstructive Arterial Surgery," Surgery, 59 (1966), pp. 325-333.

[7]Marie K. Mason, "A Cinematographic Technique for Testing Visual Speech Comprehension," Journal of Speech and Hearing Disorders, VIII (September, 1943), pp. 271-278.

[8]Edgar Lowell, "Research: Needs and Goals," Auditory Rehabilitation In Adults, Cleveland Hearing and Speech Center, Western Reserve University (Cleveland, Ohio, 1964), pp. 173-179.

Results of the pilot work indicated the following: (1) that two utterances of each sentence were insufficient because one could not be certain that these results represented a normal utterance. There was little consistency with the two repetitions. The first response to the subject was often obstructed by such preparatory actions as coughing, clearing the throat, swallowing, and the intake of breath; (2) Investigation using as many as fourteen repetitions of the same sentence exhibited boredom and fatigue from the subject, which produced what appeared to be artificial and stereotyped responses; (3) Five repetitions of each stimulus item were found to produce satisfactory results. Consistency of responses could be pinpointed in three out of every five responses. It was also noted that subjects were more motivated when they knew that they would be uttering the sentence or common expression just five times. This also promoted more cooperation and enthusiasm from the subjects; (4) It was found that the interval of time between each utterance of the stimulus material had to be varied in order to discourage an artificial, temporal patterning of speaker's responses; results indicated that the most satisfactory response was produced when a two-second interval between each response was used; (5) It was found that a verbal signal produced the most satisfactory results; this allowed greater flexibility at varying the interval between repetitions; (6) A quiet electric buzzer and a signal light were constructed as a means to signal the subject to produce the next utterance; neither of these proved to be satisfactory as each seemed to cause extraneous movements to occur.

Repeated applications of the strain gauge on the same subject were accomplished to check on the reliability of the gauge application over several repeated trials. The gauge was attached to two different subjects on three separate trials on one day, and again on the following day. The subject spoke the same group of sentences or common expressions on each trial. Graphic tracings of movements occurring on each trial were found to be very similar in amplitude, general configuration, and on the three measures to be used in the actual investigation (measures have been described in a later section of this chapter). This portion of the pilot work exhibited good reliability in terms of application of the mercury strain gauge. Finally, the results of the pilot work produced the experimental procedures as outlined in the following section and used in this study.

Experimental Procedures. In this study, each subject appeared individually and was allowed to familiarize himself with the list of sentences and common expressions prior to the actual investigation. Any questions concerning the stimulus material were asked and clarified at that time. The subject was seated so that his back was to the recording apparatus and other equipment. All visual and auditory distractions were kept to a minimum, and every effort was attempted to keep the subject relaxed.

The aerosol adherent was gently sprayed on the facial area surrounding the lips, on the nose, and on the chin. This material enables a much more secure bond with the plastic surgical tape.

Once the aerosol spray was sufficiently dry, the mercury rubber strain gauge was attached to the subject's face while his facial muscles were at rest with his mouth closed. The gauge was then attached to the subject's face at eight different points. It was first attached to the left corner of the lower lip, followed the lower border of the lower lip to the middle of that lip and attached to the face, and then on to the right corner of the lower lip and secured to the skin. The gauge was then attached to the right corner of the upper lip and drawn along the border of the upper lip and attached at the philtrim and then to the left corner of the upper lip and attached as before. At this point the gauge was brought loosely to the nose, attached at the tip of the nose and drawn to the chin for the final attachment. Each one of these attachments was made with plastic surgical tape approximately .25" x .50" in size. A small metal probe was used to apply pressure to the tape to secure good contact of the tape at all points around the strain gauge and to the skin.

The strain gauge was stretched between each point of attachment to ten per cent of its unstretched length as recommended by the manufacturer. Measuring the distance from each attachment to the next point of attachment on the skin was accomplished with a metric measure. This length was marked on the unstretched gauge, and then the gauge was stretched so that the mark was beyond the point of attachment on the skin by ten per cent of the unstretched length. At that point the gauge was attached to the face.

Figures 2 and 3 illustrate the placement of the strain gauge.

Figure 2. Diagram of strain gauge placement.

Figure 3. Picture of subject with strain gauge placement completed.

The functions and past experimental research concerning the mercury-rubber strain gauge and the plethysmograph were discussed earlier in this chapter. Some advantages in the use of the mercury strain gauge are that: (1) it is quiet; (2) temperature is not a frequent problem; (3) the frequency response of the gauge depends on the tension and dimensions of the gauge; (4) the gauge must be used under tension.[3]

---

[3]Loren Parks, A Versatile Plethysmograph for Research--Model 270 (Beaverton, Oregon: Parks Electronics Lab., 1966).

The plethysmograph is often used to record small changes in the volume of digits, limbs, etc. It allows for two main methods of detecting volume changes: (1) the impedance method, using hypodermic or surface electrodes to detect the electrical impedance (resistance) of the object under study; (2) the circumference method, which was selected for this present investigation, used the mercury-rubber strain gauge as described earlier in this chapter.[4]

The leads from each end of the strain gauge were connected to the long and common poles of the strain gauge input of the plethysmograph. The D. C. output of the plethysmograph was then fed into the low-level D. C. pre-amplifier of the polygraph, which was adjusted to an input impedance of 20K with a sensitivity setting of 20 millivolts per centimeter. The polygraph, in turn, was connected to the driver amplifier, which amplified the signal to the oscillograph. The ink writing oscellograph was adjusted to a paper speed of 25 millimeter per second. The baseline of the tracing was adjusted to the same point for each subject.

Once the strain gauge was permanently placed in position on the subject, a five-minute period was allowed for the individual to adapt to speaking normally with the gauge.

The strain gauge seemed to present little physical resistance to movement. However, the five-minute period of

---

[4] Ibid.

adaptation was helpful due to the obvious initial sensation, noted by subjects, of having this material attached to the face. The following set of instructions was then read to the subject:

> You are about to participate in a project to measure objectively differences in certain facial movements during the production of common expressions and sentences. You have already had the opportunity to familiarize yourself with those common expressions and sentences. You are to say each one in the list as a separate and individual sentence or common expression. You are to speak in a normal, relaxed conversational tone of voice. Begin each sentence or common expression from a closed and resting mouth position and return to that position at the end of the common expression or sentence. You are to say each sentence or common expression upon a verbal signal from the experimenter. There will be a short interval between each utterance. Please do not attempt to anticipate the signal. You will repeat each sentence and common expression five times. The experimenter will help you keep your place on the list by stating the number of the sentence as you begin a new sentence. Once again, please remember to begin each sentence and common expression from a closed resting mouth position and return to that position after each sentence and common expression. Are there any questions?

