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ABSTRACT

The pamphlet focused first on questions concerned with the relative ability of deaf and hearing students to visually process words when presented letter by letter, and with relationships existing among deaf students between the ability to process words presented tachistoscopically, letter by letter, and the ability of the same student to process words through finger spelling and through speech reading. Then reported was a study involving 33 deaf and 19 hearing students at the post-secondary level in which the processing of verbal information (words) visually and the relationship of the deaf students' ability to identify words presented in rapid letter-by-letter graphic sequence and ability to read finger spelling and to speech read were investigated. A comparison of the relative ability of deaf and hearing post-secondary subjects to correctly identify printed meaningful words when their letters wer presented sequentially indicated that the deaf subjects were superior under all conditions tested. Lack of a statistically significant correlation between the ability to read printed words whose letters are presented sequentially and the ability to read words formed by speech suggested that the perception of these two tasks was different. (Author/CB)

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Fingerspelling And Speechreading As Visual Sequential Processes

Fingerspelling and Speechreading
as Visual Sequential Processes

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Preface

The National Technical Institute for the Deaf, given birth in June, 1965, under Public Law 89-36, found its home at Rochester Institute of Technology for many good reasons. Among these was the interest of its faculty in addressing itself to the educational needs of post-secondary deaf students across the nation.

Dr. Zakia was at that time Professor of Photographic Science at RIT. Because of his interest in the education of the deaf, he undertook independent study at the University of Rochester in psychological factors associated with deafness, and later participated in the first NTID summer institute on deafness for RIT faculty. It was at this time that his interests turned to the rarely asked, but fundamental question of how deaf people process verbal information when their primary receptive modality is visual rather than auditory.

Subsequently, he was granted a sabbatical to complete his doctorate in educational psychology with a major interest in visual preception at the University of Rochester, a natural mix for an educator who teaches in the area of photography.

Dr. Zakia is now Director of Instructional Research and Development at RIT, a friend and mentor to deaf and hearing students on the RIT campus, and a valued friend to NTID.

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Table of Contents

List of Tables

1 Introduction

(a) Background

The roots of language for normally hearing persons are imbedded in the vocal utterance, in the auditory signal, and in meaning attached to this signal. The child with an impaired auditory mechanism is severely handicapped in establishing a language which is so dependent on sound. Hearing becomes secondary to seeing for the generation of language in the congenitally, profoundly deaf child.

Considerably more attention has been given by researchers and clinicians to auditory peception than to visual perception in the deaf child. This is not to suggest that hearing has been given undue attention, but rather that the dimension of seeing has been largely ignored.

Most deaf people are dependent upon speechreading and upon reading manual communication (signs and fingerspelling) for language reception. Both depend upon an ability to sequentially process "*bits*" of information, phonemes, letters, and words presented visually.

Researchers interested in visual perception, and particularly those interested in the reading process, have accumulated considerable information on the style and efficiency of hearing persons in forming words when they are presented graphically, letter by letter, in rapid sequence. This knowledge has led to a number of theoretical positions relating to how language is coded visually, positions which could shed light on how deaf persons code information presented visually, and, more important for the deaf child, positions which might suggest more fruitful ways of establishing language in the deaf child on a visual basis.

This investigation addressed itself toward several fundamental questions concerned with the relative ability of deaf and hearing students to visually process words when they are presented letter by letter, and with relationships which might exist among deaf students between the ability to process words presented tachistoscopically, letter by letter, and the ability of the same students to process words through fingerspelling and through speechreading.

(b) The Literature

Studies in visual tachistoscopic tasks have been numerous and can be traced back to some of the early work of Helmholtz over 100 years ago. Until recently the stimuli for such studies consisted of a spatial array of characters such as letters or numbers presented for a brief moment (example G L M F B). Some contemporary researchers have been concerned with a temporal display of stimuli, each for a brief moment, but in the same position. Each letter would fall one on top of the other, being separated in time rather than in space. This would be analogous to a person running a 100 yard dash while remaining in one place. If fingerspelling and speechreading are viewed as visual displays of information in which the stimuli are separated in time but not space, one can then refer to a considerable amount of existing theory in the area of sequential processing of visual information.

1. Short-term visual storage

Short-term visual storage is used to describe the perceived duration of a visual stimulus. This persistence, which lasts for about 200 milliseconds (msec), is thought to reside somewhere neurologically in what has been called short-term visual storage (STVS). This is to say, for example, that if a letter is flashed for 10 milliseconds, it will persist for an additional 200 milliseconds, giving the subject 210 milliseconds to process the information. This assumes that a second letter is not flashed during the interval of persistence of the first letter. If a second letter is shown immediately after the first letter, it will interfere with the persistence of the first letter. Such interference is called masking. There are no data on whether masking occurs during fingerspelling or speechreading perception.

2. Tachistoscopic tasks

If a brief visual presentation persists as a short-term visual representation somewhere in the nervous system for several hundred milliseconds after the offset of the physical stimulus, then in studies of briefly exposed stimuli, the appropriate independent variable is not the physical on time of the stimulus but the total processing time, the combined on time of the physical stimulus plus its duration in STVS.

The duration of the STVS can be controlled by the introduction of a visual noise field at some point following the offset of the physical stimulus. Haber and Nathanson (1969) used a sequential presentation of the letters of a word as a means of introducing visual noise. Each subsequent letter served to mask the preceding letter and, therefore, controlled the short-term visual storage of each letter. Their findings indicate that the total processing time, defined as onset to onset of sequentially presented visual letters, is a more valid independent variable than the on time of the stimulus alone. Further, they found that it makes little difference how the on and off times are distributed within the total processing time. For example, an on time of 25 msec and an off time of 50 msec yields the same recognition on the part of the viewer as an on time of 50 msec and an off time of 25 msec.

Aaronson (1967), using sequential *auditory* presentation of random digits, found that the distribution of on-off times within the total processing times was an important variable. As the on time decreased and the off time increased, performance improved. These findings suggest that different factors relative to short-term storage are operating in visual and auditory sequential processing.

Kolers and Katzman (1966) studied the ability of hearing college students to name letters and name words when the letters are presented sequentially. Their findings indicate that the task of naming letters is easier than that of naming words. To obtain a 90 percent correct response for naming letters, a rate of 250 msec per letter was needed. However, at least 375 msec per letter was required to name words correctly 90 percent of the time.

In naming of words Kolers and Katzman observed that although the subjects could quickly identify the letters, they would frequently pause several seconds before naming the word. This suggests that identifying letters and identifying words require two different methods of processing such visual sequential information.

3. Sequential and simultaneous visual presentations of letters in words

The findings of Kolers and Katzman (1966), and supporting evidence from the research of Haber and Nathanson (1969), Sperling (1963), and Estes and Wessel (1966), all point to the conclusion that when words are presented letter by letter in temporal sequence, these words require substantially more time to visually process than when the letters of the words are presented simultaneously. The former task seems to be much more difficult.

However, one might raise the question as to whether the difficulty is attributable to lack of experience in processing visual information sequentially. The answer to such a question has major implications for the deaf person who is dependent on the sequential processing of visual information in both speechreading and in reading manual communication.

4. Other factors influencing word recognition

Aside from whether the letters are presented sequentially or simultaneously the recognition of words is influenced by several factors. Bruner (1957) states,

"Perception involves an act of categorization... we stimulate an organism with some appropriate input and he responds by referring the input to some class of things or events... The use of cues in inferring the categorical identity of a perceived object...is as much a feature of perception as the sensory stuff from which percepts are made. (p. 634)"

Miller and Friedman (1957) found that it was possible to abbreviate passages of text by as much as 50 percent either by omitting the vowels and the space between words or by omitting alternate characters, and still have the passages read correctly. Shannon (1951) has estimated that that redundancy of printed English is something greater than 75 percent. Miller (1954) likens this redundancy to a Markov chain in which if the nth element of a sequence depends upon the preceding elements, then the nth element can often be predicted from a knowledge of the preceding elements. Broadbent (1967) uses the term *"sophisticated guessing"* to say about the same thing. He states,

"...even when a stimulus word has not been correctly perceived, the information which has arrived at the senses nevertheless rules out some English words as being impossible, and leaves a restricted set of alternatives as still consistent with

what has been heard. (p.2)."

