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AN INVESTIGATION OF INVOLUNTARY EYE BLINKS
DURING LIPREADING

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
School of The Ohio State University

By
Sharon A. Lesner, B.A., M.A., M.A.

* * * * *

The Ohio State University

1979

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ACKNOWLEDGMENTS

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CHAPTER I
INTRODUCTION

The speech message is usually highly redundant, that is, it carries a surplus of information. This information may be encoded, detected, transmitted and/or decoded in various sensory channels with the most important being the auditory and visual channels. Both the auditory and the visual speech message consist of a rapid succession of events which occur within specific temporal sequences and within brief periods of time. The normal and most efficient sensory channel for transmitting and decoding speech is the auditory system. If hearing impairment occurs or whenever an unfavorable signal to noise ratio exists, the visual system may be utilized to receive and transmit the speech message. When a person uses the visual system in this manner they are said to lipread.

Both normally hearing as well as hearing impaired persons either consciously or unconsciously lipread to facilitate communication. A wide range of skill exists with expert and poor lipreaders found in both groups. While attempts have been made to specify the variables and traits that are operative, we are still far from having a complete understanding of the lipreading process. Since lipreading is important to the hearing impaired, further study of the process seems warranted.
Lipreading is a visual-perceptual task so it is necessary to study the visual system in relation to lipreading if an understanding of the process is to occur. Both the auditory and visual systems are considered to be distance senses, yet an obvious difference exists between the manner in which the two systems function. While the auditory system transmits information continuously, the visual system is intermittent. That is, each time a person blinks, the visual system is functionally inoperative.

The significance of the intermittency of the visual system becomes obvious when one considers the nature of the speech information it must detect and transmit if a person is to lipread. Spoken language consists of a rapid succession of auditory and visual cues which result primarily from changes in the size and shape of the oral cavity. The decoding of the visual speech message is dependent upon the receiver discriminating the visible movements produced by the speaker. During conversational speech an average of five syllables per second are produced. This represents an average of 12.5 speech sounds per second so the duration of the articulatory movements made during speech averages 80 msec (Miller, 1951).

The average duration of an eye blink has been found to be from 300 to 400 msec (Adler, 1959). During the time the eye is closed as well as the time immediately preceding and following the blink, the visual system is functionally inoperative so no speech related information can be transmitted. Considering the rapidity with which speech sounds are produced, it seemed reasonable to expect that significant amounts of visual speech information might be missed during an eye
Blink. Consequently, it was the intent of this study to investigate the role of blinking during lipreading.

**Purpose of the Study**

Since the relationship between blinking and lipreading has not been investigated, this study was undertaken to determine if blinking has a detrimental effect on lipreading performance, if there is a difference in blink rate between good and poor lipreaders, if subjects can time their blinks to occur during pauses in visually presented materials, if blinking behavior varies with task requirements, if blink rate during a lipreading task can be predicted from a knowledge of resting blink rate, if there is a sex difference in lipreading ability and/or blinking, and if there is a relationship between lipreading performance on a Sentence Test and a Passage Test.

The null hypotheses which were tested during this study are:

- **H₀₁:** There is no significant correlation between blink rate and lipreading scores.

- **H₀₂:** There is no significant difference in blink rate between good lipreaders and poor lipreaders.

- **H₀₃:** There is not a significantly higher proportion of blinks that occur during visual pauses in passage material than during non-pauses.

- **H₀₄:** There is no significant correlation between resting blink rate and blink rate while lipreading.

- **H₀₅:** There is no significant difference in resting blink rate and blink rate while lipreading.

- **H₀₆:** There is no significant correlation between resting blink rate before lipreading and the resting blink rate following lipreading.

- **H₀₇:** There is no significant difference in the lipreading ability of males and females on a sentence test.
H08: There is no significant difference in lipreading between males and females on a passage test.

H09: There is no significant difference in resting blink rate between males and females.

H010: There is no significant difference in blink rate during lipreading between males and females.

H011: There is no significant correlation between lipreading performance on a sentence test and on a passage test.

**Importance of the Study**

While numerous studies have been undertaken to isolate, measure, and describe the factors that are related to lipreading, surprisingly few investigators have considered the visual system and its role. Since lipreading is a visual-perceptual task, the visual parameters that are important during lipreading should be specified and defined. Blinking is a basic feature of our visual system, consequently, it seemed desirable that a study be conducted to provide information concerning its role during the lipreading process.

The results of this study may provide additional information helpful in clarifying the confusing body of information concerning lipreading. In terms of clinical and/or habilitative importance, the results may be of importance in predicting the lipreading potential of clients. In addition, the need for modification of blink rate during lipreading may become obvious.

**Limitations of the Study**

Investigators (Evans, 1965; Farrimond, 1959; Goetzinger, 1964; Pelson and Prather, 1974) have reported that lipreading ability varies with age. Indeed, a plateau may exist such that maximum lipreading
performance occurs during the age span from approximately 20 to 29 years (Goetzinger, 1964). In order to obtain a conservative estimate of whether blinking affects lipreading, normally hearing and sighted college students in this age range were selected as experimental subjects. It was reasoned that these individuals would be least affected by disruptions of visual input.

Since lipreading skill is associated with such variables as language comprehension, age, visual acuity, hearing loss, and educational background the applicability of the results of this study to other populations is open to question.
CHAPTER II
REVIEW OF THE LITERATURE

The following discussion will present a review of the literature relevant to this investigation. Specifically, studies dealing with blinking and lipreading will be examined. In terms of the literature concerning blinking, the types, duration, rate, effects, and suppression of blinks will be reviewed as well as the methods available for recording eye blinks. The relevant lipreading literature with relation to the code, sender, medium, and receiver will also be considered. In addition, studies concerning lipreading testing methods will be examined.

Blinking

An eye blink may be defined as the temporary closure of both eyes involving movements of the upper and lower lids (Duke-Elder, 1968). Lid closing occurs due to a contraction of the palpebral portion of the orbicularis oculi muscle. The orbital portion of the orbicularis oculi may be involved with a more vigorous closure (Davson, 1949). Along with the closure of the eye lids, the eyes are rotated upward and inward at a 10 to 15 degree angle. The muscle primarily responsible for lip opening is the levator.
Types of Blinks

Blinks may be classified into three major categories. These include voluntary blinks, reflex blinks, and involuntary blinks. In their classic study, Ponder and Kennedy (1927) were the first to report that two types of involuntary blinking exist. They noted the presence of reflexive blinking and spontaneous blinking.

Reflexive blinking may result due to practically any peripheral stimulus. In this regard, Davson (1949) has pointed out that the corneal and optical reflexes are functionally significant. The first results when the Fifth cranial nerve is stimulated via receptors in the cornea, lid, or conjunctiva. It is very rapid (40 msec) and it involves impulses being relayed from the sensory nucleus of the Fifth to the Seventh cranial nerve. The optical reflex or dazzle reflex occurs in response to bright light. It involves the visual cortex and is significantly slower than the corneal reflex (100 msec).

Ponder and Kennedy (1927) demonstrated that spontaneous blinking occurs independently of any impulses arising from corneal or conjunctival stimulation, light stimuli, or from impulses arising from receptors in the eye muscles. All the people they tested, with the exception of those with lesions of the globus pallidus of the caudate nucleus, blinked at a regular and characteristic rate which appears to be internally generated. The commonly held belief that the sole function of the spontaneous blink is to moisten the cornea was dispelled by Ponder and Kennedy (1927). They found no significant difference in blink rate when they measured blinks in a "hot house" which was very dry compared to that measured in the very moist
atmosphere of a turkish bath. Furthermore they noted that even people who are congenitally blind, who possess glass eyes, or whose cornea have been treated with cocaine blink spontaneously.

**Duration of Blinks**

The average duration of a spontaneous blink is relatively constant. Hartridge (1950) reported that it takes approximately 40 to 50 msec for the lids to close during a blink. They remain shut for 150 msec and it then requires approximately 200 msec for the lids to open. Vision is therefore interrupted or absent for at least 300 msec. Normal vision is also not possible immediately preceding the time the blink begins and likewise immediately following the blink. Blinks may seem to last for much shorter periods than they actually do and they may not even be noticed, yet they do represent significant periods during which the visual system is blacked out.

**Rate of Blinking**

The rate of spontaneous blinking varies greatly among individuals. In a review of blinking research, Hall and Cusack (1972) noted that blinking rates have been found to range from 0.4 to 46 per minute. Table 1 summarizes the average blink rates per minute reported by various investigators. The average rates which are usually quoted are those of Ponder and Kennedy (1927). They calculated the inter-blink interval for males and females and found that the average period between blinks is 2.8 seconds in males and 3.8 seconds in females. Thus, men tend to blink more frequently than women. It should be noted that while the rate of spontaneous blinking varies
among individuals, an individual's interblink period is relatively constant as long as conditions are kept constant (Hall and Cusack, 1972).

**TABLE 1.** Summary of the average blink rate as determined by various researchers (after Hall and Cusack, 1972).

<table>
<thead>
<tr>
<th>Researcher</th>
<th>Blink Rate Per Minute</th>
<th>Standard Deviation</th>
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<tbody>
<tr>
<td>Ponder and Kennedy (1927)</td>
<td>15.0</td>
<td>11.0</td>
</tr>
<tr>
<td>Clites (1935)</td>
<td>7.5</td>
<td>?</td>
</tr>
<tr>
<td>Drew (1950)</td>
<td>14.0</td>
<td>7.0</td>
</tr>
<tr>
<td>Gregory (1952)</td>
<td>21.5</td>
<td>2.5</td>
</tr>
<tr>
<td>King and Michels (1957)</td>
<td>12.5</td>
<td>?</td>
</tr>
<tr>
<td>Brandt and Fenz (1969)</td>
<td>10.3</td>
<td>?</td>
</tr>
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</table>

**Effects of Blinking**

By assuming that spontaneous blink rates are constant, Lawson (1948) calculated the amount of time that vision is absent due to blinking. He did this by dividing the amount of time the lids are closed and the time immediately preceding and immediately following the blink by the frequency of occurrence of the blinks. He referred to this as the modified blackout index. On the average, males are blacked out for 20 per cent of their waking time while females are blacked out for 14 per cent. Lawson also reported that 30 per cent of his sample had an interblink interval of 1.6 seconds or less and
were therefore blacked out for at least 34 per cent of their waking time.

From this, Lawson (1948) predicted that people with high blink rates would be less efficient in performing visual tasks. Indeed, he did find that blinking interfered with visual tasks that required constant visual attention. In particular, blinking was found to interfere with a subject's ability to count scintillations during radioactive measurements. Poulton and Gregory (1951) also reported that when their subjects blinked during a visual tracking task, the blink interfered with vision and resulted in a greater chance for error. It appears then that blinking can disrupt visual input and lead to errors in tasks that require a subject to attend to randomly occurring events whose durations are short compared to the subject's modified blackout index.

**Suppression of Blinks**

Common experience dictates, however, that spontaneous blinking can be inhibited to at least a certain degree. Furthermore, during various mental tasks such as while daydreaming or doing mental arithmetic, blinking appears to be suppressed. Based on such observations, researchers have investigated the conditions that lead to an alteration in blink rate and some of these findings may be relevant in terms of lipreading.

Telford and Thompson (1933) found that spontaneous blinking varies with the type of task which subjects are engaged in. In terms of blinking frequency, they found that the greatest number of blinks
occurred during conversations. The rate was lower during a mental multiplication task and at its lowest while their subjects read. Holland and Tarlow (1972) point out that findings such as this confound the amount of mental activity or the difficulty of the task with the visual requirements of the task.

Indeed, the rate of blinking has been found to vary depending on the difficulty of the task (Gregory, 1952; Holland and Tarlow, 1972, 1975; MacPherson, 1943; Wood and Bitterman, 1950). Drew (1950) noted that blinking is inversely related to task difficulty. Poulton and Gregory (1951) also found this relationship between rate and difficulty. In addition, they found that when blinking occurred during the most difficult portion of a visual tracking task is resulted in the largest errors.

Broadbent (1958) has stated that subjects may time their blinks so that they do not suffer from interference in terms of visual input. Poulton and Gregory (1951) measured blink rate before, during, and after visual tracking trials. They found that blink rate was at an intermediate level before the tracking began, reduced during the tracking, and at a significantly higher rate immediately following the presentation and processing of the information. From this, they concluded that blinking is inversely related to the amount of concentration or attention expended by the subjects.

The relationship of blinking and the suppression of blinks has also been investigated during tasks which are not solely visual in nature. Hall (1945) observed that while subjects read aloud, they tended to blink at punctuation marks and between visual fixations.
Likewise, during conversations, subjects tend to blink between phrases and at the ends of sentences. Malmstrom, Rachofsky, and Weber (1977) have demonstrated that subjects, while listening to poetry or rhythmically presented digits, suppress blinks during the presentation of the material relative to the pauses.

Such findings concerning blink suppression have led certain investigators (Holland and Tarlow, 1972, 1975; Malmstrom, et al., 1977; Wegman and Weber, 1973) to hypothesize that blinking is related to cognitive processing. Indeed, Holland and Tarlow (1972) speculate that blinking may be disruptive to the cognitive processing of visual information. They argue that blinking causes a blackout period which is then followed by a sudden change in the visual input to the visual processing centers of the central nervous system. They hypothesized that this change of visual input may interfere with the ongoing processing and result in a loss of information from memory. Consequently, blink inhibition may be necessary and desirable in order to avoid such disruption (Holland and Tarlow, 1972, 1975).