Then the subject produced the common expressions and sentences on the list of stimulus material. A minimum of two seconds was maintained between each repetition with this interval varied in order to prevent a patterned response from occurring. Stimulus material was timed by means of a timed stylus on the oscillograph that marked one-second intervals. The verbal signal for an utterance was not given until the subject had returned to a closed and resting mouth position as exhibited by the writing stylus of the oscillograph returning to a stable position on the baseline on the recording paper. After the subject had finished uttering the list, in normal conversational manner, he was allowed to rest for a moment, and then the investigator read the following set of instructions:

> You are now to whisper each sentence and common expression in this new list. You have also had an opportunity to familiarize yourself with this list. Perform on this list in the same way as you did on the first list except say each sentence and common expression with your normal whisper. Would you please whisper the first sentence in your normal whisper?

At this point the subject whispered the first sentence on the list in order to ensure both the subject and the experimenter that the subject was not just mouthing the sentence, but was using a whisper. Once this was achieved, the set of instructions was continued as follows:

> Once again, please remember to begin whispering each sentence and common expression from a closed, resting, mouth position and return to that position after each sentence, just the same as you did for the first list. Are there any questions?

The subject then whispered the sentences and common expressions on this second list of stimulus items. The same procedure was followed as mentioned above following the first set of instructions.

Measurements: Each time the subject uttered one of the sentences or common expressions, the stylus of the oscillograph was deflected from the baseline of the recording paper. The stylus produced a tracing that indicated the relative intensity of the facial movement occurring on the area of the face covered by the strain gauge and the amount of time it took the facial movement to occur, and it also reflected changes in movement pattern as movements took place. Changes in the movement pattern were exhibited on the tracing by changes in the direction of the traced curve from positive to negative; negative to positive direction; or a period of zero change of direction on the tracing. These changes were to be noted as inflection points and established points of orientation for certain measurements. The beginning of a tracing, or curve, was defined as the point at which the curve separated from the baseline and the ending of a sentence or common expression as the point where the curve again joined the baseline (see Figure 4).

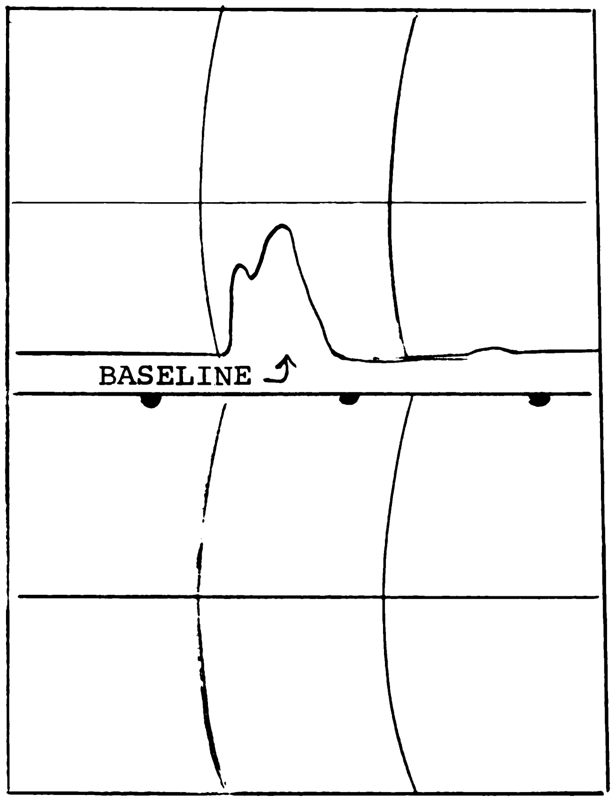

Figure 4. Illustration of tracing.

Three individual measures were made on these tracings. In order to obtain representative measures of the production of each sentence and common expression, three of the five utterances for each sentence and common expression by each subject were selected for measurement on each of the three measures. The utterances were selected for measurement that presented the greatest degree of similarity to each other, both in general configuration of the tracing and in amplitude of the tracing. A mean score value for each of the three measures of these three utterances was then obtained for each sentence. This value was then taken as a representative score for each of the measures on each sentence and common expression for every subject (see Figure 5).

One of the three measures is the measure of the total duration (D) of the curve, giving an estimate of the time taken to utter the sentence or common expression. The second measure is a measure of the amount of maximum movement (M) that occurs in each sentence and common expression for each subject. The measure is obtained by measuring the distance from the baseline to the point of the traced curve which is farthest from the baseline. The final measurement considers the amount of time (T) it takes each subject to that point of maximum movement from the time movement is initiated for each sentence and common expression (Figure 5).

Concerning the statistical analysis of this data, a mean score was obtained over the three measured utterances