Solomon and Postman (1952) found that words of high exercise freque'cy interfered with words of lower exercise frequency and that such interference resulted in a tendency for the subject's *"guesses"* to be of high frequency words.

Goldstein (1962) found that a subject enters a perceptual task with well defined response habits which are not under control of the stimuli and which can influence the subject's recognition. Kempler and Wiener (1963) take the position that all perception involves responding to partial information with the particular response being some function of previously learned co-occurrence probablitites. (p. 776).

Expectancy is a primary factor affecting recognition. Haber (1966) found that encoding is more rapid for words one expects to see and that being ready for what he will see, the individual will more likely have an appropriate strategy and cateogry available for the encoding of the stimuli.

Recognition of words, therefore, involves much more than the perception of their constituent letters. It is a problem solving task in which the subject brings to bear all his experience, his set, expectancy, encoding, categorization, guessing ability, response habits, and an array of strategies to help him recognize the word.

5. Research with deaf students

Blair (1957) in a summary of memory abilities of deaf and hearing children, lists the deaf as being superior in memory for design, tactual memory, and memory for movement; inferior in memory for dots, picture span, and digits; and equal for object location. He suggested that the poorer performance of the deaf on memory span for dots, pictures, and digits could be attributed to the fact that, in his test, the sequence of dots, pictures and digits exposed had to be conceptualized by the subjects in order for the sequence to be reported. This was unlike the other memory tasks, which he suggested *"involve a visual perceptual act rather than mental abstraction or conceptualization as do memory spans" (p. 261).* Postman (1965) seems to support this position by suggesting that inferior performance of deaf subjects on certain perceptual memory tasks can be attributed to the inability to code perceptual information into *"chunks"*. Myklebust (1960) suggests,

"... deafness influences retention and recall abilities but that the influence varies from one type of memory function to another. Apparently auditory experience is not necessary for retention of design and object location, or for retention of movement patterns, such as on the Knox Cube Test. (p. 84)."

Olsson and Furth (1966) in a comparison of deaf and hearing adolescents and adults on a visual memory span task found both groups performed alike with nonsense forms presented sequentially (1 second exposure, 2.2 seconds between successive exposures) and simultaneously. On a digit span task the performance of the deaf and hearing children on a sequential presentation of nine patterned and unpatterned + and - symbols, Ross (1969) found the hearing to be superior under only one condition of patterned sequences. On the basis of his findings he states,

"...immediate memory models that require auditory-visual systems for the storage of visual sequential information are contradicted" (p. 339)

While many comparision studies have been made between hearing and deaf subjects of varying ages on various visual memory tasks, none of these has involved STVS studies. All of them involve a one second or more exposure to the stimulus. In general, their findings indicate that when compared to hearing subjects, deaf subjects seem to show superior performance on visual tasks that require no verbal encoding and inferior performance on tasks that require encoding or verbalization. However, there are differences in opinion on why the deaf are inferior on some visual memory tasks and superior on others. Most argue that differences are attributable to the reduced ability of deaf persons to code information verbally.

A recent series of studies conducted by Allen (1969) sheds light on several aspects of verbal learning and visual memory in deaf and hearing students. She found in one experiment that profoundly deaf students were superior to hearing students in learning lists of visually paired associates such as *"snow-cow"*, while hearing students were superior in learning auditory rhyming lists of paired associates such as *"blue-two"*, even though both sets were presented to the students in printed form. This suggested qualitative differences in the way deaf and hearing

The fingerspelled word LOVE (which would normally be seen in a time sequence).

students process printed verbal information, hearing students using implicit acoustic features in the printed material, and the deaf using visual aspects.

With respect to short-term verbal memory, and following another experiment, Allen (1969) stated,

"The results of this experiment indicate that short-term verbal memory is functionally the same in children with normal or with imparied hearing.---If the hypothesis of an auditory storage is valid for normal-hearing subjects, then the hearing impaired are either using the same memory process or else are employing another process with equal efficiency." (p. 69).

6. Speechreading and the reading of fingerspelling as visual sequential tasks

Fingerspelling can be considered a sequential tachistoscopic task similar in several ways to the type Haber and Nathanson (1969), and Kolers and Katzman (1966) have examined. Each symbol is presented for a brief time, in generally the same physical position, and in a sequence that forms a word. However, although there are similarities between the two types of visual tasks there are also important differences. In fingerspelling, the symbols are in motion, each letter flowing into another. They are not presented discretely as are printed letters in a tachistoscopic task. In addition, the symbols are sent with the expressive background of the sender (smiles, frowns, etc.) additional cues to recognition.

Speechreading might also be viewed as a visual sequential task in that the lips are in various configurations over a span of time. Like fingerspelling, motion is involved but, unlike fingerspelling, the movements are much more restrictive spatially. In addition, the phonemes are not all represented by lip movements. Contextual cues are extremely important.

Goetzinger (1967) tested 18 male and 18 female hearing students between the ages of 14 and 21 to investigate the relationships between the ability to speechread and the memory for motion as measured by the Knox Cube Test. He found no relationship between speechreading ability and memory for motion as measured by the Knox Cube Test, suggesting that visual sequential memory is not a significant factor in speechreading ability.

This finding was in marked contrast to the findings of Neyhus and Mylkebust (1969), who observed a high correlation between speechreading ability and performance on the Knox Cube Test among deaf children. This led them to report, *"These results reveal the importance of (visual perception and) visual sequential memory in developmental of lipreading ability" (p. 105).*

2 Problem

(a) The Problem

Deaf children and adults are forced to rely heavily upon vision to process language input not only in the traditional sense of reading, but as an alternative to hearing. Spoken language must be percieved visually by the receiver as speechreading. If the communicator is skilled in sending manually, and the deaf communicatee is skilled in decoding manual communication, this then becomes another alternative. Both skills depend upon an ability to process verbal information visually and sequentially.

This investigation was intended to examine one aspect of the relative ability of deaf and hearing students at the post-secondary level to process verbal information (words) visually and to determine whether a relationship exists between the ability of a deaf student to identify words which are presented in rapid letter-by-letter graphic sequence, and his ability to read fingerspelling and to speechread.

(b) Objectives

The objectives of this investigation were:

1. To determine whether there is a difference between the relative ability of deaf and hearing post-secondary students to identify meaningful words when their letters are presented sequentially in printed form.

2. To determine whether there is a difference between the relative ability of deaf and hearing post-secondary students to identify letters of nonsensical words when their letters are presented sequentially in printed form.

3. To determine among post-secondary deaf students whether there is a relationship between the ability to identify printed meaningful words when their letters are presented sequentailly, and the ability to read fingerspelling.

4. To determine among post-secondary deaf students whether there is a relationship between the ability to identify printed meaningful words when their letters are presented sequentially, and the ability to speechread.

3 Procedures

(a) Subjects

The students selected for this investigation were all enrolled at Rochester Institute of Technology, an undergraduate and graduate institution offering preparation for careers in industry, business, government, and education. RIT, under an agreement with the Department of Health, Education and Welfare, established the National Technical Institute for the Deaf (NTID) which offers an opportunity for post-secondary deaf students to prepare for such careers.

Thirty-three deaf and 19 hearing students were selected from the student population. These students were all participating in courses on the RIT campus during the 1969 summer session. The deaf and hearing students represented similar major areas of study at RIT.