Malmstrom, et al. (1977, p. 165) stated that "The inhibition of spontaneous blinking appears to be an excellent and robust indicator of cognitive activity." Therefore, a blink may cause a decrement in performance because it disrupts visual input, but it may have a more serious effect because it interferes with the ongoing processing of the visual signal.

Regardless of whether blinking interrupts visual input, disrupts visual processing, and/or signifies the waning of attention,
the absence of blinking during lipreading would seem to be desirable
if a decrement in performance is to be avoided.

**Measurement of Blinks**

While various procedures are available for measuring eye
blinks, blinking is usually recorded with one of the following
methods: (a) by observer; (b) by attachment of an artificial
reference to the eye; or (c) by use of a natural reference.

Observers have been used to record the blinks of subjects
(Drew, 1950; Holland and Tarlow, 1972, 1975; Kanfer, 1960). Typically,
the observer(s) is hidden from view of the subject and they record
the occurrence of blinks by depressing a key or other similar counting
device. With this method, distortions or alterations of the subject's
blinking behavior do not typically result. There are, however, two
major disadvantages associated with this procedure. First, the
occurrence of some blinks may be missed by the observer since the
observer blinks. Secondly, it is impossible to accurately time the
occurrence of a blink due to the observer's reaction time. Conse­
quently, the reliability and accuracy of this procedure is limited.

Artificial references have been used successfully to record
blinks (Galambos, Rosenberg, and Glorig, 1954; Kennard and Glasser,
1964; Newhall, 1932). With this method, transducers are attached
to the eyelids and a permanent and reliable recording may be obtained.
Hall and Cusack (1972) have, however, cautioned that the presence of
such equipment may interfere with normal blinking behavior. Conse­
quently, the possibility exists that distortion and/or alterations
in blinking may occur.
While various methods for recording eye movements based on natural references have been used (Shackel, 1967) electro-oculography is one technique that is particularly suited for recording eye blinks.

An electrical potential difference exists between the cornea and the retina. In man, the cornea is positive relative to the fundus. The orbit therefore acts as a rotating dipole. When the eye is moved, a displacement of the potential results and this may be detected by means of properly placed skin electrodes (Aschan, Bergstedt, and Stahle, 1956; Rubin, 1973; Rubin and Norris, 1974). When the signal from the electrodes is amplified and then fed to a recorder, a permanent tracing of the eye movements may be obtained.

Tjernstrom (1973) reported that during blinking the eyeballs are rotated upward and a resulting large upward spike is recorded electro-oculographically when a vertical electrode placement is used. Shackel (1967) has also noted that due to the rapid rise and fall of potential and because of their large amplitude (1/2 to 1 mV), blinks are quite distinguishable on electro-oculographic recordings.

So with this technique, an accurate and reliable record of blinking may be obtained. In addition, no alteration or distortion of the subject's blinking behavior results.

Lipreading

In order for lipreading to occur, a speaker must formulate a thought and then translate that thought into a series of articulatory movements. These visual signals must then be seen by a receiver and
subsequently decoded. The literature concerning lipreading, therefore, can logically be classified under four categories including the code, the sender, the medium, and the receiver. In addition, various tests have been designed to measure lipreading ability. These topics will be reviewed in this section.

Code

Spoken language consists primarily of a rapid succession of auditory and visual cues which usually result due to changes in the shape of the speaker's oral cavity and the relative positions of the tongue, lips, teeth, and jaw. The individual speech sounds which are associated with articulatory movements are known as phonemes (phones) and these serve as the basic minimal units of language (Woodward and Barber, 1960). In order to lipread, the visually distinctive signals or visemes (Fisher, 1968) which are associated with spoken language must be decoded. The nature of the visual code will be discussed in this section particularly in regard to its visible, linguistic, and temporal features.

Visible aspects. In discussions of the visual code, authors have tended to rely upon and describe it in auditory terms (Berger, 1972). Traditionally, a major distinction is made between vowels and consonants. While this is essentially an acoustic differentiation, there are also visual differences associated with these two classes. That is, vowels are relatively low frequency sounds which have low visibility, while consonants are essentially high frequency sounds which have greater visibility (Erber, 1975).
In terms of vowels, various classification systems have been proposed for describing them. Nitchie (1950) advanced a system which is similar to the traditional vowel triangle used by phoneticians. That is, vowels are categorized according to the width of the mouth opening (narrow, medium, wide) and lip shape (puckered, relaxed, extended). The implication is that all vowel sounds can be visually differentiated since they each have unique articulatory positions associated with their production. Nitchie has warned, however, that some vowels can only be distinguished through context.

Jeffers and Barley (1971) have described vowels in terms of visible lipreading movements. They defined a lipreading movement as "a recognizable visual motor pattern, usually common to two or more speech sounds" (p. 42). Their system includes differentiating on the basis of lip shape (puckered, back, rounded, relaxed), lip opening (narrow, moderate) and movement (such as occurs in diphthongs).

Multidimensional scaling techniques were used by Jackson, Montgomery, and Binnie (1976) to determine which perceptual dimensions contribute to vowel recognition. They found five features which were important. These included an extended-rounded feature, a vertical lip separation feature, an area feature, and two different movement features that served to differentiate between diphthongs.

While vowels can be classified, confusions do exist in terms of their identifications. For example, Berger (1972) noted that some vowels are identified correctly less than 50 per cent of the time. Woodward and Lowell (1964) reported that their subjects correctly identified vowels only 49 per cent of the time while Jackson,
Montgomery and Binnie reported 54 per cent correct vowel identification.

Theoretically, all vowels have unique points of articulation and should consequently be visually contrastive. That is, they should be visemes, but this is obviously not the case.

Indeed, Fisher (1963, 1968) has concluded that there are only four visually contrastive vowel sounds or vowel visemes. He categorized these as:

1. /i, I, jI, 3/
2. /e, ɛ, ɛ, dI/
3. /a, ə, əv/
4. /ɔ, o, ɔ/

Consonants can also be classified in a number of ways. Since the decoding of a visible speech message is dependent on discriminating the visible movements a speaker makes and since the degree of visibility associated with a phoneme is related to its place of articulation (Erber, 1974a) consonants have usually been classified according to their place of articulation.

A traditional classification of consonants involves twelve categories (Bruhn, 1949; Ewing, 1967; Macnutt, 1952; Nitchie, 1950). These viseme categories are:

1. /p, b, m/
2. /f, v/
3. /w/
4. /r/
5. /θ, ʒ/
In a series of studies done by Woodward (1957), Woodward and Barber (1960), and Woodward and Lowell (1964) consonants are categorized into four contrastive groups:

1. /p, b, m/
2. /f, v/
3. /w, r/
4. /θ, ʒ, t, d, n, l, s, z, ñ, š, s, z, j, k, g, j, h/

They noted that in order to differentiate among the consonants within a visemic group, linguistic information was needed.

A somewhat similar classification system has been presented by Fisher (1963). He, however, listed the visemes according to their positions within syllables. In terms of consonants in the initial position, he presented the following viseme categories:

1. /p, b, m, d/
2. /k, g/
3. /f, v/
4. /w, r/
5. /t, d, n, l, s, z, ñ, j, h/

For the final position the following visemes were found:
Binnie, Jackson, and Montgomery (1976) have recently proposed yet another set of consonant visemes. Their nine classifications include:

1. /p, b/
2. /ɛ, v/
3. /k, g, m/
4. /ʃ, ʒ, dʒ, tʃ/
5. /θ, ɬ, t, d, n, l, s, z/

While there may be differences of opinion relative to classification systems, as Berger (1972) has noted, there are definitely fewer visually distinctive features than there are auditory distinctive features. Furthermore, he attributes a portion of the difficulty in lipreading to this difference between phonemes and visemes.

Some phonemes are produced in identical fashions. The amount of visual information available in such cases of homophonous sounds, therefore, is extremely low (Fisher, 1963). There are indications,
however, that the position of consonants within words relates to their discriminability. That is, coarticulation appears to influence lipreadability.

Franks and Oyer (1967) demonstrated that the correct visual identification of an initial consonant was dependent on its stem. So for example, a given consonant was identified with varying degrees of accuracy depending on which VC stem it was associated with. Differences also exist between the visual discrimination of initial and final consonants in CVC monosyllabic words. Subjects were found to be able to differentiate initial consonants better than final consonants (Greenberg and Bode, 1968). In a study in which normally hearing students were asked to lipread consonant clusters of the CCV type, percentage of correct phoneme identification varied depending on position (Franks and Kimble, 1972). This is yet another example of the effect of coarticulation on lipreading.

Coarticulation effects are not only seen within words, but also between words in connected discourse. Vocal utterances consist of a continuous flow of speech sounds and articulatory movements, usually with no pauses occurring between words. Erber and McMahan (1976) found that isolated words were significantly more intelligible than words in sentences for deaf children. They suggested that coarticulation accounted for at least a portion of this difficulty.

**Linguistic aspects.** Language is a rule governed system that relates sounds to meanings. Consequently, the syntactic and semantic redundancy of a language should aid the receiver in resolving ambiguities and in filling in gaps in the perceived message.
Erber and McMahan's (1976) study which demonstrated that isolated words were more lipreadable than sentences for deaf children, appears to contradict the hypothesis that linguistic cues can aid in lipreading. These authors have pointed out, though, that linguistic cues cannot help a lipreader unless they have sufficient knowledge of the language.

Other studies that have employed subjects who have mastered their language have demonstrated that linguistic cues can aid in lipreading. Brannon (1961) found that words within sentences were correctly identified more often than were isolated words.

Lloyd (1964) and Lloyd and Price (1971) have also reported a significant correlation between the familiarity of a sentence and the ease with which it can be lipread.

In a study done by Schwartz and Black (1967), grammatical form was also found to be an important variable in sentence intelligibility. They used six kernel sentences which they subjected to grammatical transformations. Normally hearing college students correctly identified the kernel sentence the highest percentage of the time while the negative construction was identified the least often.

Temporal aspects. In an early study, Mitchie (1917) estimated that the average duration of articulatory movements made during conversational speech is 76 msec. He also demonstrated with the use of a motion picture camera filming at 16 frames per second, that many
articulations were too rapid to be filmed by the camera. This would indicate that their durations were less than 62.5 msec.

Indeed, the speed at which the articulators can move is dependent upon their neural innervation, mass, and structure. The maximum rate at which the lips and facial structures, which are innervated by the facial nerve, can move is 2.5 to 3.0 syllables per second; the tongue can move maximally at a rate of 8.2 syllables per second; and the mandible can move at 7.2 syllables per second (Minifie, Hixon, and Williams, 1973).

Considering the time needed for respiration and for changing positions of the articulators as well as the frequency of occurrence of various syllable types, Miller (1951) made estimates concerning the average number of speech sounds made in a second during conversational speech. In particular, he stated that speech contains an average of 12.5 speech sounds per second so the average duration of an articulatory movement is 80 msec.

Similarly, Goldman-Eisler (1961) reported that the speed of articulatory movements is between 4.4 to 5.9 syllables per second. Lehiste (1970) has explained that the durations of speech sounds and articulatory movements vary depending on such factors as the point and manner of articulation, the preceding and following segmental sounds, and the position of the speech sound within higher-level phonological units. She has noted that the range of durations of speech sounds is between 30 to 300 msec. Peters (1975) has explained that vowels typically average between 100 and 300 msec while the durations of many consonants are shorter than 70 msec.
In summary then, it is difficult to decode the visual speech signal during lipreading. Many of the articulatory movements involved in the production of speech sounds look alike. Other articulatory movements are invisible. In addition, the rapid movement of the articulators during speech adds to the difficulty of the task.

**Sender**

As with auditory intelligibility, a range in lipreadability exists among senders. Variables such as facial exposure, facial characteristics, speaking rate, and extra-facial gestures appear to contribute to either the ease or difficulty with which a speaker can be lipread.

**Facial exposure.** In addition to the articulators, speech production involves the finely coordinated movement of many facial muscles. Indeed, Greenberg and Bode (1968) have demonstrated that lipreading performance is significantly better when subjects are allowed to view a speaker's entire face compared to viewing only the lip area. Stone (1957) has also reported that the more visible a speaker is, the easier they are to be lipread. It is obvious therefore, that the muscles of the face contribute information which is helpful in the decoding of the speech message.

**Facial characteristics.** Just as the amount of facial exposure contributes to the relative ease or difficulty of lipreading a speaker, so too does the speaker's facial characteristics. In particular, the facial expression, amount of lip movement, race, and the sex of the speaker appear to have a relationship to lipreadability.
Research indicates that speakers are easier to lipread when they use normal lip movements rather than exaggerated lip movements (Stone, 1957; Vos, 1965). O'Neill (1951) found that speakers who are the most intelligible visually also tend to be the most intelligible auditorily. So, it appears that a normal speaking style is desirable if optimum lipreadability is to occur.

In addition to exaggerated speech, Hardy (1970) has noted that lipreading is adversely affected when a speaker uses careless or indistinct speech. In terms of lip movement, Berger (1972) has reported the results of an unpublished study concerning the lipreadability of black and white speakers. He noted that as the lip thickness of the speaker increased their lipreadability significantly decreased. He attributed this to reduced lip mobility. It was also found that black subjects lipread black speakers significantly better than did white subjects, while white subjects lipread white speakers significantly better than did black subjects. Berger speculated that this resulted because the subjects had had more practice lipreading speakers of their own race.

In terms of the sex of the speaker, Petkovsek (1961) has speculated that females are easier to lipread than males since they tend to use lipstick which accentuates the mouth and because they tend to use freer facial expression. Leonard (1968), however, reported finding no differences in the facial movements of male and female speakers. Measures were made by attaching a strain gage to the speakers. In addition, Aylesworth (1964) failed to find a
significant difference in lipreadability between males and females.