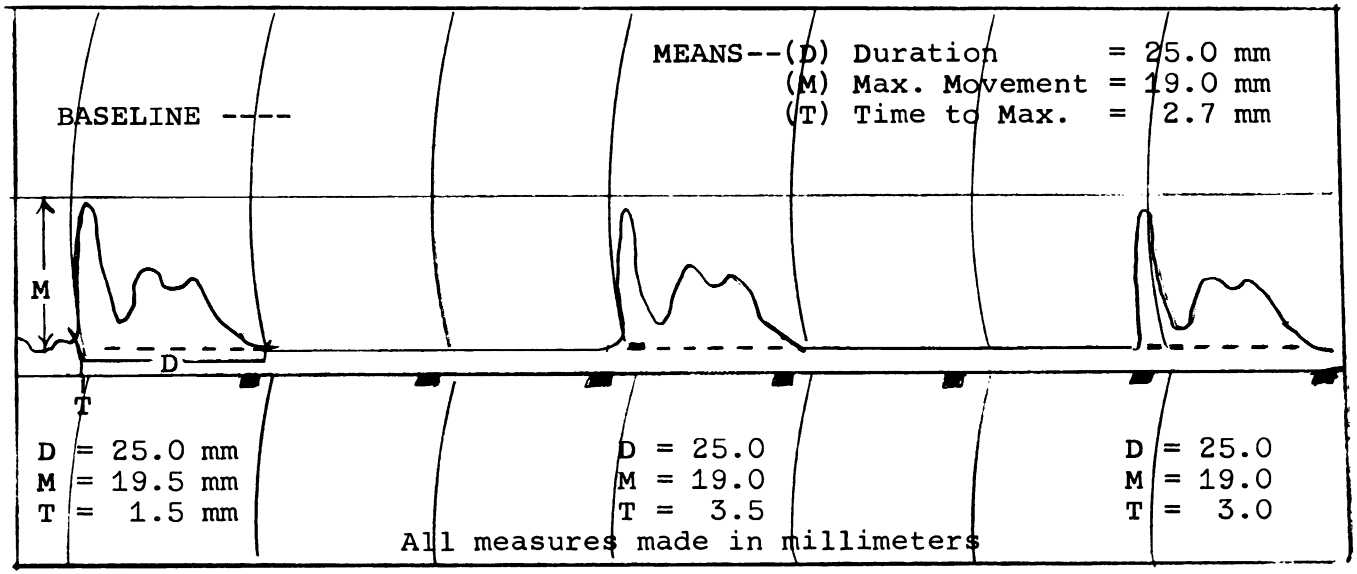

Figure 5. Illustration of three utterances selected out of five possible utterances of the voiced common expression "How tall are you?" Measurements made are also shown.

for each sentence and common expression, when voiced and when whispered by each subject, for each of the three measures employed. These mean scores served as the criterion value for a given subject in the analysis of the data.

CHAPTER IV

ANALYSIS AND DISCUSSION

Introduction

The three measures, which were discussed in chapter III, were obtained from tracings of certain facial movements from each speaker's production of the list of common expressions and sentences. The score value for each subject, on each measure, was a mean of three utterances of each of the common expressions and sentences. The three measures discussed in chapter III were as follows: (1) Duration, a measure of the total duration of facial movement, which was represented by the curve along the baseline, for each common expression and sentence, from initiation to termination of movement by a speaker; (2) Maximum movement, a measure of the greatest amount of maximum facial movement occurring for a speaker, obtained by measuring the distance vertically from the baseline to the point of the curve farthest from the baseline for each common expression and sentence; (3) Time to maximum facial movement, obtained by measuring horizontally along the baseline the distance from the point of the initiated movement to that point of greatest amount of maximum movement are illustrated in Figure 8. For each speaker the above three measures were obtained when the speaker voiced each sentence and common expression and then when he whispered each sentence and common expression. Therefore, with thirty-one sentences and expressions, a total of ninety-three voiced measures and ninety-three whispered measures was obtained for each speaker.

Hypotheses

In order to answer the questions previously stated in chapter I, the following null hypotheses were proposed and statistically analyzed:

1. There is no significant difference between the mean movement scores of males and the mean movement scores of females in the duration of certain facial movements when producing common expressions and sentences by voice.
2. There is no significant difference between the mean movement scores of males and the mean movement scores of females in the duration of certain facial movements when producing common expressions and sentences by whispering.
3. There is no significant difference in the duration of certain facial movements between the voiced mean movement scores and whispered mean movement scores, for common expressions and sentences, when produced by males or by females.

4. There is no significant difference between the mean movement scores of the males and the mean movement scores of the females in the amount of maximum movement occurring, for certain facial movements, when producing common expressions and sentences by voice.
5. There is no significant difference between the mean movement scores of males and the mean movement scores of females in the amount of maximum movement occurring, for certain facial movement, when producing common expressions and sentences by whisper.
6. There is no significant difference in the amount of maximum occurring, for certain facial movements between the voiced mean movement scores and the whispered mean movement scores for common expressions and sentences produced by males or by females.
7. There is no significant difference in the amount of time taken for maximum movement to occur, for certain facial movements, between the mean movement scores of males and the mean movement scores of females when voicing common expressions and sentences.
8. There is no significant difference in the amount of time taken for maximum movement to occur, for certain facial movements, between the mean movement scores of males and the mean movement scores of females when whispering common expressions and sentences.

9. There is no significant difference in the amount of time taken for maximum movement to occur, for certain facial movements, between the voiced mean movement scores and whispered mean movement scores for expressions and sentences for males or for females.

Analysis

Means were obtained for each speaker for each of the three measures, both voiced and whispered. These means were then computed into grand means for each measure for males, and for females, for both voiced and whispered speech (see Table 1).

Table 1.--Means Employed in Comparing Differences between Sex Groups, and Voiced and Whispered Speech for the Three Measurements.*

Sex Groups	Measurements					
	Duration		Movement		Time	
	Voiced	Whisper	Voiced	Whisper	Voiced	Whisper
Males	36.12	33.69	21.01	19.69	13.72	14.06
Females	34.79	34.90	15.19	16.29	12.90	12.42

*Mean scores in millimeters

The data were subjected to a two-factor design with repeated measures on one factor. This analysis of variance design, which was developed by Winer,[2] was employed three times, one analysis for each of the following three measures obtained: (1) duration; (2) amount of maximum movement; (3) the amount of time taken for maximum movement to occur for certain facial movements. The time unit used in this study, to secure all measurements, was 25 millimeters per second. Therefore, the greater number of millimeters taken also meant a greater amount of time taken by a speaker to complete certain facial movements for the stimulus material.

Table 2 is the summary table for the two-factor analysis of variance design with repeated measures on one factor.

Table 2.--Summary Table of Analysis of Variance Performed to Determine Whether Duration of Certain Facial Movements Differed Across the Stimulus Material as a Function of Speaker Sex, and of Voiced and Whispered Quality.

Source of Variation	SS	df	Mean Square	F-ratio	
Sex (A)	0.01	1	0.018	0.000	ns
S's within group	187.54	8	23.442		
Quality (B)	6.728	1	6.728		
A x B	8.089	1	8.089	2.067	ns
B x S's within groups	26.027	8	3.253	2.48	ns
Total	228.405	19			

ns = non-significant

[2]B. J. Winer, Statistical Principles In Experimental Design (New York: McGraw-Hill Book Company, 1962), pp. 302-304.

The F-ratio was used in testing the significance of the variables of sex and quality. A significance level of .05 was considered to be necessary. The F statistic of 2.48 for the interaction of sex between voiced and whispered speech, for the duration of certain facial movements, was not significant at the .05 level. This indicated that there was no significant difference for the duration of certain facial movements, between males and females when stimulus materials were voiced and then whispered. Table 2 indicated for the measure of duration, that levels within sex, levels within quality, and interactions were nonsignificant. Therefore, the following null hypotheses could not be rejected:

1. There is no significant difference between the mean movement scores of males and the mean movement scores of females in the duration of certain facial movements when producing common expressions and sentences by voice.
2. There is no significant difference between the mean movement scores of males and the mean movement scores of females in the duration of certain facial movements when producing common expressions and sentences by whispering.
3. There is no significant difference in the duration of certain facial movements between the voiced mean movement scores and whispered mean movement scores,

for common expressions and sentences, when produced by males or by females.