Table 1 indicates the relative age and sex of the deaf and hearing subjects, and the mean hearing loss of the deaf students (better ear, ISO) in the speech range.

Table 1. Description of Deaf and Hearing Subjects

	Deaf	Hearing
Mean age in years	21	21
Sex distribution		
male	19	13
female	14	6
Mean hearing loss, deaf students	91 dB	

(b) Experimental Setting

The experimental setting was located at the Center for Visual Science at the University of Rochester within approximately three miles of RIT. This is an interdisciplinary center composed of the pooled academic and technical resources from several departments and colleges within the University. Specialized courses and advanced research facilities are offered to graduate and post-doctoral students whose interests involve the field of visual sciences. The Center includes several research laboratories and a variety of equipment including a PDP-8 computer linked to remote teletype machines.

(c) Computerspelled Tasks

The apparatus used to present the computerspelled tasks was similar to that used by Haber and Nathanson (1969). A small computer was used to generate the letters and to present them quickly and sequentially.

The letters were presented on a single alpha-numeric display drawn on a 4 x 3 in. electroluminescent panel made by Massey Dickinson. The panel contained 15 segments, each of which could be controlled and displayed independently of the others. All letters were capitals, averaging 3-½ inches high and 2 inches wide (8 x 5 deg. at a distance of 2 ft.). The luminance of each segment was 8 ft.L. A weak luminance (less than 0.5 ft.L.) was present owing to stray light on the background of the panel when some segments were on. They were invisible when off. (Haber and Nathanson, 1969, p. 359)

The room was dimly illuminated to allow subjects to write their responses. A 25-W lamp three feet behind the subject and shielded from his view provided an illuminance of 1.3 lumens/-meter ^{2} in the area in which the subjects were seated.

Examples of the letters are presented in Figure 1.

"The display sequence for the panel was controlled by a PDP-8 digital computer. Each of the 15 segments was treated as a separate bit in the computer memory. A 15-bit buffer served as interface between the accumulator of the PDP-8 and the segments on the panel. The program specified, for each trial, the on-time for each letter, the off-time between successive letters, and the particular sequence of letters to be displayed." (ibid, p. 359)

The stimuli for both the computerspelled and fingerspelled word tasks consisted of 4, 6, and 8 letter words of high and low imagery (Appendix A and Appendix B). The words and imagery measure were taken from a word list developed by Paivio, Yuille and Madigan (1968). For the letter task, 4 and 6 letter nonsensical words were constructed by random selection from the distribution of the letters that made up the 4 and 6 letter words used in the word task (Appendix C). In some cases this resulted in a 3 or 4 letter word within the letter array. When this occurred, the letters within the array were again scrambled to break up these words within the words. No 8 letter array was used because pilot tests demonstrated their great difficulty for a written response even at the slowest rate.

For each rate of sending, the computerspelled letters were displayed for 25 msec per letter. To produce different sending rates, the off times were set at 275, 125, and 50 msec per letter respectively. The words and letter arrays used and the sequence in which they were sent is shown in Appendix A for all conditions. In general, for each condition, the first few trials were selected to be 4 and 6 letter words or letter arrays. The rest were ordered randomly.

Because of the anticipated difficulty in orally communicating with some of the deaf students, all instructions were in writing and were read by each student at the beginning of each part of the experimental sequence. The same procedure was used with RIT hearing students.

For the computerspelled task subjects were tested two at a time at a distance of 5 ½ feet from the screen. When both subjects were attending to the screen, the experimenter would initiate the display of letters. Each subject would then write out his response, taking as much time as needed. When both were again ready, the experimenter would initiate another display of letters.

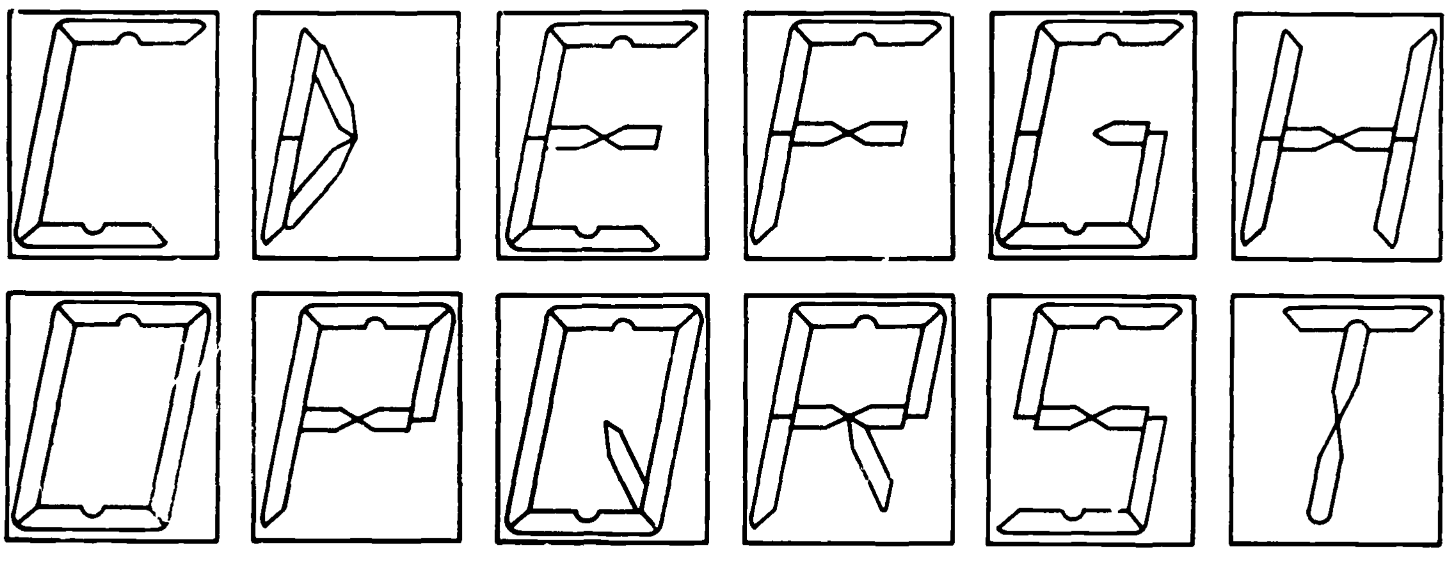
On the word task the subjects were instructed to guess if necessary and to leave a blank if they found it impossible to make out the word. For the letter task they were instructed not to guess and to make a dash for letters they missed. The sequence of stimuli was identical for each pair of subjects tested.

For the computerspelled task all subjects read the following sequence of instructions:

Because the letters you will be seeing on the screen will have a little different style from the letters you know, please take a few minutes to study these letters as they are drawn on this sheet of paper. Please note that all the letters are capital letters. The letter B is most different, so take a good look at it. When the letters are presented on the screen watch them for a while until you get used to seeing them. (The letters were presented in alphabetic order for about five minutes.)

We will now have about a 15 minute practice session. Words will be sent that are 4, 6, and 8 letters long. When you are ready

Figure 1. Style of letters constructed from segments of the alphanumeric display on the Massey-Dickenson 4" 15 segment electrolumnescent panel.