Rate. The rate of speech and its effect on lipreadability has been investigated in a number of studies. Mulligan (1954) found that college students received significantly higher scores on a filmed test that was projected at 16 frames per second compared to the normal rate of 24 frames per second. Likewise, Frisina and Bernero (1958) found that deaf college students obtained higher lipreading scores on a filmed test that was presented at a slower than normal rate.

Contradictory findings have also been reported. Byers and Lieberman (1959), for example, did not find a statistically significant difference in lipreading scores when they presented films at slower than normal speeds. Similarly, in a study done by Black, O'Reilly, and Peck (1963) no significant improvement in lipreading scores resulted when the film speed of their stimulus materials was slowed down.

Gestures. In addition to auditory and facial cues, extra-facial gestures often accompany speech. Hardy (1970) has stated that facial expression and gestures can often provide as much information as the actual words that are spoken. In fact, lipreading performance has been shown to be significantly better when appropriate gestures accompany speech compared to when either no gestures or inappropriate gestures are supplied (Popelka and Berger, 1971). In regard to inappropriate gestures, Berger, Martin, and Sakoff (1970) demonstrated that hand movements that occur around the face, such as rubbing one's chin and jaw while speaking, result in a decrement in lipreading
performance. So it appears that message related extra-facial gestures can be an aid to lipreading while non-message related gestures may function as visual detractors.

**Medium**

Environmental factors contribute to the ease or difficulty of lipreading. Such variables as lighting, distance, angle of view, distractions, and transmission channel affect lipreading performance.

**Lighting.** Common sense dictates that lipreading cannot occur in total darkness. Studies have indicated, however, that successful lipreading can occur even in poorly lit environments (Erber, 1974b; Thomas, 1962). Erber (1974b), for example, demonstrated that varying the illumination at the mouth level from 30 to .03 footlamberts did not significantly affect lipreading scores. However, when the intensity fell below .03 footlamberts word recognition scores were adversely affected.

Varying the angle of incidence of illumination in terms of the speaker's face has been found to alter lipreading performance. Erber (1974b) has reported that lighting is best at angles of 0 to 45° such that the interior of the mouth is not shadowed.

**Distance.** Conflicting evidence has been reported concerning the effect of distance on lipreading performance. Using a filmed test, Mulligan (1954) found that altering the distance between the subjects and the movie screen did not significantly affect test results. Yet, Erber (1971) found that lipreading performance decreased linearly when the distance between the speaker and the receiver was increased.
from 5 to 100 feet. He used a live presentation and held illumina-
tion constant. It is interesting to note that the effects of distance
varied depending on the type of stimulus material presented. Spondees,
for example, were found to be more resistant to increases in distance
than were trochees. Trochees were better perceived at greater
distance than were monosyllables. In addition, when VCV and CVC's
were presented to subjects at 5, 20, and 70 feet, vowel identification
scores did not decrease as fast as consonant scores.

Angle of view. Indications are that the angle at which a
receiver views a speaker contributes to their success or failure
during lipreading. Both horizontal and vertical viewing angles have
been investigated.

Subjects have been found to perform best when they view
speakers at a horizontal angle of 0 to 45°. When a speaker is viewed
at a right angle (90°), lipreading scores have been found to be
significantly poorer relative to scores obtained at angles of 0 to
45° (Erber, 1974b; Neely, 1956).

In terms of vertical viewing angle, changes from -30° to +30°
have not been found to result in significant differences in lipreading
performance (Erber, 1974b).

Distractions. Nitchie (1917) stated that success in lipreading
is largely dependent upon the concentration exhibited by the lipreader.
It would seem reasonable to hypothesize then, that the presence of
extraneous stimuli might result in a lapse in attention and a resulting
decrement in lipreading performance. Various investigators have
studied this both in terms of auditory and visual distractions.
Studies concerning the role of auditory distractions during lipreading have typically employed normally hearing subjects. Reported results suggest that auditory distractions result in significantly poorer performance relative to quiet conditions (Leonard, 1962; Pettit, 1963).

Somewhat surprisingly, visual distractions have not been found to significantly affect lipreading performance. Keil (1968), for example, employed a filmed test of lipreading in which the speaker appeared in front of various backgrounds. No significant differences in lipreading scores resulted if the speaker appeared in front of a neutral background, a stationary background of trees, cars, and buildings, a moving background of a street scene, or when a stationary slide of two females was projected on either side of the speaker.

Berger, Martin, and Sakoff (1970) used a live test of lipreading and compared performances when no distractions were present to that when various distractions were present (flashing lights, competing speakers, rotating targets, hand movements). No significant differences in lipreading performance were found.

**Transmission channel.** Lipreading takes place when a receiver decodes the message that is associated with the visual stimuli produced by a speaker. Consequently, it can occur whenever a receiver is able to see a speaker and this typically occurs via films, television, and in face-to-face situations.

Questions still remain concerning the nature of the relationship between lipreading scores obtained via recorded and live lipreading tests (Berger, 1972). Indeed, relatively low correlations
have been found to exist between filmed and live tests (O'Neill and Stephens, 1959; Reid, 1947; Simmons, 1959; Utley, 1946). Yet, Simmons has concluded that even though live and filmed tests do not measure the same thing, "what they do measure involves a fair amount of ability that is common to the two kinds of tests" (Simmons, 1959, p. 342).

The reasons low correlations exist between the two types of tests are not obvious. It may result due to the fact that live tests are three dimensional whereas recorded tests are two dimensional. Or, personality interactions between the sender and the receiver may be involved during live tests. Regardless, recorded tests and materials have been used successfully in lipreading training (Black, O'Reilly, and Peck, 1963; O'Neill and Oyer, 1961; Oyer, 1961; Strain, 1960) and in lipreading assessment (Erber, 1971; Morkovin, 1947; Simmons, 1959; Utley, 1946).

Receiver

Much research and clinical interest exists concerning the variables that serve to differentiate good lipreaders from poor lipreaders. Past efforts at identifying and defining these factors have, however, resulted in a number of conflicting and often confusing findings. These data are reviewed in this section.

Training. Various investigators have attempted to determine if lipreading skills can be improved with training. Both hearing impaired and normally hearing subjects have been tested in this regard.

Coscarelli and Sanders (1968) reported that good lipreaders could not be differentiated from poor lipreaders on the basis of
training. Similarly, other investigators have noted that wide ranges in performance exist among hearing-impaired subjects who have either had no training or equal amounts of lipreading training (Craig, 1964; Heider and Heider, 1940).

There have been some reports of improvement in lipreading performance following practice. These studies, though, employed normally hearing subjects (Black, O'Reilly, and Peck, 1963; Oyer, 1961). It may be that these normal subjects had no need to lipread prior to the training and consequently the training may have resulted in an improvement in lipreading performance. If this were the reason, then hearing impaired subjects who were dependent on lipreading could be expected to have developed these skills prior to training.

Walden, Prosek, Montgomery, Scherr, and Jones (1977) have reported on the effects of training on the visual recognition of consonants by hearing impaired adults. They found that after 14 hours of concentrated individual training an improvement resulted in the number of visemes that their subjects were able to recognize. While these results may appear to indicate that training is also beneficial to hearing impaired subjects, it is questionable whether this type of training can be generalized to typical communication encounters which involve the reception of more complex linguistic material. In addition, the improvements noted in this study as well as in the studies done by Black et al. (1963) and Oyer (1961), may have occurred not because of improvements in lipreading skills, but rather because of the development of test specific performance
skills. That is, subjects may have obtained higher scores because they became familiar with the test situation, speaker, and/or speech materials.

**Age.** Various investigators have compared chronological age to lipreading performance as an indirect measure of training. That is, chronological age was considered synonymous with years of training.

Early investigators (Conklin, 1917; Heider and Heider, 1940; Reid, 1947) reported finding very low correlations between age and lipreading for deaf students between the ages of 8 to 22 years. Similarly, Utley (1946) found low correlations between age and lipreading ability in her study of both normally hearing and deaf students between the ages of 9 to 19 years. So if the assumption that age is synonymous with training is correct, then it would appear that training does not result in improvements in lipreading performance. Furthermore, as Farwell (1976) has pointed out, lipreading does not appear to be a naturally developing compensatory skill.

The relationship of lipreading and age has also been investigated with older subjects. Indications are that young adult subjects tend to score better than older subjects. Goetzinger (1964), for example, reported finding the best lipreading scores for subjects in the age range of 18 to 22 years. Farrimond (1959) reported that subjects in their third decade scored significantly higher on his specially designed lipreading test than did subjects in their second, fourth, fifth, or sixth decade. He also noted that lipreading scores fell at a rate of 8 per cent per decade. Ewertsen and Nielsen (1971)
also found that lipreading scores declined with age.

In an investigation of the effects of age on lipreading, Pelson and Prather (1974) found that young subjects (19 to 26 years of age) scored significantly better than older subjects (51 to 61 years of age). They also found a difference in terms of hearing loss such that their older subjects with hearing impairments tended to score higher than their older subjects with normal hearing. They concluded that this resulted because the hearing impaired subjects had an increased dependency on visual cues.

Hearing loss. Studies have been undertaken to compare lipreading and hearing loss. Such factors as age of onset of the loss, degree of the loss, and duration of the loss have been examined.

Utley (1946) reported finding low correlations between scores on her lipreading test and the age of onset of hearing loss. This study employed 761 deaf and hearing-impaired individuals from schools and societies for the acoustically handicapped.

In a study of deaf children, Heider and Heider (1940) found that the degree of hearing loss was significantly correlated with lipreading performance. Costello (1957) found that children with average hearing losses of 80.4 dB obtained significantly better lipreading scores than a similar group of deaf children (mean hearing loss of 106.7 dB).

Erber (1971) compared the lipreading performances of normally hearing, severely hearing-impaired, and profoundly deaf children in quiet and in noise. He found a significant difference between the groups with the severely hearing impaired and the profoundly deaf
children respectively scoring higher than the normally hearing children. Evans (1960, 1965) has similarly reported that lipreading scores decline gradually as hearing loss increases. He has suggested that this is related to the corresponding language deficit that results due to profound hearing loss.

In terms of adults, Simmons (1959) investigated the correlation of duration of loss, amount of hearing loss, and discrimination score to lipreading performance. None of these factors were found to be significantly correlated with scores on either the Mason or Utley lipreading tests. The duration of loss was, however, significantly correlated with an interviewer's rating of lipreading ability. Donnelly (1969) on the other hand, did a multiple regression analysis of 30 various factors and found that the degree of hearing loss at 2000 Hz was the best single predictor of lipreading skill. His experimental population consisted of 249 deaf students from Gallaudet College.

Berger (1972) has noted that the hearing impaired and the normally hearing both rely on the same processes to lipread and they both possess the same capacity to lipread. The difference in the two groups may be that the hearing-impaired tend to be more dependent on visual cues. Consequently, any differences in performance between the groups may be attenuated if the normally hearing subjects receive some prior practice.

Intelligence. Non-significant correlations have been found in studies that have compared general intelligence to lipreading (O'Neill, 1951; O'Neill and Davidson, 1965; Pintner, 1929; Reid,
1947; Simmons, 1959). There have been some studies (Craig, 1964; Evans, 1965; O'Neill, 1951) which have reported significant relationships between performance tests of intelligence and lipreading performance. Jeffers and Barley (1971) have concluded that the tests which were used in these investigations were primarily measuring visual memory and non-verbal associative reasoning rather than general intelligence.

In terms of reasoning, investigators have been concerned with synthetic and analytic abilities and their relationship to lipreading. Synthesis involves the ability to perceive the whole based upon a part whereas analytic reasoning proceeds from the whole to the part (Jeffers and Barley, 1971). During lipreading a synthetically oriented person might decode a message by filling in the material which they did not see. An analytically oriented person might be expected to be less successful since presumably they would try to see every speech movement that occurred (Berger, 1972).

In an early investigation by Kitson (1915), a significant correlation between lipreading ability and synthetic ability was found. A reading test and a sentence completion test were used to measure this factor. Simmons (1959) presented three tests which supposedly measured synthetic ability and found that only one (fragmentary sentences) correlated significantly with lipreading performance. Since she believed that synthetic ability was actually necessary during lip-reading, she questioned the validity of the two tests with which non-significant correlations were obtained.
Worthington (1956) compared the lipreading performance of deaf high school students to their scores on the Rotter Sentence Completion test. No significant relationship was found suggesting that those students who were better at predicting succeeding words (supposedly more synthetic) were not necessarily better lipreaders. Likewise, Tatoul and Davidson (1961) failed to find a significant relationship between lipreading performance and the ability to predict missing letters by subjects with normal hearing.

Kitchen (1968) measured visual synthesis by means of several tasks such as recognition speed for geometric forms, speed of organizing geometric form patterns, speed of organizing words from letters, recognition speed of common words, and speed of organizing sentences from scattered words. Significant correlations were found between the speed of forming words from scattered letters, the ability to recognize letters and digits from their outlines, and the total synthesis score with lipreading performance.

Bode, Nerbonne, and Sahlstrom (1970) have also reported a significant, although weak correlation between lipreading performance and synthetic ability. While the exact nature of the relationship remains unclear, synthetic ability does appear to be a basic factor in lipreading (Jeffers and Barley, 1971).

Sex. A difference in language abilities has been found to exist between males and females with females being superior in terms of verbal facility (Bolinger, 1975; Myklebust, 1964). Likewise with lipreading, several studies have found that females are significantly
better than males (Aylesworth, 1964; Costello, 1957; Frisina, 1961; Taaffe, 1957; Wynn, 1969).