It should be noted in Table 2, that the sum of squares indicates very large variability between subjects within the two sex groups; however, this variability evidently was balanced when the grand mean for each group was computed and therefore no significant difference between groups was indicated.

Figure 6 illustrates a difference between the two sexes when voicing and whispering common expressions and sentences.

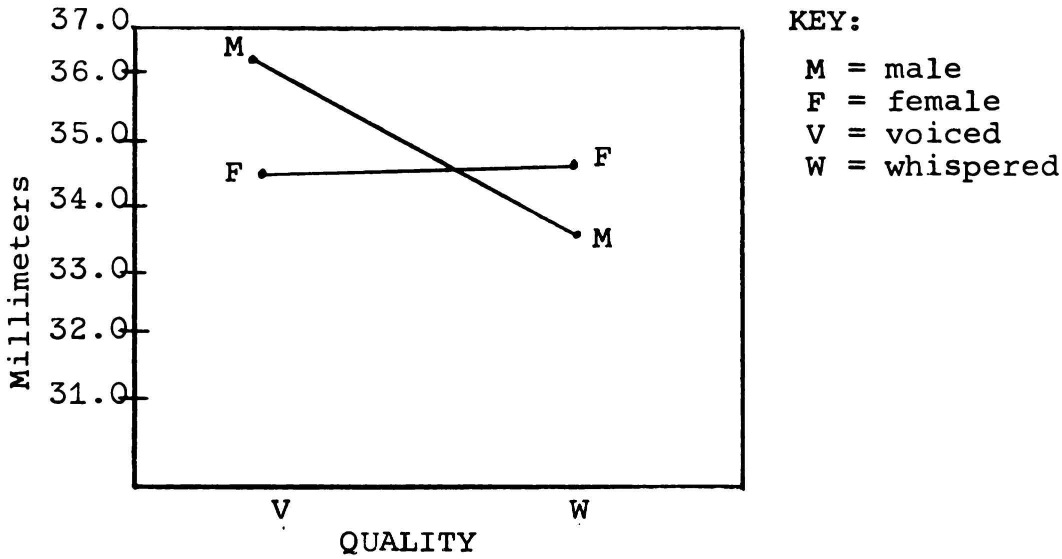

Figure 6. Shows differences in mean measurement of duration of certain facial movements, in millimeters, between male and female groups when whispering and voicing stimulus material.

The male group exhibited a mean of 36.13 mm when voicing and 33.69 mm when whispering stimulus material, indicating the duration of less facial movement when whispering than voicing. The female group performed in the opposing direction, exhibiting a slight increase in facial movement when whispering. The means for females were 34.79 mm when voicing and 34.91 mm when whispering. Difference between means was not significant for the statistic employed in this study. Certainly the differences are very small; however, this could be important because of the following observations: (1) The male group produced movement over a longer period of time than the female group when using voice. (2) When using whisper, the female group produced movement over a longer period of time than the male group.

Table 3.--Summary Table of Analysis of Variance Performed to Determine Whether the Amount of Maximum Movement of Dertain Facial Movements Differed Across the Stimulus Material as a Function of Speaker Sex, and of Voiced and Whispered Quality.

Source of Variation	SS	df	ms	F-ratio
Sex (A)	106.214	1	106.214	2.619 ns
S's within groups	324.325	8	40.540	0.012 ns
Quality (B)	0.057	1	0.057	1.627 ns
A x B	7.381	1	7.381	
B x S's within groups	36.290	8	4.536	
Total	474.267	19		

ns = non-significant

In Table 3 the F statistic of 1.627 for the interaction of sex between voiced and whispered speech for the amount of maximum movement occurring for certain facial movements was not significant at the .05 level. This indicated that there was no significant difference in the amount of maximum movement occurring, when uttering the stimulus material by voice and by whisper, between males and females. Table 3 indicated for the measurement of amount of maximum movement that levels within sex, levels within quality, and interaction were nonsignificant. The F statistic of 0.012 concerning the amount of maximum movement occurring for the qualities of voice and whisper across sexes was not significant at the .05 level. Therefore, the following null hypotheses could not be rejected:

4. There is no significant difference between the mean movement scores of males and those of females in the amount of maximum movement occurring, for certain facial movements, when producing common expressions and sentences by voice.
5. There is no significant difference between the mean movement scores of males and those of females in the amount of maximum movement occurring, for certain facial movement, when producing common expressions and sentences by whisper.
6. There is no significant difference in the amount of maximum movement occurring, for certain facial

movements between the voiced mean movement scores and the whispered mean movement scores for common expressions and sentences produced by males or by females.

Though the three preceding null hypotheses were rejected by the analysis of variance statistic used in this study, a comparison of means of the amount of maximum movement occurring between the male and female groups for voiced and whispered quality was performed (see Figure 7).