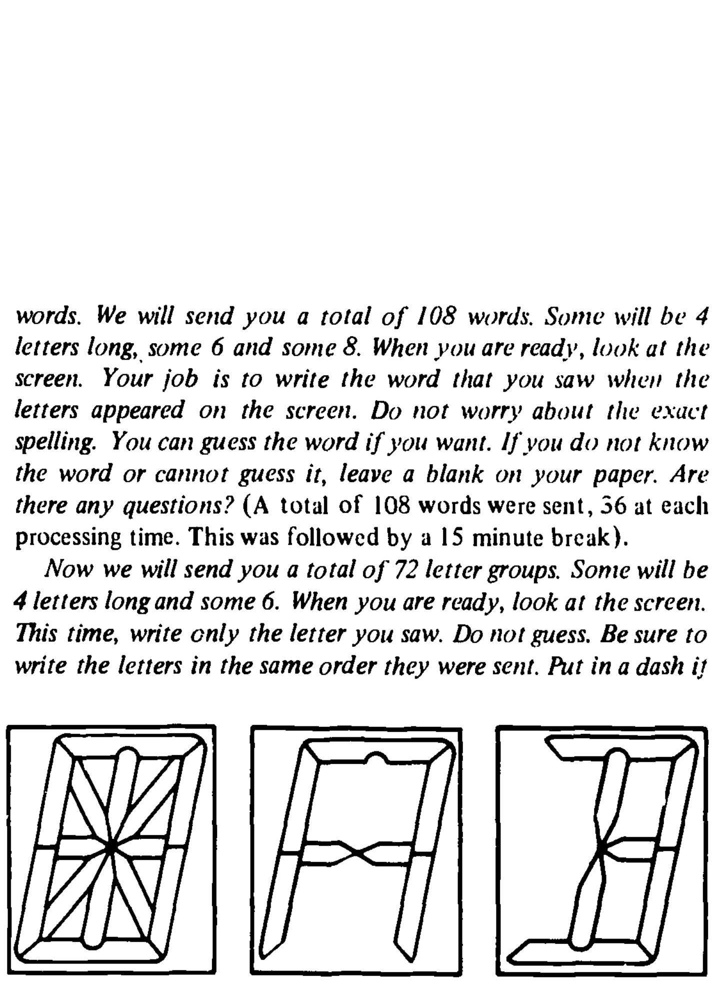


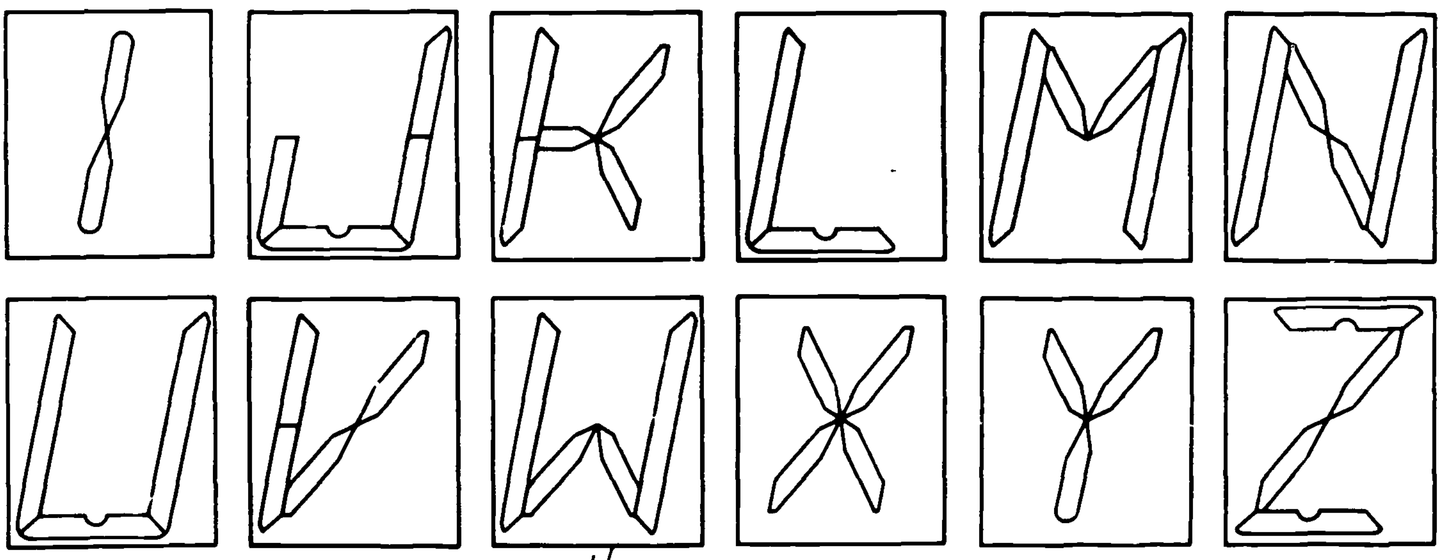
to see the letters on the screen look at the screen. I will then press a button and you will see the letters. After you see the letters on the screen, write the word they form. Guess if you want. If you cannot make out the word, please leave a blank on your paper. When you are ready for another word look at the screen and I will press the button. I will only press the button when you are both ready. Take whatever time you need to write the word. (Subjects were then shown a total of 45 practice words, 15 at each of three processing times.)

We will now send you 4 and 6 letter combinations that do not make up words, for example: XRVT or MJOZRN. Write only the letters that you see. Do not guess this time. If you do not see a letter, or if you forget it, leave a blank space between letters or make a dash. After the letters are shown, write as quickly as you can so you do not forget the letters you see. For example, if we send the letters RXFB, and you see only RFB, you should write R-FB. (A total of 30 practice letter groups were shown, 10 at each of three processing times. This was followed by a 5 minute break.)

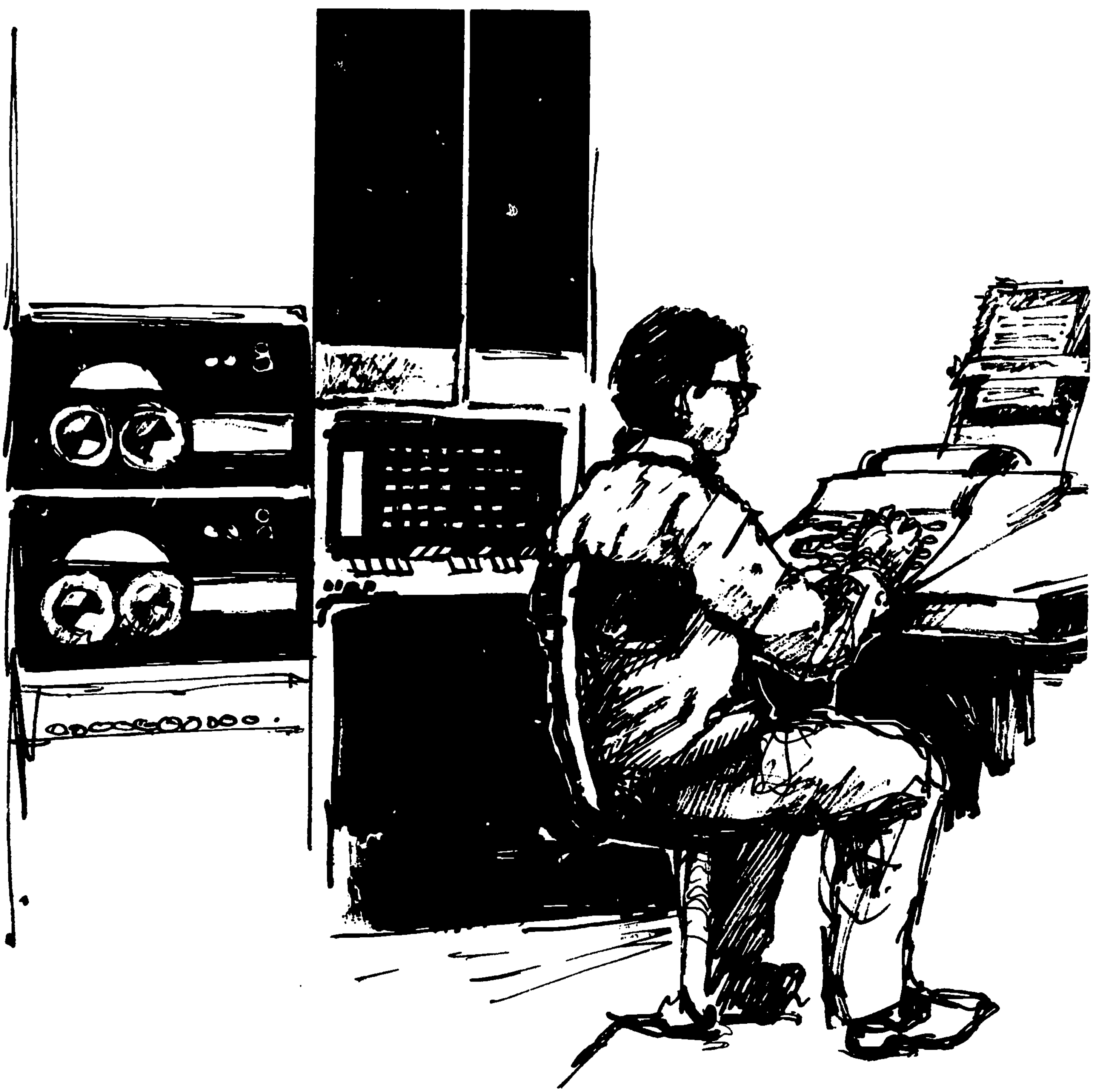
Now that the practice session is over, we will start with some words. We will send you a total of 108 words. Some will be 4 letters long, some 6 and some 8. When you are ready, look at the screen. Your job is to write the word that you saw when the letters appeared on the screen. Do not worry about the exact spelling. You can guess the word if you want. If you do not know the word or cannot guess it, leave a blank on your paper. Are there any questions? (A total of 108 words were sent, 36 at each processing time. This was followed by a 15 minute break).