Myklebust (1964) has also reported finding differences between the sexes on a questionnaire concerning the benefits of lipreading. Among a sample of hearing impaired adults, more females reported that lipreading was beneficial than did males.

Emotional factors. Differences in personality factors have also been reported by Myklebust (1964) in terms of male and female deaf adults. He found significant differences in depression and hysteria scores between the sexes. The greatest maladjustment was associated with the males who rated themselves as poor lipreaders. From this he concluded that inferior lipreading ability is related to greater emotional disturbance.

Costello (1964) has also investigated the relationship between attitudes and lipreading. She found that children who had a more positive attitude toward lipreading lipread better. In addition, children who were better lipreaders tended to have parents and friends who held positive attitudes toward lipreading and oral communication.

In a study with normally hearing college students, Wong and Taaffe (1958) correlated lipreading scores with scores on the Guilford-Zimmerman Temperament Survey. They found low yet statistically significant correlations between lipreading and general activity, personal relations, and emotional stability.

Motivation during lipreading has been studied by Giolas, Butterfield, and Weaver (1974). They found that intrinsically oriented children scored higher than extrinsically motivated children on the
John Tracy Test of Lipreading. From this they suggested that the use of reinforcement and feedback might increase the motivation of a child to lipread.

O'Neill and Davidson (1956) studied various psychological factors including concept formation, reading comprehension, and level of aspiration and their relationship to lipreading. Their findings indicated that, except for non-verbal concept formation, no statistically significant relationship exists between lipreading and either level of aspiration, reading comprehension, or digit memory span. These results were obtained with normally hearing college students. When the same types of tests were given to congenitally deaf high school students by Worthington (1956), no significant correlations were found.

Visual perception. Various studies have been done in which lipreading ability has been compared to performance on non-verbal visual perceptual tasks.

Tiffany and Kates (1962) found a difference in the manner in which good and poor lipreaders arrived at a non-verbal concept. They employed students from the Clark School for the Deaf and presented them with a card sorting task. The task consisted of determining the non-verbal concept which was associated with a focus card by choosing from a group of various cards. Poor lipreaders required more time to arrive at the correct concept and they also tended to perseverate in their choices of cards. There was no difference between the groups, though, in terms of the number of guesses which were made in order to reach a concept.
Evans (1965) developed a Visual Recognitions of Designs Test which he presented to a sample of deaf children. The task required that the children reproduce a design after it was presented for a controlled amount of time, by means of a duplicate design. He reported a significant correlation between the test results and lipreading scores. From this he concluded that visual perceptual skills and the ability to recognize visual symbols are important factors in lipreading.

In O'Neill and Davidson's (1956) study, the visual perceptual skills of their subjects were tested by means of tachistoscopically presented digits. No significant differences were found between their good and poor lipreaders, although the good lipreaders did score somewhat higher. Simmons (1959) also found that the ability to recognize and remember a series of digits was not significantly related to lipreading. However, she did report finding a significant correlation between lipreading and the ability to recognize and remember a group of objects.

Unlike the previous studies, Costello (1957) used longer exposure times and reported finding a significant correlation between lipreading and memory span for digits. She stated that the results on this test are often described as a measure of attention. She has suggested, therefore, that children who have longer attention spans may be more successful as lipreaders (Costello, 1964).

In terms of attention, Frisina (1964) has presented data comparing the performance of subjects on a lipreading task and on the Continuous Performance Task (Rosvold, Mirsky, Sarason, Bransome, and
Beck, 1956). This is a test that measures sustained visual attention, yet no significant correlation was found between lipreading and the performance on this test. Frisina (1964) did not, however, interpret these findings as indicating that attention was not important during lipreading. In fact, visual attention may be expected to vary depending on such factors as the task requirements as well as the interests, motivations, and skills of the subjects. Consequently, extrapolating from the results obtained on only one test may be quite tenuous.

**Visual acuity.** In order to lipread, it is necessary that the speaker be seen. In this regard a number of investigators have reported on studies dealing with the role of visual acuity during lipreading. Acuity refers to the ability of the eye to distinguish fine details (Borish, 1954).

Goetzinger (1964) and Evans (1965) have both reported finding no significant relationship between lipreading performance and visual acuity. Various other investigators, however, have found that lipreading performance is adversely affected by reductions in visual acuity (Glaser, 1972; Hardick, Oyer, and Irion, 1970; Lovering, 1969; Romano and Berlow, 1974). Indeed, even minor visual acuity errors have been found to result in significant decrements in performance (Glaser, 1972; Hardick, Oyer, and Irion, 1970).

**Visual phorias.** Phoria refers to muscle balance and the tendency of the two eyes to act together. Goetzinger (1964) tested lateral and vertical phoria at far vision for a group of subjects with a Modified Ortho-Rater (Bausch and Lomb Optical). He failed
to find significant differences in lipreading scores between those subjects who had ocular imbalances and those who did not.

**Depth perception.** The relationship of depth perception to lipreading was also examined by Goetzinger (1964). He found no significant differences in lipreading scores when binocular versus dominant eye monocular, binocular versus nondominant eye monocular, or dominant versus nondominant eye vision was used. In addition, no significant correlation was found between lipreading scores and depth perception scores as determined by a Modified Ortho-Rater.

**Visual neural firing times.** Shepherd, DeLavergne, Frueh, and Clobridge (1977) have recently reported finding high negative correlations between lipreading scores and visual neural firing times as determined by averaged visual electroencephalic responses. They concluded that lipreading is associated with the rate at which a subject's visual neurons "are able to transmit coded visual information through the visual nervous system" (p. 763).

**Lipreading and blinking.** While no direct investigations of blinking during the lipreading process have been reported, at least two studies measured the blink rates of subjects either before or after lipreading.

While investigating the effects of visual status on lipreading performance, Hardick, Oyer, and Irion (1970) obtained lipreading scores for their subjects and subsequently had those subjects examined optometrically. During the examination, the number of blinks per minute was obtained while the subjects were engaged in an unspecified
visual task. No significant correlation was found between blink rate and lipreading score.

Quigley (1966) has reviewed a Japanese study done by Arakawa and Furumaya (1962). These investigators measured eye blink rates before and after a 10 minute lipreading session and found that blink rate was greater following the sessions relative to before. They also measured blink rate after their subjects read a book and found that blinking was greater after lipreading. They interpreted these results as evidence of eye fatigue. That is, their criterion for eye fatigue was eye blink rate and they concluded that lipreading results in greater eye fatigue than does reading. No information was presented concerning their methodology or why they did not measure blinking during the lipreading task.

Tests of Lipreading

A great number of tests for assessing lipreading have been described in the literature. While several rationales and types of materials have been championed, no currently available test has gained universal acceptance.

One of the first attempts to measure lipreading ability was reported by Nitchie in 1913. He made a silent film of a speaker saying three proverbs which happened to contain all the vowel movements with the exception of "y." While he did not present a record of data gathered with this test, he did provide information about the actions of the speaker. Specifically, he concluded that the movements associated with the production of a given speech sound vary depending
on its context. From this he argued that individual sounds should not be used for lipreading practice or assessment, but rather he proposed the use of sounds within their "natural combinations" such as in sentences.

Ignoring this proposal, Conklin (1917) developed a test of lipreading which consisted of 8 consonants, 52 words, and 20 sentences which he administered in a face-to-face manner. This test and its use of individually produced consonants was subsequently criticized by Nitchie (1917) on the basis that isolated sounds are not usually spoken during communication.

Heider and Heider (1940) filmed three lipreading tests which also included meaningless phonetic combinations as well as unrelated nouns, names of animals, unrelated sentences, and stories. They used these tests to assess the lipreading ability of deaf students at the Clark School for the Deaf and from their results they concluded that no correlation exists between the ability to lipread nonsense syllables and general lipreading ability.

Mason (1942, 1943) developed a series of filmed multiple-choice lipreading tests which were designed to objectively measure the lipreading ability of children. They consist of the presentation of various nouns with the child's task being to draw a line through the picture which corresponded with the test word. This material has not been used to a great degree since Mason's death.

The Utley test (1946) is currently the most widely used instrument for assessing lipreading skill (Oyer and Frankmann, 1975).
It includes three subtests: (a) a word test; (b) a sentence test; and (c) a story test and has been standardized on 761 deaf and hearing-impaired children. Based upon results obtained with this sample, Utley concluded that while an interrelationship exists between the skills necessary for the visual recognition of words, sentences, and stories, a single skill is not operative in all three cases. She further suggested that the ability to lipread words, sentences, and stories be measured separately for diagnostic purposes. It was also interesting to note that the lowest correlation among the various parts of the test occurred between the word test and the story test.

The Utley test has, however, been criticized on a number of points by DiCarlo and Kataja (1951). Most importantly, they demonstrated that it is very difficult and does not differentiate between good lipreaders and poor lipreaders. In addition, the word test did not prove to be a consistent measure of lipreading. They also found that few subjects wrote the test sentences out entirely and since these are scored by calculating a point for each word correctly recorded, this portion of the test is actually "reduced to a test of words" (p. 238). Finally, they concluded that the story tests were inadequate since even the best lipreaders failed to understand them.

Morkovin (1947) reported on a series of training materials entitled "Life Situation Films" which have subsequently been used as a test of lipreading. O'Neill and Stephen (1959) investigated the relationship of the Morkovin film "The Family Dinner" to the Mason and the Utley tests. They found significant relationships between the three tests, however, no relationship was found between the
Morkovin test and the story portion of the Utley test. They suggest, therefore, that the Morkovin film is actually more of a word recognition test than a thought recognition test.

Yet another sentence test was proposed by Taaffe (1957) at the John Tracy Clinic. This "Filmed Test of Lipreading" consists of 60 short unrelated sentences which have been standardized on 408 college students with normal hearing. As with the Utley test, a point is given for each correctly recorded word. Based on their standardization data, the average score on Form A is 49.6 per cent and 54.4 per cent on Form B. This suggests that this is a very difficult test.

Lovering (1969) reported the development and use of a series of 10 sentences which were standardized on a population of normally hearing college students. These test items were chosen particularly because of the ease with which they were lipread. He reported a mean score of 63.4 per cent for males and females. So while the Utley and John Tracy tests are difficult and may consequently lead to frustration and discouragement among test takers, Lovering's sentences are both discriminating and readily intelligible.

Other sentence tests have been proposed in addition to those already mentioned (Day, Fusfeld, and Pintner, 1928; Hardick, 1973; Nielsen, 1970; Reid, 1947). Yet as Utley (1946) concluded, these appear to measure only one aspect of lipreading ability. O'Neill and Stephens (1959) have similarly questioned whether the recall of word or thought units is more representative of lipreading skill. In this regard, Sach has demonstrated that during the auditory
reception of sentences, "The original sentence which is perceived is rapidly forgotten, and the memory then is for the information contained in the sentence" (1967, p. 422). O'Neill and Stephens (1959) have similarly cited Lashley's (1951) associative chain theory of language recognition as an argument for the use of thought units as opposed to word units in assessing lipreading. In addition, Liberman, Cooper, Shankweiler, and Studdert-Kennedy's (1967) findings in studies of speech perception that listeners actively interpret acoustic speech signals on the basis of their knowledge of language may also apply. Since it seems reasonable to expect that these individuals would similarly impose the same processes during the visual reception of speech, then measuring lipreading skill by means of thought units may be more representative of what actually occurs during communication.

Some investigators have similarly suggested that stories and not sentences be used to assess lipreading ability (Nitchie, 1917; Utley, 1946). Yet of the two most widely used story tests, the Morkovin and Utley, serious problems exist in terms of their use. As previously mentioned, the Morkovin materials may actually be a test of word recognition and not thought recognition and the extreme difficulty of the Utley reduces its utility. A story test that has been successfully employed to assess the amount of information received through lipreading was used by Robert Gates (see Goetzinger and Proud, 1975; Stuckless, 1971). He presented this material to a sample of students at the National Technical Institute for the Deaf and unlike the Utley and Morkovin story tests, this passage test was
found to sample the intelligibility of visual input and not the reception of individual words (Stuckless, 1971).

As Giolas and Epstein (1963) have explained, continuous discourse is representative of the type of speech that is usually encountered in everyday situations. It would seem desirable therefore, that a further investigation of lipreading during the reception of this type of material be undertaken.

Summary

The literature concerning blinking was reviewed in this chapter. Previous investigators have found that blinking can lead to decrements in performance on visual tasks which require that a subject attend to randomly occurring events which have short durations relative to the blinking blackout period. In addition, some researchers have hypothesized that blinking may be disruptive to visual processing and may, perhaps, be correlated with attention. Since lipreading requires that a subject attend to non-repetitive visual stimuli which have durations shorter than the blinking blackout period, it follows that blinking may be disruptive to lipreading performance.

A review of the lipreading literature revealed, however, that this hypothesis has not been tested. Consequently, some variables that have been found to contribute to success during lipreading were reviewed. In terms of the speech message, its degree of visibility, its linguistic aspects and its rate were considered. Those variables which influence the ease with which a speaker can be lipread were also
discussed. These included facial exposure, facial characteristics, speaking rate, and extra-facial gestures. Contributing environmental factors such as lighting, distance, angle of view, distractions, and transmission channel were examined. In terms of the lipreader such variables as training, age, hearing loss, intelligence, emotional factors and visual perception were considered. Materials which have been developed for testing ability to lipread were also discussed.