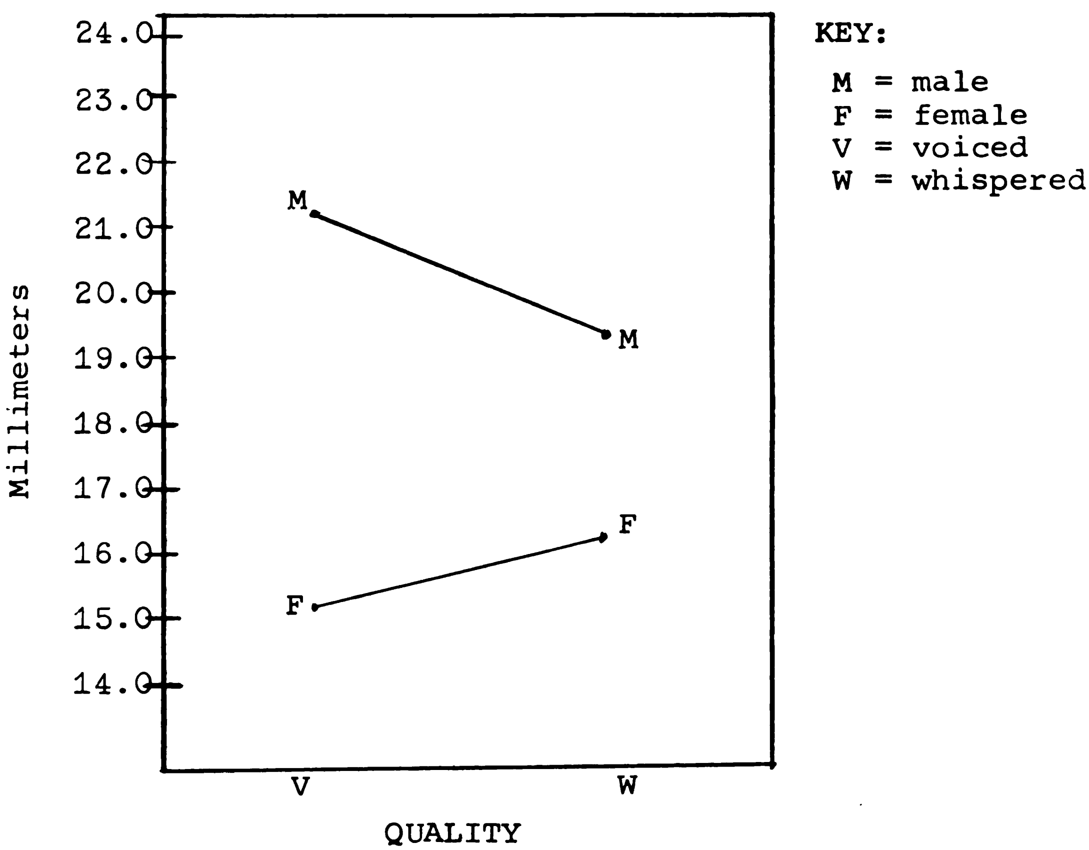

Figure 7. Shows differences in mean measurement of the amount of maximum movement occurring of certain facial movements, in millimeters, between male and female groups when whispering and voicing stimulus material.

Figure 7 illustrates that the mean amount of maximum movement for males was greater when voicing than when whispering. For the female group, the mean amount of maximum movement was less when voicing than when whispering. In both cases concerning quality, the mean amount of maximum movement was greater for males than for females.

In Table 4 the F statistic of 1.002 for the interaction of sex between voiced and whispered speech for the amount of time taken in millimeters for the maximum amount of movement occurring for certain facial movements was not significant at the .05 level. This indicated that there was no significant difference concerning the amount of time taken for the maximum amount of movement to occur, when uttering the stimulus material by voice and by whisper, between males and

Table 4. Summary Table of Analysis of Variance Performed to Determine Whether the Amount of Time Taken in Millimeters for the Maximum Amount of Movement to Occur for Certain Facial Movements Differed Across the Stimulus Material as a Function of Speaker Sex, and of Voiced and Whispered Quality.

Source of Variation	SS	df	ms	F-ratio
Sex (A)	7.576	1	7.576	0.656 ns
Subjects within groups	92.293	8	11.536	
Quality (B)	0.023	1	0.023	0.027 ns
A x B	0.861	1	0.861	1.002 ns
B x S's within groups	6.870	8	0.858	
Total	107.623	19		

ns = non-significant

females. Table 4 indicated that for the measure of time taken for the amount of maximum movement to occur, levels within sex, levels within quality, and interactions were non-significant. Therefore, the following null hypotheses could not be rejected.

7. There is no significant difference in the amount of time taken for maximum movement to occur, for certain facial movements, between the mean movement scores of males and those of females when voicing common expressions and sentences.
8. There is no significant difference in the amount of time taken for maximum movement to occur, for certain facial movements, between the mean movement scores of males and those of females when whispering common expressions and sentences.
9. There is no significant difference in the amount of time taken for maximum movement to occur, for certain facial movements, between the voiced mean movement scores and whispered mean movement scores for expressions and sentences for males or for females.

Though the statistic used in this study shows no significance, Figure 8 illustrates that the male group take more time to reach maximum amount of movement, for the stimulus material, than the female group. Males take longer to arrive at the point of maximum movement when whispering and less time when voicing. Females take more time to arrive at the point of maximum movement when voicing and less time when whispering.

To compute the statistics for this investigation, the Control Data Corporation 3600 Digital Computer was used.[1]

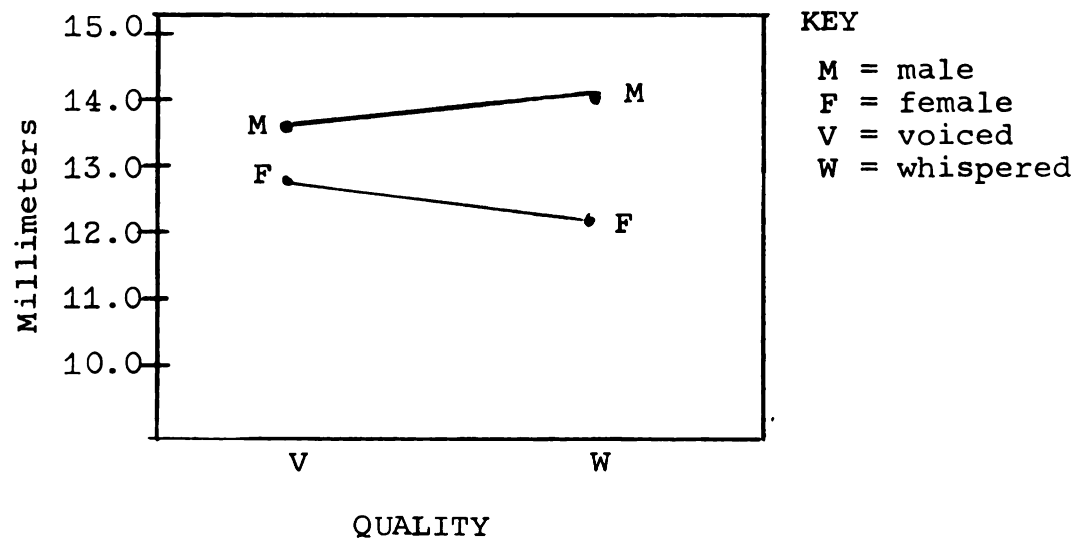

Figure 8. Shows differences in mean measurement of the amount of time in millimeters, taken for males and females to reach the maximum amount of movement when voicing and whispering the stimulus material.

Discussion

Analysis of the data showed that <u>no significant variation</u> of certain facial movements existed between males and

---

[1]Michigan State University, Agricultural Experiment Station, "Calculation of Basic Statistics on the BASTAT Routine," <u>STAT Series Description</u> No. 14 (March, 1966).

females when voicing and then whispering common expression and sentences for the following three measurements of movement: (1) duration of movement; (2) amount of maximum movement; (3) amount of time taken to reach point of maximum movement across the stimulus material.