Now we will send you a total of 72 letter groups. Some will be 4 letters long and some 6. When you are ready, look at the screen. This time, write only the letter you saw. Do not guess. Be sure to write the letters in the same order they were sent. Put in a dash if





14



The experimental environment for the computer spelled task.

you did not see the letter. For example, we send V R E N Z O and you see only VEZO you should write ... V-E-ZO. Write the letters as quickly as you can so you do not forget them. (A total of 72 letter groups were then displayed, 24 at each processing time.)

(d) Fingerspelled Tasks

The fingerspelling task was presented only to the 33 deaf subjects. The procedure used in the fingerspelling task was similar to that in the computerspelled task except that the stimuli were presented live to from one to five subjects at a time in a well illuminated classroom at RIT.

Examples of the fingerspelled letters are shown in Figure 2. They were sent by a deaf person judged excellent in the clarity and consistency of his fingerspelling ability. The sender was given the following written instructions.

Send at a constant rate and make each letter distinctly. After a word or letter group has been sent, slowly drop your hand. Bring your hand back up to position before beginning the next word. Wait until everyone has written the word and is looking at you before sending the next word. (The time between words is not important.) If you make a mistake in sending a word, stop, let everyone know it was a mistake and then start the word over again. Begin each session with about a 5 minute practice session. First send the alphabet a few times. This will allow the sender and receiver to adjust to each other. Avoid facial expressions or any other clue that might help the reader identify the word or letters being sent.

The deaf subjects, already familiar with the computerspelled sequence, were given the following written instructions:

Thank you for coming. Our purpose today is to obtain a measure of how you read fingerspelled WORDS and LETTERS. Some of you will do better than others because of your experience and style of communications. This is expected. I ask you to do the best you can. We should finish in about 45 minutes. First, we will have about a 5 minute practice session. Second, words will be sent to you that are 4, 6, and 8 letters long. Write the word. (Guess if you want.) Third, letter groups that are 4 and 6 letters long will be sent to you. Write the letters. (Do not guess.) If you do not see some of the letters, leave a dash. Example: R-LNFJ.

Tight control over the rate of sending the fingerspelling to the subjects under live conditions was exercised. The sender was asked to spell clearly at a constant rate. This rate was timed over a period of ten separate sessions, and the mean rate per letter for

The experimental environment for the fingerspelled task.

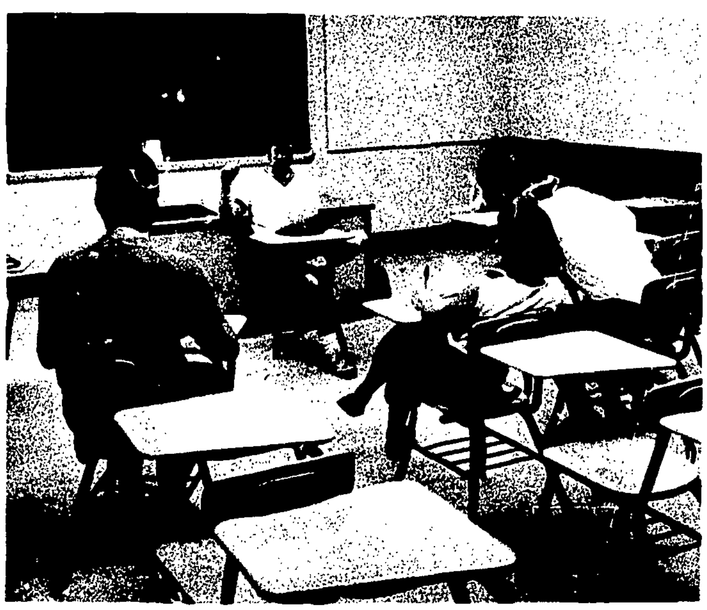


Figure 2. The fingerspelled alphabet.

the word task was determined to be 485 msec, and for the letter task, 527 msec, with a standard deviation of 22 and 21 respectively. The longer sending rate for the letter task resulted from the sender's difficulty in sending the peculiar letter combination.

(e) Speechreading Tasks

The deaf subjects had been administered form C of the Illinois Communication Scale (1966) approximately ten months before the balance of the testing took place.

At present, no fully satisfactor test of speechreading exists. This scale had been selected for prior administration because it yields separate scores for lipreading and listening, lipreading alone, reading fingerspelling, and reading the language of signs. Since scores for each of the deaf subjects on form C, lipreading, were already available, the performance of the students on this subtest was used as measure of speechreading proficiency.

Form C of this scale, like the other forms, has five parts, in which vocabulary, simple sentences, stories, narration, and random sentences and phrases are respectively presented. Each part has 10 items, yielding a possible score of 50.

4 Results

(a) Identification of Printed Meaningful Words

A comparison of the relative ability of deaf and hearing post-secondary subjects to correctly identify printed meaningful words when their letters were presented sequentially indicates that the deaf subjects were superior under all conditions tested. This is shown in Table 2.

Table 2. Mean Percent of Meaningful Words Identified Correctly by RIT Deaf and Hearing Subjects as Speed, Word Length and Imagery Change

Speed (in milliseconds)[1]	Deaf (n=33)	Hearing (n=19)
300	78	67
150	47	41
75	18	10
Length		
4	61	53
6	44	35
8	37	30
Imagery		
Low	45	37
High	50	41

An analysis of variance of the four possible sources, group (deaf and hearing), speed, word length, and imagery, indicated, as seen in Table 3, that the variance due to groups was statistically significant at the 10 percent confidence level, favoring the deaf group, while the remaining three sources were each statistically significant beyond the 1 percent confidence level, favoring slower speed of presentation, shorter word length, and high imagery.

Table 3. Analysis of Variance for Printed Meaningful Words

Source	dF	M.S.	F	p
Group	1	14747.29	2.87	.10
Speed	2	271849.96	398.52	.001
Length	2	46421.12	197.96	.001
Imagery	1	3743.42	21.52	.001

Of the meaningful computerspelled words that were not correctly identified, some were identified incorrectly and others were simply omitted. Table 4 shows the breakdown of total correct, mistaken, and omitted words. The error analysis revealed that while the proportion of omissions was similar for the deaf and hearing subjects, the hearing subjects made more mistakes, and the deaf got more words correct, both significant at the 0.10 level.