These various results were subsequently considered in the formulation of this study. That is, the experimental hypotheses, the choices of the test stimuli, the speaker, the transmission channel, and the lipreaders were made based upon the review of the lipreading literature. Specifically, blinking behavior was studied in those individuals who by virtue of their hearing, visual, emotional, and intellectual status were considered to have maximum lipreading potential. Environmental variables were controlled so as to optimize the lipreaders successful reception of the stimuli. In addition, the choices of speaker and test materials were based primarily upon the assumption that the lipreaders task should be made as easy as possible. In this manner, it was reasoned that a conservative estimate of the effects of blinking could be obtained. The specific details concerning the experimental procedures are presented in the next chapter.
CHAPTER III

EXPERIMENTAL METHODS

The primary purpose of this study was to investigate the relationship between involuntary eye blinks and lipreading performance. Consequently, the blinking behavior of 30 subjects was evaluated before, during, and after they lipread some sentences and a passage. Information concerning the equipment, subjects, speaker, stimulus materials, blink recording method, and procedures utilized during the study are included in this chapter. In addition, the experimental measures and statistical considerations are discussed.

Equipment

The following instrumentation was used during this experiment:

1. Amplifier: (Hewett Packard, Model 450 A)
2. Audiometer: (Beltone, Model 10A)
3. Dual channel recorder: (Brush Recorder Mark II, Model 2522)
4. Electrodes: (Medcraft Silver Disc EEG electrodes)
5. Microphone: (Sony ECM 16)
6. Modified Ortho-Rater: (Bausch and Lomb Optical)
7. Power supply: (Tektronix, Type RM 125)
8. Pre amplifier: (Tektronix, Type RM 122)
9. Television monitor: (Sony Trinitron, Model KB 120)
10. Video cassette recorder: (Wollensak, Model VR 210)
11. Video camera: (Sony, Model VO 3800)
12. Video recorder: (Sony, Model DXC 1600)

**Subjects**

The subjects were 15 males who ranged in age from 20 to 29 years with a mean chronological age of 24.3 and 15 females who ranged in age from 20 to 27 years with a mean chronological age of 22.6 years. All were students at The Ohio State University. Only native English speakers who had no formal lipreading training were qualified to serve as subjects. In addition, they were required to pass both hearing and visual screening tests.

Potential subjects received bilateral pure tone air conduction threshold tests at 500, 1000, and 2000 Hz. Anyone with a hearing loss greater than 15 dB (re: ANSI, 1969) at any frequency was eliminated from participation in the experiment.

The visual status of potential subjects was assessed prior to inclusion in the study. Testing was accomplished by means of a Modified Ortho-Rater. With this specialized stereoscope, the following measures were obtained: (a) monocular and binocular visual acuity at near and far distance, (b) lateral and vertical phoria at near and far distance, (c) stereopsis, and (d) color vision.

Binocular visual acuity of 20/25 was required in order to serve as a subject. Those subjects who normally wore corrective lenses (glasses or contacts) were instructed to wear them during both the visual screenings as well as during the actual testing.
Speaker

Prior to this study, a group of 10 adults was asked to lip-read each of five speakers. Based on their scores and comments, the speaker who was the easiest to lipread was chosen to present the test material for this study. The person selected was a 23 year old female who was photogenic and had no facial characteristics which would serve to distract a lipreader.

Stimulus Materials

Although lipreading skill is usually assessed by means of sentence tests, as Utley (1946) concluded, only one aspect of lip-reading ability may be measured in this manner. Because of this and since passage materials may be more representative of everyday communication (Giolas and Epstein, 1963; Mitchie, 1917; Stuckless, 1971; Utley, 1946), the experimental subjects were required to lip-read both a sentence test and a passage test.

The Sentence Test. The 20 sentences described by Lovering (1969) were selected for presentation. These sentences (Appendix A) were standardized on 67 normally hearing college students and were demonstrated to be a reliable measuring instrument. Judging from the standardization data, the test represented a relatively easy lipreading task.

The Passage Test. The story test used by Gates (see Goetzinger and Proud, 1975; Stuckless, 1971) was chosen for use in this experiment. The passage was originally developed for another study by Clesson Martin at Michigan State University. It is a 948 word story
about two fictitious African tribes known as the Mambos and Yams (Appendix B) and it has a readability level of approximately the seventh grade. While two forms were available, the shorter version (Form B) was chosen for use.

A 39 item objective, multiple choice test (Appendix C) was used to assess the amount of information the subjects received. This test was a modification of Martin's original version in that it only covered the material found in Form B of the passage. In order to verify that the questions sampled the amount of information communicated visually, a pilot study was first carried out to determine if the questions could be answered if subjects received both visual and auditory input. Three graduate students viewed a recording of the passage on a television monitor while listening to the audio portion of the recording. After a 2 minute rest period following the presentation, they were given the 39 item multiple choice test. Their scores were: 34, 34, and 33. In no instance did more than two of the three miss the same question, so while the task was difficult, the test did appear to sample the information received. In addition, it was apparent that the subjects could successfully receive and retain the information within the time frame imposed by the experimental procedure.

Preparation of the Stimulus Materials

Since the method that was to be used to record blinks necessitated that subjects be tested individually, recorded tests were desired so that variables such as speaker rate and degree of
articulator movement could be controlled. Video tape was chosen as the means to record the test materials. It has been used successfully both as a lipreading testing medium (Erber, 1971, 1972; Myklebust and Neyhus, 1971; Nielsen, 1970) as well as a training medium (Oyer, 1961; Strain, 1960; Walden, Prosek, Montgomery, Scherr, and Jones, 1977). Berger (1972) has also reported that students tend to prefer watching televised lipreading presentations compared to filmed presentations.

A color video taped recording of the stimulus materials was made in a brightly lit recording studio. Two spotlights were used to illuminate the speaker who sat in front of a navy blue backdrop. The recorded image was a front view and included the speaker's head and shoulders. During the recording of both the sentences and the passage, the speaker spoke the test materials aloud at a normal rate without any exaggerated lip or jaw movement.

While recording the sentences, the speaker held a series of cue cards. The sentence which was to be spoken was written on one side of the card with the number corresponding to the sentence written on the other side. In this manner, the speaker was able to read which sentence was to be said while she displayed the number of the sentence for taping. The resulting video taped image consisted of a full screen presentation of the numbered cue card which was followed by the speaker lowering the card and revealing her face. Following a brief pause the sentence was spoken and the screen was then blanked out to allow sufficient time for the subjects to record their responses. This sequence was repeated until all 20 sentences
had been spoken.

Since a natural and relaxed speaking manner was desired, the speaker was not required to attend to external timing cues. The actual times involved in the various filmed sequences, therefore, did vary somewhat. These times were measured after completing the recording and it was found that the numbered cue cards were shown for an average of 2.2 seconds with a range from 2.0 to 3.0 seconds. The average amount of time the speaker paused between the lowering of the card and beginning to speak the sentence was 2.8 seconds with a range of from 2.0 to 3.5 seconds. Finally, the average amount of time during which the screen was blank was 11.5 seconds with a range of from 10.0 to 13.5 seconds.

During the recording of the passage, the speaker read continuously from cue cards. These were situated near the camera in such a manner that the speaker did not give the appearance of reading. The entire passage recording was 366 seconds in length and it was spoken at an average rate of 155 words per minute.

**Blink Recording Method**

The subject's blinks were recorded electro-oculographically. With this method, the electrical potential difference that exists between the cornea and the retina is used to monitor the movements of the eye. During a blink the eye undergoes a rapid upward and inward rotation, so the resulting electro-oculographic recording appears as an obvious spike.
Figure 1 is an example of an electro-oculographic recording of a series of blinks. In order to establish that the recorded spikes correlated with blinks, a videotape recording of two pilot subjects was made while their blinks were recorded electro-oculographically. It was found that the occurrence of their blinks could be reliably determined from the electro-oculographic record.

FIGURE 1. An electro-oculographic recording of a series of eye blinks recorded at 5 mm/seconds.

Three silver disc EEG electrodes were used to detect eye blinks. A small amount of electrode jelly was placed on the electrodes and these were then attached to the subjects with a small piece of adhesive tape. A vertical placement was used such that one electrode was placed supra-orbitally while the other was placed infraorbitally. A ground electrode was attached to the forehead. Since these non-polarizable skin electrodes were used, no interference with the eyes of the subjects resulted. It was also possible to obtain a reliable and accurate recording while not sensitizing the subjects to the fact that their blinks were being studied.
Figure 2 is a schematic representation of the equipment that was used during this study. The signal from the electrodes was fed into a differential amplifier which had a time constant of 1 second. The resulting signal was then fed into one channel of a two channel recorder which was run at a speed of 5 mm/second. This permanent record was then used to determine blink frequency and distribution. In order to make a more detailed analysis of the occurrence of blinks relative to the visual test material, the audio correlate of the speech samples was amplified, rectified and then fed into the second channel of the recorder. In this manner, it was possible to tell when a subject blinked in terms of the test message by comparing the two simultaneously recorded records. Figure 3 is an example of such a recording in which the electro-oculographic record is displayed in the lower trace while a sample of the audio correlate of the speech signal is in the upper trace.

FIGURE 2. Block diagram of the equipment used during testing.
FIGURE 3. A simultaneous recording of the audio correlate of the speech sample (upper tracing) and eye blinks (lower tracing) recorded at 5 mm/second.

It was established that the recording accurately represented the onset of the speech signal. This was done by passing a 1000 Hz signal through an electronic switch and then through the rectifier and into an oscilloscope. The resulting rectified signal followed the original signal accurately within the millisecond range. The offset of the rectified signal did not, however, accurately represent the termination of speech. It was possible, though, to determine when the end of a phrase or sentence occurred by noting the last point of maximum deflection of the signal trace before its exponential fall.
Procedure

All testing was carried out individually in a sound booth which was illuminated indirectly. Figure 4 is a diagram of the test and control rooms. The video cassette playback recorder and the eye blink measuring equipment were located in the control room and only the television monitor, Modified Ortho-Rater, and audiometer were in the test room. The subjects sat at a desk 1.2 meters from the center of the video monitor.

Prior to testing, each subject was given written instructions which stated the general nature of the experimental task (Appendix D).

Although Luckeish and Moss (1942) reported finding no difference in blinking whether their subjects knew their blinks were being counted or not, all attempts were made to avoid sensitizing the subjects to
the purpose of this study. Consequently, they were only told that small involuntary eye movements were being measured. Following the completion of testing, each subject was questioned concerning whether they realized that their blinks were being recorded. None of the 30 subjects reported being aware of this.

After the general instructions were delivered, the subjects were given the auditory and visual screening tests which were described earlier. The electrodes were then applied and the subjects were given other written instructions (Appendix E) concerning the Sentence Test. The following oral instructions were also given:

Watch the speaker closely and try to write down on your answer sheet exactly what was said. If you are not sure, then guess. It takes a few minutes for the electrodes to stabilize, so I would like you to sit here quietly for two minutes. At the end of this time the test will begin.

The subjects were told that it would take time for the electrodes to stabilize so that their resting blink rates could be measured without alerting them to this fact. After delivering the written and oral instructions, the subjects were left alone in the test room. Their blinking was then recorded for a two minute period.

Following this, the Sentence Test was administered. The subjects recorded their responses on answer sheets which were provided. Their blinks were recorded throughout this period.

At the completion of the sentence task, the subjects were then given written instructions concerning the Passage Test (Appendix F). In addition they were told;
The speaker will now read a passage about two groups of people known as the Mambos and the Yams. Don't become upset if you don't understand everything that is said, but please watch closely. After the passage, I'll wait a few minutes and then bring in a test concerning it.

The videotaped passage was then presented. The subject's blinks were recorded while they viewed the Passage and for two minutes following the completion of the Passage. After this two minute period, they were given a copy of the 39 item multiple choice test (Appendix C) and were allowed as much time as necessary to complete it. The entire session lasted for approximately 45 minutes and the same protocol was followed for all subjects.

Experimental Measures and Statistical Considerations

Four basic measures were obtained for each subject. These included a Sentence score, Passage score, average blink rate, and inter-blink interval. In addition, the proportion of blinks which occurred during the visual pauses was also calculated.

Descriptive statistics, including medians and interquartile ranges (Q), were calculated (Edwards, 1954). Non-parametric inferential statistical analyses were also conducted. Specifically, Mann-Whitney U-tests and Wilcoxon signed ranks tests (Siegel, 1956) were employed to test experimental hypotheses concerning the Sentence Test scores. These were chosen since the assumptions underlying the use of parametric tests were not met. That is, the variances associated with the scores of the males and females on the Sentence Test were not homogeneous.
The Passage Test scores were subjected to the same descriptive and inferential statistical analyses. The Passage score was obtained for each subject by determining the number of correct responses with the maximum possible score being 39.

The rate at which subjects blinked was determined from their electro-oculographic record. Each time a subject blinked, a spike was recorded on their record. Since the recorder was run at a constant speed of 5 mm/second, the rate of blinking could be determined by measuring the distance between successive spikes. Because of the eye movement that occurs during blinking, the electro-oculographic recording appears as a rapid upward deflection followed by an exponential decay. Consequently, the beginning of the blink is quite obvious while its termination cannot be accurately determined with this recording method. Because of this and since investigators (Adler, 1959; Duke-Elder, 1968; Hall and Cusack, 1972) have found that blink durations are relatively constant across subjects, measures of blink duration were not calculated. In addition, to reduce measurement error, the time between successive blinks was measured from the beginning of one spike to the beginning of the next.

In this manner, the average blink rate per minute was determined for each subject as well as the inter-blink interval (IBI). The later is a measure of the average amount of time that occurs between successive blinks. Hall and Cusack (1972) have demonstrated that blink rate is clearly not normally distributed. Consequently, non-
parametric statistical analyses were used to test experimental hypotheses concerning blink rate and IBI.