It appeared that the most significant result of this study was the extreme similarity of grand means for males and females, when voicing and whispering common expressions and sentences, concerning all three measures involved in the study. All measures were made in millimeters, and differences in grand means were too small to be significant. These results make one question whether there is very much difference between whispering and voicing common expressions and sentences by male or female speakers. Certainly the objective physiological measures made in this study indicated no <u>significant</u> difference.

Some trends must be mentioned concerning the minor differences in mean score values of the three measures of the speaker variable during the production of the stimulus material by voice and then by whisper. Figures 6, 7 and 8 indicated the following results: (1) For all three measures, for <u>voicing</u> stimulus materials, the male group exhibited more facial movement than did the female group, and the grestest difference between the male and female group, mean scores, when voicing was a 5.28 mm difference in the amount of maximum movement utilized (see Figure 7). (2) For the three measures, when whispering the stimulus material, the male group exhibited only a 3.40 mm difference in amount of maximum movement over the female group. Figure 11 supports this decreased difference between sex groups from voice to whisper. Males exhibited less amount of maximum movement when whispering than when voicing, this tends to indicate that males under-exaggerate certain facial movements when whispering while females tend to exaggerate certain facial movements when whispering. To a lesser degree this same trend occurred for the duration of movement measure (see Figure 6).

The results of this study did not agree with general statements made concerning a difference in certain facial movements between voiced and whispered speech. More specifically, these results did not agree with the findings of Fulton.[2] Fulton was able to show that when speakers produced monosyllabic words unvoiced, greater variation and fluctuation existed than when voicing the words. Measurements for the unvoiced words were predominantly greater than when the same words were voiced. This was true for measurements of size of lip openings, mouth widths, jaw movements, and mouth and teeth areas between voiced and unvoiced words. Conclusions indicated the tendency toward exaggeration of these movements when speaking without voice.

---

[2]Richard M. Fulton' "Comparative Assessment of Visible Differences Between Voiced and Unvoiced Words," (Unpublished Master's Thesis, Department of Speech, Michigan State University, 1964).

Fulton's study and the present study were both concerned with measurement of movement occurring on speaker's faces when voicing and not voicing stimulus materials. It must be realized that Fulton was attempting to measure visible differences via motion picture film while this study was attempting to measure physiologically certain facial movements. The measurements made in this study are not necessarily visible.

Fulton's study has been mentioned because it is the only study that has been concerned with differences in measurements of facial movement between voiced and unvoiced stimulus materials.

Also, the results of his study indicated some visible differences between voiced and unvoiced words by the 6 speakers used. The present study indicated no significant differences concerning the sex variable or the quality (voice vs. whisper) variable.

The study by Moser, Oyer, O'Neill, and Gardner,[3] which was reviewed in chapter II, indicated that when monosyllabic words were mouthed by speakers and then voiced on a silent lipreading film, the speakers were lipread in both cases, and the mouthed presentation and voiced silent film presentation correlated highly. This study indicated that there was not a significant difference between voicing and mouthing stimulus materials by the speakers.

---

[3]H. Moser et al., Selection of Items for Testing Skill in Visual Reception of One-Syllable Words, Department of Speech, The Ohio State University, Development Fund No. 5818 (Columbus, Ohio, 1958).

CHAPTER V

SUMMARY, CONCLUSIONS, AND IMPLICATIONS FOR FUTURE RESEARCH

Summary

There is no doubt that the individual who has a permanent hearing loss can benefit from lipreading training, and certainly lipreading is an important recommendation toward the total rehabilitation for the hard of hearing individual. Many times the teaching of lipreading is a demanding task for both the teacher and the prospective lip-reader. During the first few meetings with the lipreader it is most important that the lipreading teacher be aware of all of the factors and variables operating in the lip-reading process. As Streng indicates: "The teacher's first task is not to discourage her pupils, but to encourage them and to stimulate them to want to learn lipreading."[1] Streng's suggestion is a good one, but even today it is very difficult for the teacher of lipreading to be certain what is the best method to use in which to motivate the potential

---

[1]A. Streng, W. J. Fitch, L. D. Hedgecock, J. W. Phillips, and J. A. Carrell, Hearing Therapy for Children (Second, Revised Edition, New York: Grune and Stratton, Inc., 1958), p. 197.

lipreader to lipread. Certainly more evidence is needed to indicate what speaker characteristics are most desirable in the lipreading situation, and if voice is really necessary when the speaker is presenting materials to the lipreader.

The purpose of this research was to investigate and analyze three aspects of the speaker variable during the production of code by voice and then by whisper. It is also the purpose of this study to demonstrate a means of measuring and quantifying measures of certain facial movements.

The review of the literature was divided into two parts. Part I consisted of ways and means that measurements have been made on speaker faces. It has been generally agreed that lip movements, eye movements, jaw movements, and mouth openings are important factors in determining whether a speaker is easy or difficult to lipread. Most of the investigations attempted in measuring movements have been accomplished by frame-by-frame analysis of moving picture film of speakers saying monosyllabic words, and homophenous words. Visible differences in the size of the mouth opening at the philtrum were revealed, and minute differences in mouth widths were also detected. One investigator attempted to secure several measurements by standardized simultaneous frontal and lateral photographs, lateral X-rays, plaster casts of a speaker's lips, and measurements of lip protrusion. Most of the studies concerned with measurements of facial movement were exploratory in nature, and more research needs to be continued in this area.

In Part II, literature pertaining to other factors related to lipreading as well as studies concerned with voiced and whispered speech were reviewed. The ease or difficulty in which different units of code are lipread were reported. Study has been accomplished with the visibility of consonants vs. vowels homophenous words, and sentence length, along with several other types of code. The visual analysis of stimulus material seems to be one of the most hopeful areas for future research in lipreading.

Research pertaining to speaker's facial characteristics were reviewed. This included studies concerned with speaker rate, expression, best face angle for lipreading, and lip mobility. Again, much work was accomplished with use of speakers pictured on motion picture film. Results of much of the research done indicated some uniformity between speakers, but certainly finer tests and equipment are needed to measure these facial characteristics of the speaker.

Investigations available concerning voiced and whispered speech were reviewed. This area seems to lack enough reliable information to form any clear-cut conclusions. Many statements have been made in the past, concerning differences between voiced and whispered speech, by the speaker, in the lipreading situation. However, past research seems to be exploratory in nature and much future research is needed in this area.