Table 4. Mean Percent Performance of Deaf and Hearing Subjects in Identifying Printed Meaningful Words

Percentage of Words	Deaf	Hearing
Correct	47	39
Mistakes	31	37
Omissions	22	24

The performance of the deaf and hearing groups in identifying printed letters of nonsensical words is indicated in Table 5.

Table 5. Mean Number of Letters of Printed Nonsensical Words Correctly Identified by Deaf and Hearing Subjects

	Correct order		Any order	
Speed	Deaf	Hearing	Deaf	Hearing
300	3.0	3.5	3.8	4.2
150	1.8	1.9	2.9	3.1
75	1.2	1.3	2.2	2.5
Length				
4	2.1	2.3	2.9	3.1
6	1.9	2.1	3.1	3.4

Two analyses of variance were run, one for letters identified in correct order, the second for letters identified in any order. For each analysis, three possible sources of variance were examined, group (deaf and hearing), speed, and word length. Table 6 indicates the results of these analyses.

The performance of the hearing group on the number of letters co-rectly identified both in correct and in any order was superior (p. .05 and .10 respectively). Again, performance was superior at slower speeds and shorter words lengths.

Table 6. Analysis of Variance for Printed Letters of Nonsensical Words

		Correct order			Any order		
Source	dF	M.S.	F	p	M.S.	F	p
Group	1	4.98	4.30	.05	4.71	2.80	.10
Speed	2	104.78	364.74	.001	71.10	232.60	.001
Length	1	2.20	17.23	.001	6.64	31.45	.001

The superior performance of the deaf subjects in writing words and of the hearing subjects in writing letters suggests a basic difference in the way each group perceived the given task. The deaf subjects seemed to be attending more to the word formation when the letters were sent while the hearing subjects seemed to be attending more to the individual letters. Forming words from sequentially presented letters is a task familiar to many deaf persons while identifying letters is not. The lower performance of the deaf subjects and the higher performance of the hearing subjects on the letter task emphasizes a difference in the way each group was processing sequential information. It illustrates, moreover, that the two tasks are different.

(b) Printed Meaningful Words and Reading Fingerspelling

A Pearson product moment correlation was run to determine if, among post-secondary deaf students, there was a relationship between their ability to identify printed meaningful words when their letters are presented sequentially and the ability to read fingerspelling. Highly significant correlations were found, as indicated in Table 7.

Table 7. Correlations Between the Ability of Deaf Subjects to Read Fingerspelled Words and Printed Meaningful Words Whose Letters are Presented Sequentially (n=33)

	Fingerspelled Words (485 msec per letter).	
Printed Words	r	p
300 msec	0.71	.01
150	0.50	.01

As shown in Table 7, the correlation, although lower at the faster 150 msec speed, remains high. These high correlations indicate that both methods of sequentially presenting letters that form words are in some sense similar, and call on similar skills in the receiver.

(c) Printed Meaningful Words and Speechreading

No statistically significant correlation was found between the ability of the deaf subjects to identify computerspelled words and their ability to speechread as measured by the Illinois Communication Scale. This, as well as the negligible correlation found between the ability to read fingerspelled words and the ability to speechread is shown in Table 8.

Table 8. Correlations Between the Ability to Speechread and the Ability to Read Printed Words or Fingerspelled Words

	n	r	p
Printed Words			
300 msec	30	.06	n.s.
150 msec	30	.24	n.s.
Fingerspelled Words			
485 msec	28	.06	n.s.

Lack of a statistically significant correlation between the ability to read printed words whose letters are presented sequentially, and to read words formed by speech suggests that the perception of these two tasks is different. However, it should be added that the particular speechreading task used in this investigation involved more than reading words, but extended to sentences and stories.

5 Discussion

(a) Words and Letters

The superior performance of the deaf students in identifying words and the hearing students in identifying printed letters indicates that, although the method in which the stimuli were sent was identical, the perception of those stimuli was different for the hearing and the deaf. Hearing students attend to each letter regardless of whether the task is to identify words or to identify letters. The deaf students, being experienced in attending to words when letters are sent sequentially, as in reading fingerspelling, do better at seeing words when letters that are sent make up words. When letter arrays which do not make up words are sent, the deaf students are at a disadvantage since this is not a familiar perceptual experience for them. In fact, their habit in seeing words when letters are sent could be interfering with the requirement to see only letters and not words. This is suggested by the fact that some deaf students forced nonsensical letter arrays into words. For example, when the letter array IEGRFH was sent, several students wrote EIGHTH.

The difference in performance between the deaf and hearing students might be explained on the basis of theory in transfer of learning. Learning in one situation is best transferred to a new situation if the situations have similarities. Deaf students have learned to see words when letters are sent sequentially, i.e. fingerspelled. If both the stimuli and the new task to be learned have similarities in terms of required skills, a transfer of the previous learning to the new task can facilitate that learning. The high correlation found between identifying words that are fingerspelled and words that are computerspelled indicates a similarity in the two tasks.

The higher performance of the deaf students on identifying words and the hearing students on identifying letters indicates that although the physical stimuli are the same in each case, the *perception* of those stimuli is not. For transfer of learning to occur not only is it necessary for the physical stimuli to bear a resemblance, but it is essential that the perception of those stimuli be similar. This emhasizes the fact that the first stage of any learning is perceptual and that the perception is influenced by experience. In addition, as mentioned earlier, it is quite possible that the habit of identifying words when letters are sent sequentially can actually interfere with the new learning expected. The new learning was to identify letters when letters of nonsensical words are sent sequentially.

Kolers and Katzman (1966), in their study *Naming Sequentially Presented Letters and Words*, found that their subjects performed better in naming letters than in naming words. The results of this study have a bearing on their finding: *hearing* subjects do better than *deaf* subjects at identifying letters. Deaf subjects, however, do better than hearing subjects at identifying words, which suggests that the two tasks are different and that experience in the perception of sequential stimuli is important.

In reading fingerspelled words a highly experienced reader is not attending to the individual letters but rather to the total pattern of the finger configuration, or at least enough of that pattern to identify the word. Persons who teach fingerspelling reading recognize that those persons who continue to attempt to form a word by identifying each letter and its order never gain proficiency in reading fingerspelling.

In this study, when letters that form words were sent, some deaf subjects would indicate they knew the word but could not write it because they did not know how to spell it. This was surprising since it had just been spelled. In one case a subject wrote the word *bug* because he did not know how to spell the word "*mosquito*" which had just been seen. Such incidents support the belief that they were attending to the word and not the individual letters. Kolers' and Katzman's statement (1966, p. 91) that, "*Correct spelling does not by itself insure correct naming of the word*", can be varied to read that correct recognition of the word does not by itself insure correct spelling. The importance of experience in performing a sequential task encourages one to speculate whether other methods of processing verbal information might be more efficient for many deaf people. For example, with captioned films the captions might be a single word or short phrase per frame rather than a sentence. This would require less picture area, a very important factor with small film or TV formats. Equally important, this type of captioning would require only a small visual field, making it possible for a person to attend more to the pictorial image and to use peripheral vision to process the captions. In addition, since there is a persistence of stimuli for about 200 msec (short-term visual storage), and since each motion picture frame is on for about 1/24 of a second (about 40 msec), it may be necessary to caption only every third or fourth frame. This could mean that fewer than half the frames need to be captioned.