Since blink rate is not normally distributed, a Spearman rank-order correlation coefficient (Siegel, 1956) was used to determine the degree of relationship between this measure and measures of lip-reading performance. In addition, a similar correlation was calculated between the lipreading scores obtained on the Sentence and Passage tests, as well as the blink rates during the various experimental tasks.

In addition to determining lipreading scores and measures of blink rate, the timing of blinks relative to the Passage material was also examined. While the speaker spoke continuously for 366 seconds during the recording of the Passage, a number of pauses did occur during which the speaker assumed a closed mouth position for a period of time. Three viewers were asked to watch the videotape recording of the Passage and signal when they thought that the speaker paused. Those loci which were chosen by at least two of the three viewers were considered to be visual pauses. In this manner, a total of 18 were identified and of these the viewers were unanimous in all choices except two. The proportion of the visual speech message which could be labelled a pause was also determined and a test for the significance of a proportion was conducted to determine if more blinks occurred during the pauses than would be expected by chance.
CHAPTER IV
RESULTS AND DISCUSSION

This chapter includes a presentation of the experimental results including a discussion of the lipreading and blinking measures, the distribution of blinks, a comparison of the good and poor lipreaders, the relationship of blinking and lipreading, as well as the relationship between blinking behavior and task requirements. This is followed by a general discussion of the findings and their implications. Finally, a summary of the results is presented.

Experimental Results

Lipreading Measures

Sentence Test. Each subject's score on the Sentence Test was determined by counting the number of sentences correctly recorded on the answer sheet, with credit given only for responses written exactly word for word. The maximum score was 20.

Measures of central tendency and dispersion for the sentences are displayed in Table 2. The scores ranged from a low of 2 to a high of 20 with an overall median score of 14.50. This compares favorably with Lovering's (1969) standardization data and indicates that it was a discriminative measure. Female subjects obtained substantially higher median scores relative to those of the males.
A comparison of the scores with a one-tailed Mann-Whitney U-test indicated that the females performed significantly better than the males on this task (U = 44, p < .01).

<table>
<thead>
<tr>
<th>Group</th>
<th>Median</th>
<th>Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>Females</td>
<td>17.00</td>
<td>1.93</td>
</tr>
<tr>
<td>Males</td>
<td>11.00</td>
<td>3.94</td>
</tr>
<tr>
<td>Total</td>
<td>14.50</td>
<td>3.75</td>
</tr>
</tbody>
</table>

Note: Maximum score = 20.

Passage Test. The scores on the 39 item multiple choice test were used as a measure of the amount of information received through lipreading on the Passage Test. The median scores as well as the interquartile ranges are listed in Table 3. The scores on this task ranged from 7 to 29 with 10 being a chance score. It can be seen that, unlike the Sentence Test, the performance of the males and females on this task was essentially identical. In fact, a comparison of these scores by means of a Mann-Whitney U-test indicated the lack of a significant difference.

Relationship Between the Sentence and Passage Tests. In order to establish if the subject's Sentence score and Passage score were related, a Spearman rank-order correlation coefficient was calculated. A rho = 0.20 was obtained indicating the lack of a significant
relationship between the two sets of scores.

<table>
<thead>
<tr>
<th>Group</th>
<th>Median</th>
<th>Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>Females</td>
<td>18.00</td>
<td>2.69</td>
</tr>
<tr>
<td>Males</td>
<td>18.00</td>
<td>4.68</td>
</tr>
<tr>
<td>Total</td>
<td>18.00</td>
<td>3.17</td>
</tr>
</tbody>
</table>

Note: Maximum score = 39.

Measures of Blinking

Data concerning the frequency of blinking were derived for each subject from their electro-oculograph. Since a constant chart speed of 5 mm/second was employed, the rate at which blinks occurred could be measured directly from this record.

An examination of when the blinks occurred in relation to the stimulus materials was also made. With the two channel recorder, eye blinks were recorded in one channel while a signal corresponding to the audio correlate of the stimulus materials was recorded in the second channel. Since this was done simultaneously, it was possible to determine when a blink occurred relative to the stimulus material merely by comparing the blink record and the stimulus record.

Blink frequency. A total of 7227 blinks were recorded during the experimental sessions with the number of blinks per subject
ranging from a low total of 117 to a high of 643. In all, 1716 blinks were counted during the presentation of the Passage, 1157 during the two minute period prior to lipreading, and 1299 during the two minute period following the presentation of the Passage.

In terms of the Sentence Test, the number of blinks that occurred during the presence of the cue card, the pause before speaking, the sentences, and the blank interval between successive sentences was determined. The results are presented in Table 4. It is noteworthy that although the subjects blinked a total of 3055 times, there were only two blinks that occurred during the time the speaker was actually saying a sentence. In both of these cases, the subjects who blinked answered incorrectly. While there were many instances in which a subject gave an incorrect response yet did not blink, in both cases when a blink did occur the sentences were missed. It is presumed that blink suppression was occurring during this task.

TABLE 4. Number of blinks during the presentation of the Sentence Test.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Blank Screen</th>
<th>Cue Card</th>
<th>Face Visible</th>
<th>Presentation of Sentence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Females</td>
<td>844</td>
<td>454</td>
<td>109</td>
<td>2</td>
</tr>
<tr>
<td>Males</td>
<td>1024</td>
<td>507</td>
<td>115</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>1868</td>
<td>961</td>
<td>224</td>
<td>2</td>
</tr>
</tbody>
</table>
**Blink rate.** The average number of blinks per minute is a more convenient measure for describing a subject's resting blink rate as well as their blinking behavior during the presentation of the Passage. The blink rate measured during the two minute interval prior to the time the subjects lipread as well as during the two minute interval following the Passage presentation was considered to be a reflection of their basic resting blink rates. The two minute interval prior to lipreading is referred to as Base Period (Pre) while the two minute period following the Passage is referred to as Base Period (Post).

Table 5 is a summary of the average blink rates that occurred during the Base Period (Pre), Base Period (Post), and Passage. These data are displayed graphically in Figure 5. Inspection of the data reveals that the rate varied depending on the task with the highest rates occurring during the two Base Periods. An analysis by means of a Wilcoxon signed-ranks test indicated that there was no significant difference between the average resting blink rate as measured during these two intervals. However, a significant difference was found between these average resting blink rates and the average blink rate during the Passage. The rate during the Passage was significantly lower than that during the Base Period (Pre) \((T = 22, \ p < .025)\) and that during the Base Period (Post) \((T = 7, \ p < .005)\).

In order to establish if a sex difference existed, the average blink rates of the males and females during the Base Period (Pre), Passage, and Base Period (Post) were compared by means of a series of
<table>
<thead>
<tr>
<th>Group</th>
<th>Base Period (Pre)</th>
<th>Passage</th>
<th>Base Period (Post)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X</td>
<td>SD</td>
<td>X</td>
</tr>
<tr>
<td>Females</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>15.33</td>
<td>7.34</td>
<td>9.27</td>
</tr>
<tr>
<td>Males</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>23.23</td>
<td>12.87</td>
<td>9.78</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>19.28</td>
<td>11.05</td>
<td>9.52</td>
</tr>
</tbody>
</table>

\[a\] The two minute interval prior to testing during which the resting blink rate was measured.

\[b\] The 366 second interval during which the speaker presented the Passage.

\[c\] The two minute interval following the Passage during which the resting blink rate was measured.
FIGURE 5. Average blink rates per minute during the experimental sessions.
Mann-Whitney U-tests. The results indicated that the average blink rates of the males were significantly higher than those of the females during the Base Period (Pre) \( (U = 59, p < .025) \). The other rates were not significantly different.

A close examination of the average blink rate data revealed that a wide range existed across subjects. During the Passage the blink rate ranged from 2.66 to 48.1 blinks per minute. The range in resting blink rate was 6.5 to 47.5 blinks per minute. Because of this high degree of variability and since blink rates are not normally distributed, the interblink interval may be a more appropriate measure (Hall and Cusack, 1972).

**Interblink interval.** The interblink interval (IBI) is a measure of the average amount of time that occurs between successive blinks. The IBI's during the Base Period (Pre), Passage, and Base Period (Post) are depicted in Table 6. Figure 6 is a graphic representation of that data. As with the mean blink rate per minute, the IBI varies across the experimental tasks. A series of one-tailed Wilcoxon matched-pairs signed rank tests were used to compare the IBI's and a significant difference was found between the IBI during the Passage and during the Base Period (Pre) \( (T = 22, p < .025) \). The subjects blinked more during the Base Period (Pre) than during the Passage. In addition, the IBI during the Base Period (Post) was significantly lower than during the Passage \( (T = 7, p < .005) \). So, the subjects tended to blink less often during the Passage than during either the Pre or Post Base Periods. No significant difference
TABLE 6. Median IBI in seconds during the experimental sessions.

<table>
<thead>
<tr>
<th>Group</th>
<th>Base Period (Pre)</th>
<th>Passage</th>
<th>Base Period (Post)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Females</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>4.19</td>
<td>7.44</td>
<td>3.57</td>
</tr>
<tr>
<td>Q</td>
<td>1.75</td>
<td>3.62</td>
<td>1.34</td>
</tr>
<tr>
<td>Males</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>2.99</td>
<td>8.30</td>
<td>2.48</td>
</tr>
<tr>
<td>Q</td>
<td>1.43</td>
<td>2.75</td>
<td>1.03</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>3.63</td>
<td>8.05</td>
<td>3.06</td>
</tr>
<tr>
<td>Q</td>
<td>1.65</td>
<td>3.12</td>
<td>1.15</td>
</tr>
</tbody>
</table>
FIGURE 6. Median Interblink interval in seconds during the experimental sessions.
in IBI was found, however, between the two Base Periods.

The difference in IBI between the sexes was also subjected to statistical analysis. The results of a Mann-Whitney U-test indicated that a significant difference in IBI existed between males and females during the Base Period (Pre) \( (U = 47, p < .01) \). Males tended to blink more frequently. No significant differences between the sexes were found when the IBI during the Passage and during the Base Period (Post) were compared.

**Relationship of Lipreading Proficiency and Blinking**

A primary concern of this study was to examine the role of blinking during lipreading and to determine if the blinking behavior of good lipreaders differs from that of poor lipreaders. Consequently, the 10 experimental subjects who received the highest scores on the Passage Test and the 10 who received the lowest scores were designated as good lipreaders and poor lipreaders respectively. Their lipreading scores as well as their blinking behavior was then examined and compared.

The median score of the good lipreaders was 23 while the median score for the poor lipreaders was 13. A further breakdown of the two groups indicated that each had the same number of males \( (N = 6) \) and females \( (N = 4) \). In terms of the good lipreaders, the males who comprised this group had a median score of 23 while the female's median score was 23. Among the poor lipreaders, the median score of the males was 13 and that of the females was 13.5. It was obvious—therefore, that the differences between these groups could
not be attributed to sex differences.

So, the IBI's of the two groups were calculated and compared. No significant differences were found between the IBI's of the good and poor lipreaders during the Base Period (Pre) and the Base Period (Post). Table 7 summarizes this data and it is graphically presented in Figure 7. A significant difference was found, however, between the IBI's of the good and poor lipreaders during the Passage.

TABLE 7. Median IBI in seconds of the good and poor lipreaders.

<table>
<thead>
<tr>
<th>Group</th>
<th>Base Period (Pre)</th>
<th>Passage</th>
<th>Base Period (Post)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good lipreaders</td>
<td>3.23</td>
<td>8.97</td>
<td>2.82</td>
</tr>
<tr>
<td>Poor lipreaders</td>
<td>3.00</td>
<td>5.57</td>
<td>2.69</td>
</tr>
</tbody>
</table>

Table 8 summarizes the measures of central tendency and dispersion that were computed for these two groups. The results of a Mann-Whitney U-test indicated that good lipreaders blinked less frequently during the Passage than did the poor lipreaders ($U = 23.5, p < .05$).

TABLE 8. IBI median and interquartile range scores for the good and poor lipreaders during the Passage

<table>
<thead>
<tr>
<th>Group</th>
<th>Median</th>
<th>Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good lipreaders</td>
<td>8.97</td>
<td>3.00</td>
</tr>
<tr>
<td>Poor lipreaders</td>
<td>5.57</td>
<td>2.00</td>
</tr>
</tbody>
</table>
FIGURE 7. Median interblink interval during the experimental sessions for the good and poor lipreaders.
Distribution of Blinks

Pause blinks. Each subject's record was examined to determine when they blinked in relation to the Passage content. While the speaker spoke continuously for 366 seconds during the recording of the Passage, a number of pauses did occur during which the speaker assumed a closed mouth position for a period of time. A total of 18 of these pauses occurred with their average length being 1.28 seconds with a range of 0.8 to 2.2 seconds.

The average proportion of blinks that occurred during the visual pauses was .12. Based upon the fact that the proportion of the Passage recording that consisted of visual pauses was .06, the obtained proportion was higher than expected. Indeed, a z-test comparing the obtained proportion and the expected proportion resulted in a significant difference (z = 1.57, p < .05) indicating that more blinks occurred during the pauses than would be expected on the basis of chance.

Modified IBI. Since essentially no information was being presented, the occurrence of a blink during a visual pause should not have resulted in a loss or disruption of input. A modified IBI was calculated, therefore, to reflect this fact. Only non-pause blinks were used in its computation. If a blink occurred during a visual pause, it was ignored and the time interval until the next blink was added to that which had been measured up to the pause blink. Theoretically, if a subject blinked only during the visual pauses, their modified IBI would be 366 seconds which is the length of the Passage.
A summary of the Modified IBI's is presented in Table 9. The median amount of time between successive non-pause blinks was 11.28 seconds for good lipreaders and 5.92 seconds for poor lipreaders. A comparison of the IBI's of these two groups indicated that good lipreaders blink significantly less frequently than did poor lipreaders while watching passage materials (U = 23, p < .025).