The speaker subjects employed in this study consisted of five male and five female graduate students selected from the Department of Speech at Michigan State University.

After a pilot study, a unique procedure was devised to measure speaker's facial movements when producing stimulus materials. Aerosol adherent was sprayed on the speaker's facial area surrounding the lips, on the nose, and on the chin. A mercury strain gauge, which detects minute changes in movement, was attached to the speaker's face while he was relaxed and at rest. Beginning at the left corner of the lower lip the gauge was attached with a small amount of plastic surgical tape, making a small point attachment. The aerosol adherent and the plastic surgical tape made a secure bond between the speaker's face and the gauge. This was done at six different points around the lip region of the speaker, and one attachment on the tip of the nose, and one on the point of the chin (see Figure 2, Chapter III)

Once the strain gauge attachments were made on the speaker's face, the leads from each end of the gauge were then connected to the long and common poles of the strain gauge input of the plethysmograph. The plethysmograph intensified movement measurements, and the output of the plethysmograph was fed into one of the D. C. preamplifiers on a polygraph, feeding one channel of the polygraph. The movements detected by the strain gauge were intensified by the plethysmograph, and were recorded on the polygraph strip chart recording paper.

The stimulus material used in this study was the list of thirty-one common expressions and sentences from Form A of Utley's lipreading test.[2] Twenty separate randomizations of the list were prepared to prevent any order effect of similar words. Each speaker voiced one list and whispered a second list. The speaker subjects were given an opportunity to familiarize themselves with the lists previous to the experiment. Once the strain gauge was attached to the speaker's face, the speaker was allowed a five-minute period to adapt to speaking normally with the gauge. During the investigation each speaker voiced one randomized list and whispered another randomized list. When the experiment was completed, five females and five males had voiced ten separate randomized lists and had whispered ten separate randomized lists.

Each time the speaker uttered one of the sentences or common expressions, the stylus of the oscillograph on the polygraph was deflected from the baseline of the recording paper. The stylus produced a tracing that indicated the relative intensity of facial movement and changes in movement pattern as movements took place, on the area of the face covered by the strain gauge. Measurements made from the recorded movements secured on the chart paper included; a measure of a total duration of movement, amount of maximum

---

[2]Jean Utley, "How Well Can You Read Lips?" _Teacher's Lesson Manual and Motion Picture_ (Chicago: DeVry Corporation, 1946).

movement, and time to amount of maximum movement. These three measures were made for each sentence and common expression produced by each speaker. Therefore, there was a total of 93 whispered measures. The total experiment yielded 1860 measures for the ten subjects used. There were 930 voiced measures and 930 whispered measures.

One mean score was obtained for each male subject for each of the three measures voiced and each of the three measures whispered over the total list of 31 common expressions and sentences. Grand means were computed for the male groups for the three voiced measures and for the three whispered measures. The same procedure was followed for the female group. These means and grand means scores served as the score values used in the analysis of the data.

Conclusions

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

1. There is no significant difference in the amount of time taken for maximum movement to occur, for certain facial movements, between males and females when voicing and then whispering common expressions and sentences.

2. There is no significant difference between males and females in the amount of maximum movements occurring, for certain facial movements, when producing common expressions and sentences by voice and then by whisper.

3. There is no significant difference between males and females in the duration of certain facial movements when producing common expressions and sentences by voice and then by whisper.

4. There is no significant difference in the amount of time taken for maximum movement to occur, the amount of maximum movement, and the duration of certain facial movements, between voicing and whispering common expressions and sentences, when produced by males.

5. There is no significant difference in the amount of time taken for maximum movement to occur, the amount of maximum movement, and the duration of certain facial movements, between voicing and whispering common expressions and sentences, when produced by females.

6. This experiment has developed and demonstrated a refined method for measuring, quantifying, and amplifying speaker's facial movements.

Implications for Future Research

The results of this study indicated that there was no significant difference in certain facial movements, between male and female speakers when voicing and whispering common expressions and sentences for the measure secured in this investigation. However, a unique procedure was explored and accepted, after much preliminary investigation, for securing fine objective measurements of facial movement. This study was exploratory in nature, and many new areas for future research are indicated. Some of the suggestions offered for future research are as follows:

1. The objective physiological movement measurements of the eyebrow, head, ear, cheek, jaw, vertical and horizontal lip movements could be utilized to make measures of many facial movements simultaneously, via mercury strain gauge plethysmography.

2. The objective physiological measurements, via mercury strain gauge plethysmography, could be used to make measures of many facial movements simultaneously. Once measurements have been made, an expression rating of speakers, by a group of lipreaders could be performed. One could then attempt to view if there was any correlation between speakers that illustrated the greatest movement of stimulus material, and the subjective rating of the lipreaders of speakers expressiveness.

3. Replication of the present study using stimulus materials including both monosyllabic words, and common expressions and sentences. These stimulus materials could be voiced, whispered, and mouthed to investigate any similarities or differences between these three variables of quality.

4. It would be interesting to pursue a study investigating whether there is any correlation between the frame-by-frame analysis of motion picture film of a speaker and movement measures obtained by mercury strain gauge plethysmography of a speaker.

BIBLIOGRAPHY

BIBLIOGRAPHY

Books

American Hearing Society, New Aids and Materials for Lipreading. Washington, D. C.: American Hearing Society, 1943.

Blalock, H. M., Social Statistics, New York McGraw-Hill Book Company, Inc., 1960.

Bunger, Anna M., Speech Reading-Jena Method. Daniville, Illinois: The Interstate Press, 1944.

Davis, Hallowell, M. D. and Silverman, Richard. Hearing and Deafness. New York: Holt, Rinehart and Winston, Inc., 1960.

Ewing, Irene R., Lipreading and Hearing Aids. Manchester: Manchester University Press, 1946.

Harris, Donald J., Some Relations Between Vision and Audition. Springfield, Illinois: Charles C. Thomas, 1950.

O'Neill, John J., and Oyer, Herbert J. Visual Communication for the Hard of Hearing. Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1961.

Streng, A., et al. Hearing Therapy for Children, 2nd ed. revised, New York: Grune and Stratton, Inc., 1958.

Utley, Jean, "How Well Can You Read Lips?" Teacher's Lesson Manual and Motion Picture. Chicago: DeVry Corporation, 1946.