(b) Theory

If the deaf subjects' superior performance on the meaningful word task was due strictly to experience in perceiving a sequential display of letters as a pattern, this fact could explain why deaf persons have been found to be superior in perceptual memory tasks as requiring no coding or *"chunking"* of perceptual information - why they are superior to hearing persons in such tasks as memory for design and for movement (Blair, 1957; Postman, 1965). Their superior performance is perhaps explainable on the basis of the experience they have acquired in coping with communication problems and methods associated with deafness. Being deaf has caused them to process visual sequential information differently from hearing persons. They do not see the stimuli as discrete but as patterns including movement. The hearing subjects' superior performance on the letter task, which required the recognition, coding and rehearsal of each letter further supports this contention.

(c) Teaching Fingerspelling Reading

Many of the results of this study can be used as experimental evidence in support of present practice in teaching fingerspelling reading. The superior performances of the deaf on the word task and the hearing on the letter task support the view that the learner should attend to the overall pattern of letters that make up the word. Once this technique is learned, one can see the word as it is sent, and not have to attend to each letter, followed by rehearsal of the array in an attempt to recognize the word. This is a difficult and time consuming process. Persons who are good readers of the printed word do not attend to the spatial array of letters that make up a word but rather to the word itself. Similarly, one should not attend to the temporal array of letters that make up a word but attend to the word itself if he wishes to be a good fingerspelling reader.

If one wishes to learn how to read words, he must attend to the whole word. If he is interested only in recognizing letters, he should attend to the letters. Further, since the two tasks are different, as this research and that of Kolers and Katzman (1966) have demonstrated, one should not expect efficient transfer of learning between tasks, particularly as the rate of presentation increases.

Persons who learn to see the whole word when letters are fingerspelled and become highly proficient in such a task do significantly better at longer words as evidenced by the superior performance of a group of interpreters. For these persons the reaction time between the presentation of the letter stimuli and the response (writing the word that the letters formed) was almost immediate - regardless the word length. This was not so with the less experienced persons. Again, when a person is attending to the whole word, length is relatively unimportant, just as it is for a person reading the printed word.

The rate at which the letters are sent is important to the recognition of the word. Too slow a speed forces one to attend to each letter while too fast a speed can interfere with the recognition of the pattern that makes up the word. Since optimum speed is a function of the person receiving, it would be ideal to gear the rate of presentation to his ability, and as he gains experience, to increase the speed accordingly.

Imagery is another important factor in word recognition. Words of high imagery are better identified at all word lengths and for all speeds, than are words of low imagery.

In teaching fingerspelling, the present practice of drilling the student to see words or groups of letters that express the basic morphemes in a word and to do this at a comfortable rate of presentation is supported by findings in this experiment. Further, it might be helpful to start a beginner with high imagery words, 3 to 6 letters in length.

(d) Speechreading

Again it is pointed out that the measure used for assessing speechreading considered speechreading not only words, but sentences. However, one might still expect to find some relationship between reading the computerspelled meaningful words and speechreading. Apparently the skills required for the two tasks are quite dissimilar, in spite of the sequential nature of both.

The finding of no relationship between the ability to read fingerspelling and the ability to speechread encourages speculation. The two tasks are sequential and similar in the sense that finger or lip configurations are formed in the same position over a span of time. Following from the argument that transfer of learning is facilitated if the physical stimuli *and* the perception of those stimuli are similar, the following quesitons are raised:

1. Are fingerspelling and speech movements perceived in a similar manner? Finding of no relationships suggests that they are not.

2. Would amplifying the lip movements help? If the lip configurations were of the same size as the fingers, would it help? Motions and size are very important in perception. Perhaps lip configurations for various words spoken are themselves not sufficiently dissimilar and, therefore, easily confused. A study on confusability of speechreading similar to those on confusability of spoken words might be warranted.

3. Would the use of a stroboscopic light directed towards the mouth area make the visual perception of speech easier?

4. Could such a technique make it easier for good speechreaders to read persons speaking on television or motion pictures?

5. Could some type of optical amplification be used? Need the entire mouth area be presented or can just a small number of select areas of the mouth be used?

6. How much information is actually being picked up by watching speechreading and how much by other visual clues? For a given situation is it possible to equate the amount of information picked up exclusively by speechreading and by fingerspelling?

6 Conclusions

1. Post-secondary deaf students are superior to their hearing peers in the identification of words whose printed letters are presented sequentially.
2. Post-secondary deaf students are inferior to their hearing peers in the identification of letters of nonsensical words when their letters are presented sequentially in printed form.
3. There is a strong positive relationship between the ability of post-secondary deaf students to read fingerspelled words and words whose printed letters are presented sequentially.
4. There is no relationship between the ability of post-secondary deaf students to speechread and to identify words whose printed letters are presented sequentially.

References

Aaronson, D. "Temporal factors in perception and short-term memory," *Psychological Bulletin*, 1967, *67*, pp. 130-144.

Allen, D.V. "Modality aspects of mediation in children with normal and impaired hearing ability," *U.S.O.E. Report*, Wayne State Univ., 1969.

Averbach, E. and Coriell, A. "Short-term memory in vision," *Bell Systems Technical Journal*, 1961, *40*, pp. 309-328.

Blair, F.X. "A study of the visual memory of deaf and hearing children," *American Annals of the Deaf*, 1957, *102*, pp. 254-263.

Bornstein, H. *Reading the Manual Alphabet*, Gallaudet Research Publication: Centennial Series 2 (Washington, D.C., Gallaudet College Press, 1965).

Broadbent, D.E. "Word-Frequency Effect and Response Bias," *Psychological Review*, 1967, *74* pp. 1-15.

Bruner, J.S. and Potter M.C. "Interference in visual recognition," *Science*, 1964, *144*, pp. 424-425. In R.N. Haber (ed.) 1968c, pp. 730-733.

Bruner, J.S. "On perceptual readiness," *Psychological Review*, 1957, *64*, pp. 123-152. In R.N. Haber (ed.) 1968c, pp. 634-662.

Conrad, R. "Order error in immediate recall of sequences," *Journal of Verbal Learning and Verbal Behavior*, 1965, *4* pp. 161-169.

Estes, W.K. and Taylor, H.A. "Visual detection in relation to display size and redundancy of critical elements," *Perception and Psychophysics*, 1966, *1*, pp. 9-16.

Estes, W.K. and Wessel D.L. "Reaction time in relation to display size and correctness of response in forced-choice visual signal detection," *Perception and Psychophysics*, 1966, *1*, pp. 369-373.

Goetzinger, Rita Bennet "A study of speech reading ability in relation to memory for motion and to visual perception with deaf subjects," unpublished master's thesis University of Kansas, 1967.

Goldstein, M.J. "A test of the response probability theory of perceptual defense," *Journal of Experimental Psychology*, 1962, pp. 23-28.

Haber, R.N. "The effect of prior knowledge of the stimulus on word recognition processes," *Journal of Experimental Psychology*, 1965, *69*, pp. 282-286. In R.N. Haber (ed.) 1968c, pp. 764-769.

Haber R.N "Nature of the effect of set on perception," *Psychological Review*, 1966, *73* pp. 335-351.

Haber, R.N. (ed.) *Contemporary Theory and Research in Visual Perception*, New York: Holt, Rinehart and Winston, 1968c.

Haber, R.N. and Nathanson, L.S. "Processing of sequentially presented letters," *Perception and Psychophysics*, 1969, *5*, pp. 359-361.

Hirsh, I.J. and Sherrick, C.E. "Perceived order in different sense modalities," *Journal of Experimental Psychology*, 1961, *62* pp. 423-432.

Huey, E.B. *The Psychology and Pedagogy of Reading*, Cambridge: MIT Press, 1968.

Keele, S.W. and Chase, W.G. "Short-term visual storage" *Perception and Psychophysics*, 1967, *2*, pp. 383-386.

Kempler, B. and Wiener, M. "Personality and perception in recognition threshold paradigm," *Psychological Review*, 1963, *70*, pp. 349-356. In R.N. Haber (ed.) 1968c, pp. 769-777.