<table>
<thead>
<tr>
<th>Group</th>
<th>Median</th>
<th>Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good lipreaders</td>
<td>11.28</td>
<td>4.00</td>
</tr>
<tr>
<td>Poor lipreaders</td>
<td>5.92</td>
<td>3.00</td>
</tr>
</tbody>
</table>

**Relationship of Blinking and Lipreading**

The degree to which the subject's Passage score and IBI were related was determined by means of a Spearman rank-order correlation coefficient. A rho = 0.40 (z = 2.15, p < .01). This indicated that there is a relationship between blinking and lipreading such that the less frequently one blinks the higher the lipreading score. The correlation between the Modified IBI and the Passage score was rho = 0.46 (z = 2.47, p < .006). When only the IBI's of the good and poor lipreaders were used in the calculation of a Spearman rank-order correlation coefficient, a rho = 0.52 was obtained (z = 2.58, df = 18, p < .01). This moderately high positive correlation indicates that with this sample blinking and lipreading are significantly related.
Relationship of Blinking Behavior and Task

Another correlation was calculated to determine if a relationship existed between a subject's resting blink rate and their performance blink rate. A non-significant rho (rho = 0.16) was obtained. Consequently, it would appear that it is not possible to predict a subject's blink rate during a lipreading task based upon a knowledge of their resting blink rate.

A significant correlation (rho = 0.72, p < .001) was found between the IBI during the Base Period (Pre) and that during the Base Period (Post). So it may be possible to predict blink rates during a particular activity, but only if the prediction is made based upon data that have been obtained during the same type of activity.

Discussion

The results of this study demonstrated that involuntary blinking behavior and its consequences vary depending on the nature of the task a subject is involved in. Blink rates are lower when demand for visual attention increases. In addition, blinking does appear to be disruptive to lipreading performance.

Blink suppression was quite obvious during the Sentence Test. Subjects tended to blink during those times when important visual information was not being presented. Their blink rates were at their lowest when they were anticipating the presentation of a sentence and during the actual presentation of the sentence.

There were two instances in which blinks did occur during the presentation of the speech message. It is important to note
that when they did occur, the message was lost. Because of the
time parameters involved and the repetitive and consequently
predictable sequence involved in the test, blinking did not prove
to be an important disruptive factor in terms of the visual input.

A sentence test may not, however, be a completely adequate
means for assessing lipreading ability. The extremely low correla­
tions found between the scores on the Passage Test and the Sentence
Test seem to support Utley's (1946) contention that different skills
are involved during the lipreading of these types of materials.
Indeed, in typical visual communication situations, skill in lip­
reading sentences is required. However, it is often necessary to
be able to understand continuous discourse (Berger, 1972; Giolas
and Epstein, 1963) especially, for example, during classroom lectures.
Since it is often difficult to predict the nature and length of this
type of speech, it is often difficult or even impossible to suppress
blinking.

In fact, blinking did occur during the Passage Test, yet a
significantly greater number of blinks occurred during the visual
pauses than would be expected purely by chance. The designation of
the visual pauses was made very conservatively. Although pauses did
occur at the ends of sentences and phrases, only the very obvious
pauses were examined in relation to the occurrence of blinks. Even
so, the results indicate that subjects tend to time their blinks so
they occur when they will be least disruptive in terms of visual
input. That is, they tended to blink when visual speech information
was not being presented.
Blinks also occurred during the time information was being presented and those subjects who blinked less received higher scores on a test measuring the amount of information received through lipreading. Since the type of material presented is representative of what is usually encountered, especially in the classroom, blinking and/or its suppression appears to contribute to a lipreader's success or failure on such a visual task.

All lipreading failures cannot, however, be attributed to blinking. During the Sentence Test, for example, many incorrect sentences were recorded yet the subjects had not blinked. Successful lipreading involves a number of skills and blinking is only one of a number of factors that appear to be involved.

The finding of a sex difference in lipreading performance on the Sentence Test is an example of this. The finding is consistent with those of a number of other investigators (Costello, 1957; Craig, 1964; Frisina, 1961; Wynn, 1964). Since practically no blinking occurred during the presentation of the sentences, it was obviously not the reason for the difference in scores. This should emphasize the fact that one's success or failure in lipreading cannot be predicted on the basis of only one variable.

As with the Sentence Test lipreading results, a sex difference was also found to exist in resting blink rate with males blinking more frequently. This finding is in agreement with results published by Ponder and Kennedy (1927). Yet, during the Passage this difference did not exist. Furthermore, no differences in the lipreading scores...
of the males and females were found on the Passage Test. Apparently whatever the causes for the previously noted differences in blinking behavior and lipreading performance between males and females, they were not operative during the Passage Test. The lack of a difference between males and females on this test as well as the low correlation found between the Sentence and Passage Tests would seem to be an additional argument that lipreading be examined in a broader context than solely during the reception of sentence material.

In terms of the difference in resting blink rates between males and females, the reason or reasons for this are not obvious. For that matter, there is currently no widely accepted comprehensive theory concerning involuntary eye blinks. Some investigators have suggested that blinking is related to attention (Kennard and Glasser, 1964; Hall and Cusack, 1971). The results of this study are consistent with such a formulation. When a subject's attention is externally focused, a decrease in blinking occurs. During the Sentence Test, for example, blinks were inhibited while the subjects attended to the speaker. When visual attention was not focused, blink rates increased. Also during the Passage, the blink rates were significantly lower than during those periods when the subjects were not required to watch the monitor. One subject reported, following the experiment, that mid-way through the recording, he stopped concentrating on the speaker. The record of his blinking during the Passage revealed that during the first half of the Passage his blink rate was low and it then subsequently increased to the point that the subject was blinking nearly once every second.
While it may be impossible to determine if lack of attention leads to more blinking or if increases in blinking result in a decrease in attention, lipreading performance may be improved if visual attention is increased. Various investigators have suggested means by which visual attention span might be developed (Barlett, 1949; O'Neill and Oyer, 1961). If attention can be improved, the possibility exists that less visual information might be missed due to a decrease in blinking.

The failure of previous studies (Hardick, Oyer, and Irion, 1970) to find a relationship between lipreading and blinking may be due to inadequate experimental designs. As demonstrated in this study, it is not possible to predict blink rate on a task based solely upon a knowledge of resting blink rate. Blink rate appears to be rather stable as long as the experimental demands are kept constant. In order, therefore, to predict or specify the role of blinking during lipreading, it must be investigated during the lipreading task.

Lipreading is a multi-faceted process that involves various perceptual and cognitive skills. A basic prerequisite to the processing of visual information is that it be seen. Estimates are that only 10 to 25 per cent of the information that is available in audible speech can be obtained through vision only (Jeffers and Barley, 1971). Blinking can result in a further reduction and/or disruption of visual input. While blinking cannot account for all failures in lipreading, it does appear to play a basic and significant
role in the process. Future studies concerning lipreading should consider the contributions of blinking and blink suppression.

**Summary**

A review of the descriptive and inferential statistical results presented in this chapter has led to the rejection of seven null hypotheses and the failure to reject four others.

**H₀₁**: There is no significant correlation between blink rate and lipreading scores.

A Spearman rank-order correlation coefficient was calculated and the results indicated that a significant negative correlation existed between blinking and lipreading. Since the rho was significant, the null hypothesis was rejected.

**H₀₂**: There is no significant difference in blink rate between good lipreaders and poor lipreaders.

A Mann-Whitney U-test was used to compare the blink rates of those subjects who received the top 10 scores on the Passage Test to those who received the lowest 10 scores. Significant U values were obtained indicating that poor lipreaders blink more frequently while lipreading than do good lipreaders. Consequently, H₀₂ was rejected.

**H₀₃**: There is not a significantly higher proportion of blinks that occur during visual pauses in passage materials than during non-pauses.

Results of a z-test indicated that a significantly higher proportion of blinks occurred during the visual pauses in the Passage material than expected by chance. So, the hypothesis was rejected.
H₀₄: There is no significant correlation between resting blink rate and blink rate while lipreading.

A Spearman rho comparing the Base rates to the Passage rates was computed. Since a statistically significant relationship was not found, H₀₄ could not be rejected.

H₀₅: There is no significant difference in resting blink rate and blink rate while lipreading.

A series of Wilcoxon signed-ranks tests were used to compare the average blink rates and the IBI's during the Base Period (Pre), Base Period (Post), and Passage. The rate during the Passage was significantly lower than during the two Base Periods so the null hypothesis was rejected.

H₀₆: There is no significant correlation between resting blink rate before lipreading and the resting blink rate following lipreading.

A Spearman rank-order correlation coefficient was calculated and a significant rho was obtained between the resting blink rate as measured before and after lipreading. This finding led to the rejection of this hypothesis.

H₀₇: There is no significant difference in the lipreading ability of males and females on a sentence test.

The lipreading scores of males and females on the Sentence Test were compared by means of a Mann-Whitney U-test. Females scored significantly higher than did the males. Consequently, the null hypothesis was rejected.
Ho₈: There is no significant difference in lip-reading between males and females on a passage test.

A Mann-Whitney U-test was used to test if the scores of the males and females on the Passage Test differed. A significant U value was not obtained, so the null hypothesis could not be rejected.

Ho₉: There is no significant difference in resting blink rate between males and females.

Results of a Mann-Whitney U-test indicated that males blinked significantly more often during the Base Period (Pre) so the null hypothesis was rejected.

Ho₁₀: There is no significant difference in blink rate during lipreading between males and females.

The blink rates of the males and females during the Passage were not found to be significantly different when compared by means of a Mann-Whitney U-test. It was not possible, therefore, to reject the null hypothesis.

Ho₁₁: There is no significant correlation between lipreading performance on a sentence test and a passage test.

A Spearman rank-order correlation coefficient was calculated to compare the scores on the Sentence Test and the Passage Test. A low and non-significant correlation resulted. The null hypothesis could not be rejected.
CHAPTER V
SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The basic purpose of this research was to investigate the role of blinking during lipreading on a series of short sentences and a passage. Questions were raised concerning whether a sex difference existed in terms of lipreading ability and/or blinking as well as whether subjects could time their blinks to occur during pauses in visually presented material. The degree to which lipreading and blinking were related was evaluated and the difference in blinking between good lipreaders and poor lipreaders was investigated. In addition, the difference in blink rate with task was examined and the possibility of predicting blink rate during lipreading based on resting blink rates was tested.

Summary

The subjects were 15 males and 15 females who had normal hearing and vision, or vision corrected to normal. They ranged in age from 20 to 29 years and were native English speakers who had no formal lipreading training.

Their blinks were recorded electro-oculographically while they lipread a sentence test and a passage test. In addition, measures of resting blink rate were also obtained before and after they had lipread.
The data were subjected to descriptive and inferential statistical analysis in order to test hypotheses that were originally posed. Mann-Whitney U-tests and Wilcoxon signed-ranks tests were used to investigate whether blinking rates varied with tasks, sexes, and between good and poor lipreaders. Spearman rank-order correlation coefficients were calculated to assess the degree of relationship between lipreading ability and blinking behavior as well as whether blinking rate during a lipreading task could be predicted based on a knowledge of resting blink rate.

The results indicated that blinking rate varied with task. Blink suppression was found to occur during the Sentence Test. In terms of the Passage, subjects tended to time their blinks to occur during visual pauses. In addition, better lipreaders blinked less frequently than did poorer lipreaders. A sex difference in lipreading performance was found on the Sentence Test with females performing better than the males. The resting blink rate of males was also found to be higher than that of females. Finally, no relationship was found between resting blink rate and blink rate during the Passage.

Conclusions

Within the limits imposed by the design of this study the following conclusions appear warranted:

1. Blink rates vary depending on the visual tasks subjects are involved with.
2. Blink rates on a particular task cannot be predicted from
a knowledge of resting blink rate.

3. Subjects tend to time their blinks so they occur when they
are least likely to interfere with visual input.

4. Blinking is disruptive to lipreading.

5. Sentence tests and passage tests measure different aspects
of lipreading ability.

6. Females perform better than males on lipreading tests that
involve sentences.

Recommendations for Future Research

Further investigation of blinking and its role during lip-
reading seems warranted. The role of blinking during audio-visual
tasks should be assessed to determine if it plays a significant
role.

An investigation of blinking and its role during lipreading
in the classroom also seems warranted. Information concerning the
frequency and distribution of blinking in school-age children may
have implications for lipreading training.

In addition, blinking and its effect on lipreading with people
who have reduced visual acuity should be investigated. Indications
are that seemingly minor visual impairments (i.e. 20/30 acuity) are
associated with poorer performance in lipreading tasks (Glaser, 1972;
(1942) have also reported that blinking rates increased in normal
subjects when even minor artificial refractive errors were
introduced through the use of lenses. It may be that poorer performance noted on lipreading tasks may in part be due to an increase in blinking. Considering that the incidence of ophthalmological deficiencies among deaf children are reportedly higher than among the normally hearing (Lawson and Myklebust, 1970; Myklebust, 1964), this may again have implications relative to the education of these children.

Another area that might profitably be investigated is that of noise and blinking. Galambos, Rosenberg, and Glorig (1954) have reported that reflexive blinking occurs in response to certain sounds. If particular hearing aid settings increase the rate of blinking, audio-visual communication efficiency may be reduced. Hearing aid parameters such as maximum power output and gain setting may need to be re-examined in light of the effect they have on blinking and visual communication.