Winer, B. J., Statistical Principles In Experimental Design. New York: McGraw-Hill Book Company, Inc., 1962.

Articles and Periodicals

Black, J. W., O'Reilly, P. P., Peck, Linda. "Self-Administered Training in Lipreading," Journal of Speech and Hearing Disorders, 28 (1963), 185.

Brannon, J. B. "Speech Reading of Various Speech Material," Journal of Speech and Hearing Disorders, 26 (1961), 348-354.

Brannon, J. B., Kodman, F. "The Perceptual Process in Speech Reading," A. M. A., Archives of Otolaryngology, No. 70 (1959), 118.

Brehanan, George E. "Programed Discrimination Training for Lipreading," American Annals of the Deaf, CX (November, 1965), 553-562.

Byers, V. W., Lieberman, L. "Lipreading Performance and the Rate of the Speaker," Journal of Speech and Hearing Research, II (September, 1959), 271-276.

Fromkin, Victoria A. "Lip Positions in American English Vowels," Language and Speech, VII (October-December, 1964), 215-225.

Fujimura, Osama. "Movements of the Lips in the Generation of Bilabial Consonants," Journal of Acoustical Society of America, No. 32 (July, 1960), 913.

Fusfield, Irving. "Factors in Lipreading as Determined by the Lipreader," American Annals of the Deaf, CIII (March, 1958), 229-242.

Gibbons, G. E.,M. D., Strandness, D. E., M. D., Bell, J. W., M. D. "Improvements in Design of the Mercury Strain Gauge Plethysmograph," Surgery, Gynecology and Obstetrics, 116 (1963), 679-682.

Harbold, George J. "Pitch Ratings of Voiced and Whispered Vowels," Journal of the Acoustical Society of America, 30 (July, 1958), 600-601.

Heider, F. K., Heider, G. H. "An Experimental Investigation of Lipreading," Psychological Monographs, LII (February, 1940), 124-153.

Keaster, Jacqueline. "An Inquiry into Current Concepts of Visual Speech Reception (Lipreading)," Larynogoscope, LXV (January, 1955), 80-84.

Larr, Alfred. "Speechreading Through Closed-Circuit Television," Volta Review, LXI (January, 1959), 19-20.

Lowell, Edgar. "Research: Needs and Goals," Auditory Rehabilitation in Adults. Western Reserve University (Cleveland, Ohio, 1964), 173-179.

Lowell, Edgar. "New Insights into Lipreading," Rehabilitation Record, II (July-August, 1961), 3-5.

Mason, Marie K. "A Cinematographic Technique for Testing Visual Speech Comprehension." Journal of Speech and Hearing Disorders. VIII (September, 1943), 271-278.

McGinnies, E., Conner, P. B., Lacey, O. L. "Visual Recognition Thresholds as a Function of Word Length and Word Frequency," Journal of Experimental Psychology, XLIV (1952), 65-69.

Montogue, Harriet. "Lipreading--A Continuing Necessity," Journal of Speech and Hearing Disorders.

Neely, Keith. "Effects of Visual Factors on the Intelligibility of Speech," Journal of the Acoustical Society of America, XXVII (June, 1956), 1275-1277.

Numbers, M. E. "An Experiment in Lip Reading," Volta Review, XII (1939), 261-264.

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

O'Neill, John J. "An Exploratory Investigation of Lipreading Ability Among Normal Hearing Students," Speech Monographs, XVIII (1951), 309-311.

Reid, Gladys. "A Preliminary Investigation in the Testing of Lipreading Achievement," Journal of Speech and Hearing Disorders, 12 (1947), 82.

Samuelson, Estelle. "Fundamentals of Lip-Reading, Including Demonstrations with Audience as Subjects," Larynogoscope, XXXXVII (April, 1937), 237-238.

Simmons, Audry, "Factors Related to Lipreading," Journal of Speech and Hearing Research, II (December, 1959), 340-352.

Smith, Robert. "Let's Lipread: Television Production Criteria," American Annals of the Deaf, CX (November, 1965), 571-578.

Strandness, D. E. Jr., M. D., Radke, H. M., M. D., Bell, J. W., M. D. "Use of a New Simplified Plethysmograph In The Clinical Evaluation of Patients with Arteriosclerosis Obliterans," Surgery, Gynecology, and Obstetrics, 112 (1961), 751-756.

Strandness, D. E. Jr., M. D. "Abnormal Exercise Response after Successful Reconstructive Arterial Surgery," Surgery, 59 (1966), 325-333.

Sumby, W. H., Pollack, I. "Visual Contribution to Speech Intelligibility in Noise," Journal of the Acoustical Society of America, XXVI (1954), 212-215.

Taafe, Gordon, Wong, Wilson, "Studies of Variables in Lip-reading Stimulus Material," John Tracy Clinic Research Paper, III (December, 1957).

Whitney, R. J. "The Measurement of Volume Changes in Human Limbs," Journal of Physiology, 121 (London:1953), 1-27.

Reports

Lowell, Edgar, Woodward, Mary and Barber, Carroll. Education of the Aurally Handicapped: A Psycholinguistic Analysis of Visual Communication, University of Southern California, John Tracy Clinic, Coop. Res. Proj. No. 502, Los Angeles, 1960.

Moser, H., et al. Selection of Items for Testing Skill in Visual Reception of One-Syllable Words. Department of Speech, The Ohio State University, Development Fund No. 5818, Columbus, Ohio, 1958.

Oyer, Herbert J. "Research Needs in Aural Rehabilitation," Aural Rehabilitation of the Acoustically Handicapped, Department of Speech, Michigan State University, SHSLR, No. 266, East Lansing, Michigan, 1966.

Unpublished Material

Fulton, Richard M. "Comparative Assessment of Visible Differences Between Voiced and Unvoiced Words." Unpublished Master's Thesis, Department of Speech, Michigan State University, 1964.

Joergenson, Ann Marie. "The Measurement of Homophenous Words." Unpublished Master's Thesis, Department of Speech, Michigan State University, 1962.

Mason, Marie K. "A Cinematographic Technique for Testing More Objectively the Visual Speech Comprehension of Young Deaf and Hard of Hearing Children,." Unpublished Doctoral Dissertation, Department of Speech, The Ohio State University, 1942.

Roback, Ila Mae. "Homophenous Words. "Unpublished Master's Thesis, Department of Speech, Michigan State University, 1961.

Other Sources

Michigan State University. Personal interview with Herbert J. Oyer, Chairman, Department of Speech, East Lansing, Michigan. June 28, 1967.