Kolers, P.A. and Katzman, M.T. "Naming sequentially presented letters and words," *Language and Speech*, 1966, *9*, pp. 84-95.

Miller, G.A. "Psycholinguistics," in *Handbook of Social Psychology*, Lindzey, G., (ed.), Addison-Wesley, Cambridge, Mass., 1954, pp. 693-708.

Miller, G.A. and Friedman, E.A. "The reconstruction of mutilated English tests," *Information and Control*, 1957, *1*, pp. 38-55.

Murdock, B.B., Jr. "The retention of individual items," *Journal of Experimental Psychology*, 1961, *62* pp. 618-625.

Myklebust, H.R. *Psychology of Deafness*, New York: Grune and Stratton, 1966.

Newman, E.B. "Speed of reading when the span of letters is restricted," *American Journal of Psychology*, 1966, *79*, pp. 272-277.

Neyhus, A.I. and Myklebust, H.R. "Speechreading failure in deaf children," *U.S.O.E. Report*, Northwestern Univ., 1969.

Olsson, J. and Furth, H. "Visual memory span in the deaf,"*American Journal of Psychology*, 1966, *79*, pp. 484-486.

Paivio, A. Yuille, J.C. and Madigan, S.A. "Concreteness, imagery and meaningfulness values for 425 nouns," *Journal of Experimental Psychology*, 1968, *76*, monograph supplement, Part 2.

Posner, M.I. Boies, S.J., Eichelman, W.H. and Taylor, R.L. "Retention of visual and name codes of single letters," *Journal of Experimental Psychology*, 1969, *79*, monograph supplement, Part 2.

Postman, L.J. *Invariance in Learning and Retention*. In Stuckless, *E.R. (ed.)*, Research on Behavioral Aspects of Deafness, *proceedings of a National Research Conference on Behavior Aspects of Deafness, U.S. Department HEW, Vocational Rehabilitation Administration, 1965.*

Ross, B.M. "Sequential visual memory and the limited magic of the number seven," *Journal of Experimental Psychology*, 1969, *80*, pp. 39-347.

Scharf, B., Zamansky, H.S. and Brightbill, H.S. "Word recognition with masking," *Perception and Psychophysics*, 1966, *1*, pp. 110-112.

Shannon, C.E. "Prediction and entropy of printed English," *Bell Systems Technical Journal*, 1951, *30*, pp. 50-64.

Solomon, R.L. and Postman, L. "Frequency of usage as a determinant of recognition thresholds for words," *Journal of Experimental Psychology*, 1953, *43*, pp. 195-201.

Sperling, G. "The information available in brief visual presentations," *Psychological Monograph*, 1960, *74*, Whole No. 498.

Sperling, G. "A model for visual memory tasks," *Human Factors*, 1963, *5*, pp. 19-31.

Withrow, F.B. "The development of a receptive communication scale for deaf children," *U.S.O.E. Report*, Illinois School for the Deaf, Jacksonville, Illinois, 1966.

Appendix A

Words used in computerspelled task

FOUR LETTER WORDS

Low Imagery			High Imagery		
300	150	75	300	150	75
SOUL	IDEA	FACT	GIRL	FROG	FIRE
MIND	FATE	HINT	SHIP	GOLF	STAR
DUTY	PACT	HOPE	LAKE	WINE	MEAT
COST	LIFE	HOUR	FLAG	MULE	FORK
HIDE	JOKE	TIME	NAIL	WIFE	LAWN
STUB	FORM	CODE	OVEN	SKIN	PIPE

SIX LETTER WORDS

Low Imagery			High Imagery		
300	150	75	300	150	75
SURTAX	ORIGIN	CHANCE	GARDEN	VALLEY	HAMMER
EXCUSE	RATING	MOMENT	FOREST	CHURCH	FLOWER
THEORY	ANSWER	METHOD	MOTHER	DOCTOR	FRIEND
MEMORY	ADVICE	SAVANT	WINTER	CATTLE	SQUARE
PLEDGE	EFFORT	CUSTOM	PENCIL	HURDLE	INFANT
LENGTH	VIRTUE	SPIRIT	ROBBER	CRADLE	CIRCLE

EIGHT LETTER WORDS

Low Imagery			High Imagery		
300	150	75	300	150	75
TENDENCY	ATTITUDE	REMINDER	ELEPHANT	MOUNTAIN	REVOLVER
INTEREST	NONSENSE	POSITION	UMBRELLA	MOSQUITO	MAGAZINE
NAMESAKE	JEOPARDY	EVIDENCE	HOSPITAL	MACARONI	DAYBREAK
CAPACITY	HEREDITY	QUANTITY	PRISONER	RAILROAD	LEMONADE
MAJORITY	CONTENTS	SEMESTER	CLOTHING	MUSICIAN	MARRIAGE
VELOCITY	REACTION	PRESTIGE	MOISTURE	GARMENTS	INDUSTRY

Appendix B

Words used in fingerspelled task

FOUR LETTER WORDS		SIX LETTER WORDS		EIGHT LETTER WORDS	
Low Imagery 485	High Imagery 485	Low Imagery 485	High Imagery 485	Low Imagery 485	High Imagery 485
MOOD	BIRD	PATENT	BREAST	OCCASION	BUILDING
LINK	GOLD	UPKEEP	STREET	HARDSHIP	TWEEZERS
CORE	JAIL	DECEIT	DOLLAR	PRESSURE	HILLSIDE
ODOR	CORN	CRISIS	BEAVER	CITATION	FOOTWEAR
LICE	FORK	MENACE	PRISON	ATROCITY	BEVERAGE
JURY	COIN	HATRED	STRING	VOCATION	DAYLIGHT
LIME	HOME	VANITY	POSTER	CONQUEST	BASEMENT
DEED	TANK	HEALTH	TICKET	FRICTION	LEGGINGS
LUMP	ROCK	ERRAND	MARKET	MISCHIEF	LECTURER
BARD	ARMY	SAFETY	SINGER	EXERTION	KERCHIEF

Appendix C

Letters used in the computerspelled and fingerspelled letter tasks

Computerspelled task			Fingerspelled task	
300	150	75	527	
GHKG	AICE	KTFA	IMKD	EBEIRI
IEFI	DTLE	EOTM	ORNG	CFJO
GTRTIO	NRNVOG	EHCTLV	URCEIR	TEHNSE
TSTI	IATIFU	PNPA	ODLO	VSLERT
OGHXSE	FMKO	CTOTAO	PIOESD	EQUI
YNCO	ESAIRO	HMNHSM	AKTECE	LMKE
RLPL	KSIE	CDEI	ELTS	NTGTRT
ARHLRE	WGFN	AEOTCP	DBIL	IEDT
UCORLE	HLIANI	NDNSUI	ETDTIA	MHDA
LSNA	AOERTC	IRWE	PBERSA	ENTMAI
NVAI	GLIO	ESER	OLRC	IRHNCA
EHXMDT	MWNEIE	ATULEL	EDRI	EOEN
USDO	ERFQFC	LRORHU	AVCNHS	TPERDK
RURYPE	OFWI	TNHC	TNERLT	OCDY
TDUS	MDSNRE	CTMASR	OJRO	YEOKEA
OSYMLN	ETPI	EMEVTI	LRCN	SFTSNE
REERPO	AFAO	RLMO	ERMPTR	UKBA
OAEL	IEDRVE	LCRCEA	IKYC	MRAR
DSRBEW	RTVCTI	IATF	PDAOAG	AEYIAR
HTDB	EFNM	EHDRDA	RNAO	PMLR
AETEBG	RFRLUA	AOEH		
EISU	GNEAFR	YCOTDC		
NFONEC	LREU	IPRF		
ETMNIE	RJFE	HTOU		