A study concerning presentation methods in the classroom may suggest optimum ways to present material to minimize blinking effects. Alternatives to lengthy continuous lectures, for example, may be desirable in order to reduce disruptive blinking and consequently increase communication efficiency.

Finally, further work relative to the development of a reliable and valid lipreading test is necessary. In particular, research attention should be directed toward the development and standardization of story materials.
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APPENDIX A

SENTENCE TEST

1. Do you smoke?
2. How many sisters do you have?
3. How old are you?
4. What is your name?
5. Do you have a phone?
6. What time is it?
7. How many brothers do you have?
8. Where have you been?
9. Have you ever been fishing?
10. Do you watch TV?
11. Do you have a roommate?
12. Do you wear glasses?
13. Oh boy!
14. How long have you gone to college?
15. Where do you live?
16. What time do you get up in the morning?
17. The weather is bad.
18. Do you have a driver's license?
19. Did you go home for Christmas?
20. Do you have a scholarship?
APPENDIX B

PASSAGE

In the year 1800 on the continent of Africa, two unfriendly nations existed, Mambo and Yam. The Nile River separated them. Yam was richer.

King Koko began to plan the defeat of Yam. Koko was a military man; most of his subjects were expert warriors; none were merchants. They liked war and often fought another tribes' battles for money and glory.

However, Koko was getting old. If Koko conquered Yam, he would be rich and control thousands of people; he could rest his body, live in luxury, enjoy personal wealth and power; and be the strongest ruler on the continent.

Koko felt the time for war against Yam was suitable because his Mambo warriors disliked King Lester of Yam. Koko knew his warriors would welcome the chance to defeat Lester and his followers because of their dislike and jealousy of Lester plus their greed for the wealth of Yam.

However, a small band of expert Mambo warriors disliked Koko's plans. These Mambo warriors compared Koko and Lester and Lester was the kind of king they wanted to serve; they would be traitors to Koko. As a result this small band of traitor Mambo
warriors secretly met with a small group of Yam merchants who agreed to pay them money and supply them with weapons so they would defend Yam. The small band of strong, fierce, traitor Mambo warriors and a small group of weak, fat merchants formed the Pro Lester Union.

Lester and his followers never thought much about war because they were too busy trading the plentiful goods of Yam all over the continent. Most of Lester's followers were merchants; none were expert warriors.

King Koko prepared his army for war and most important was the worship of Solmambo, the sun-god. The witch doctor looked directly into the sun at high noon and chanted; all the Mambo warriors did the same; any who fainted from the heat or looked away from the sun were killed. The witch doctor executed fifty warriors. The Mambo warriors also painted their faces with goat's blood for courage.

Now that the Mambo warriors were ready to fight, they climbed into their war canoes and paddled down the river toward Yam. The paddles were also the spears of the warriors. These spears were heavy and well balanced; they could be used as clubs in close fighting due to their heaviness. The wide iron tips had very sharp edges so they could also be used as swords or doubled edged axes.

When the war canoes approached Yam, Lester's lookouts shouted the alarm. Yam musicians beat drums, blew ram horns, and shook rattles while doing a native tribal dance. This religious ceremony was to chase away any evil spirits who might harm Lester during the
battle. All the Lester Followers, consisting of all Yam merchants
and other Yam subjects and the Pro-Lester Union prepared to meet the
invaders.

King Lester lead his camel cavalry into the battle. However, Lester
and his forces were losing the battle. The fat merchant
warriors were no match for the tough expert Mambo warriors; Lester's
army was outnumbered by five to one; Lester's cavalry wielded heavy
iron swords which were difficult to use. Lester decided he could win
only if he could fight Koko in personal combat and kill him. Lester
charged at Koko with his sword but before he could strike, Koko sent
his spear in Lester's chest with such force that it came out through
Lester's back. Mambo had won the battle.

King Koko was proud of his victory; he was now the master of
seven thousand slaves, two hundred thousand cattle and sheep, and the
business wealth of Yam. The original social structure of Mambo
remained the same with most of the Mambo citizens still being expert
warriors because Koko had to keep the Yam citizens under control and
protect his wealth. However, the social structure of Yam changed;
all of the Yam people and the traitor Mambo warriors were now slaves
of King Koko.

After King Koko killed King Lester, some of Lester's faithful
subjects succeeded in rescuing his dead body and secretly buried it
to prevent the traditional burning up of killed enemy leaders that
the Mambo warriors liked to perform. These Yam subjects never
revealed their deed but instead they claimed that some friendly
spirits had taken the seriously wounded Lester away to safety so he
could recover and return to free his people. This is known as the Lester Legend. It is no comfort to Koko that a rather sizable number of Yam slaves believe this legend and he is beginning to wonder about it himself. He feels certain that he killed Lester but his dead body had never been found.

But if Koko knew about the Freedom Group, he wouldn't worry about the legend so much. The Freedom Group is made up of some Legend Believers and the traitor Mambo warriors who fought for Lester but don't believe the legend. This group is secretly hiding weapons in the jungle, keeping the Lester Legend alive, and planning for the overthrow of Koko. From time to time Koko finds a skull in front of his hut or a dead Mambo warrior. Shipments of goods to other nations often never reach their destinations. Koko's food often contains poison. Koko is grouchy, irritable, and suspicious. His relation with his troops is becoming unfriendly because he blames them for not keeping control of the slaves. He sometimes thinks they are plotting against him with the slaves. The future for Koko is not promising. Perhaps his victory was not so sweet after all.
APPENDIX C

PASSAGE TEST

Name__________________________ Date__________________________

Circle the letter that corresponds with the best answer.

1. In 1800 two unfriendly nations existed in:
   a) South America
   b) Africa
   c) Europe
   d) North America

2. These two nations were separated by:
   a) a mountain
   b) the Nile River
   c) a lake
   d) the Atlantic Ocean

3. King Koko of Mambo was a:
   a) military minded man
   b) peace loving man
   c) a generous man
   d) a satisfied man

4. Among Koko's subjects, there were many:
   a) priests
   b) merchants
   c) warriors
   d) sailors

5. Koko and his followers earned money from other tribes by:
   a) trading with them
   b) fighting their battles
   c) selling them slaves
   d) protecting their camel caravans
6. Koko was getting old and tired so he planned:
   a) to take a vacation
   b) to defeat Yam
   c) to retire as ruler of Mambo
   d) to sign a treaty with Yam

7. Koko would become very rich if he:
   a) signed a treaty with Yam
   b) defeated Yam
   c) sold slaves to Yam
   d) fought a war for Yam

8. The Mambo warriors were willing to fight Yam because:
   a) they wanted the wealth of Yam
   b) they did not like any Yam citizen
   c) they wanted to live in Yam
   d) all of the above

9. A small band of Mambo warriors decided:
   a) to help Lester in case of war
   b) to trade with some Yam merchants
   c) to work for peace
   d) to overthrow Koko

10. The Pro Lester Union consisted of a small group of Yam merchants and:
    a) Lester's warriors
    b) some traitor Mambo warriors
    c) some Mambo merchants
    d) none of the above

11. King Lester had not thought about war or prepared for war because:
    a) he was a coward
    b) he had a strong army
    c) he was too busy trading the goods of Yam
    d) all of the above

12. The Yam merchants of the Pro Lester Union were learning:
    a) how to become warriors
    b) how to become spies
    c) how to make weapons
    d) none of the above
13. Most of Lester's followers were:
   a) merchants
   b) warriors
   c) union members
   d) musicians

14. The Mambo army prepared for war by:
   a) dancing and shaking rattles
   b) painting their faces with goat's blood for courage
   c) beating drums and singing
   d) none of the above

15. The worship of Solambo consisted of:
   a) fasting
   b) making human sacrifices
   c) staring at the sun at high noon
   d) none of the above

16. The Mambo witch doctor killed fifty Mambo warriors because:
   a) they were weak
   b) they were old
   c) they were traitors
   d) they were sick

17. The Mambo warriors had spears that were also:
   a) canoe paddles
   b) clubs
   c) swords
   d) all of the above

18. The Mambo warriors had an advantage in war because:
   a) they had a versatile weapon
   b) the Yam citizens were not warriors
   c) Lester was not a good warrior
   d) all of the above

19. King Lester's lookouts announced the beginning of the war by:
   a) sending mirror signals
   b) shouting loudly
   c) setting a fire
   d) waving red flags
20. The Yam musicians danced and played music on seeing war canoes:

   a) to encourage King Lester's warriors for fighting
   b) to welcome the coming of the brave warriors
   c) to show poser and to frighten the enemy
   d) to chase away any evil spirits that might harm
      Lester during the battle

21. Lester had a cavalry of:

   a) horses
   b) camels
   c) elephants
   d) donkeys

22. Lester's army:

   a) outnumbered Koko's army
   b) had fewer warriors than Koko's army
   c) was more fierce than Koko's army
   d) was in better physical shape than Koko's army

23. King Lester's weapons were:

   a) sharp-pointed heavy daggers
   b) sharp-edged light knives
   c) sharp-pointed light arrows
   d) heavy iron swords

24. Who was losing the battle?

   a) King Lester and his followers
   b) Lester's lookouts who used the spears
   c) King Koko and his followers
   d) Koko's warriors who used the swords

25. King Lester's warriors were different from King Koko's warriors
    because most were:

   a) expert warriors
   b) non-expert warriors
   c) disloyal warriors
   d) all of the above

26. King Lester's plan to get rid of Koko was to:

   a) bribe one of Koko's warriors to kill him
   b) ask one of Koko's servants to poison his food
   c) fight Koko in personal combat and kill him
   d) say religious prayers for spirits to hinder and
      harm Koko
27. Lester was killed:
   a) by Koko's warriors
   b) by Koko's spear
   c) by Lester's warriors
   d) by committing suicide

28. Lester's followers after his death:
   a) became more fierce
   b) became more courageous
   c) became more rebellious
   d) none of the above

29. At the end of the battle Koko was:
   a) unsatisfied with his victory and his new wealth
   b) unsatisfied with his new found wealth
   c) unsatisfied with his victory, but proud of his new found wealth
   d) proud of his victory and his new found wealth

30. The new found wealth of King Koko after the battle was:
   a) 7000 slaves
   b) 200,000 cattle and sheep
   c) the business wealth of Yam
   d) all of the above

31. After the battle the people of Yam were:
   a) slaves for their new ruler
   b) more prosperous than ever
   c) merchant warriors
   d) unhappy but proud of their occupations

32. Lester's dead body was buried by:
   a) Koko's warriors
   b) Lester's subjects
   c) Koko's merchants
   d) none of the above

33. The rumor about Lester after his death was that:
   a) the doctor of King Koko was treating him of his wounds
   b) he was treated by some friendly spirits of his serious wounds
   c) he was a guest at one of the neighboring tribes
   d) he was burned up by King Koko's warriors
34. The rumor of Lester's return was told by:

a) Lester Legend Believers
b) Koko's doctor
c) neighboring tribes
d) Koko's food tasters

35. The attitude of King Koko about the rumor of Lester's return was that he:

a) felt indifferent since there was not too much harm in it
b) discouraged the rumor to avoid the annoyance of his slaves
c) felt uneasy about the increasing number of believers of this rumor
d) none of the above

36. The Freedom Group was made up of:

a) Lester Legend believers and traitor Mambo warriors
b) Mambo warriors
c) Mambo merchants
d) Yam warriors

37. The behavior of the Freedom Group was characterized by:

a) negotiating with other tribes to invade Koko
b) telling lies about Koko
c) planning the overthrow of Koko
d) helping slaves escape to other countries

38. After the war, King Koko became:

a) grouchy, irritable, and suspicious
b) very satisfied
c) a good and beloved ruler
d) a peace-loving man
APPENDIX D
PRELIMINARY SUBJECT INSTRUCTIONS

This is a study of small involuntary eye movements which occur during lipreading. Your task will involve watching two videotaped recordings of a person speaking. You will then be asked questions concerning these.

In order to measure the eye movements, three electrodes will be placed on you. There is no discomfort or shock danger associated with this procedure. Once the electrodes are in place, you should feel free to breathe normally, blink, yawn, or scratch as you need to, but please avoid making any large head or body movements.

You may discontinue participation if you desire. Do you have any questions?
APPENDIX E

SENTENCE TEST INSTRUCTIONS

You will now see, but not hear a person saying some sentences. Your task is to watch the television monitor, and then write on the answer sheet what you think the person said. Try to write down exactly what the person said, and if necessary, guess.

Remember to avoid making any large head or body movements.

Do you have any questions?
APPENDIX F

PASSAGE TEST INSTRUCTIONS

You will now see but not hear a person reading a passage. Your task is to watch the entire passage. At the end of the presentation, please sit quietly. Following a short period of time you will be given a multiple choice test covering the material in the passage. Please watch closely and do not be upset if you do not understand everything that is spoken.

Do you have any questions?
APPENDIX G

RAW SCORES
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NUMBER OF BLINKS DURING PASSAGE

(MALEs)

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# INTERBLINK-INTERVAL DURING BASE PERIOD (PRE) AND BASE PERIOD (POST) (FEMALES)

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**Mean =** 4.83 3.88  
**SD =** 2.15 1.72
INTERBLINK-INTERVAL DURING BASE PERIOD (PRE) AND BASE PERIOD (POST) (MALES)

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**MEAN =** 3.40 2.93  
**SD =** 1.89 1.33
## INTERBLINK-INTERVAL DURING PASSAGE

**(FEMALES)**

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**MEAN =**

|        | 8.45 | 9.91 |

**SD =**

|        | 4.20 | 6.30 |
**INTERBLINK-INTERVAL DURING PASSAGE**

*(MALES)*

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**MEAN =**

9.55  10.81

**SD =**

5.05  5.83