Final Report

The Relation Between Eye Movement and Reading Captions and Print by School-Age Deaf Children

Department of Education
Technology, Educational Media, and Materials for Individuals with Disabilities

Grant Award Number

H327H000002

Submitted in September 2003

Carl Jensema, Ph.D.
Principal Investigator
Institute for Disability Research and Training, Inc.
11323 Amherst Avenue
Wheaton, MD 20902
301-942-4326

Abstract

The eye movements of deaf students were recorded as the students watched captioned video clips and read a paragraph on a computer monitor. The eye movement data was evaluated to determine if the students were displaying eye-scanning behavior consistent with reading. It was found that caption reading skills appeared to develop concurrently with paragraph reading skills. Reading skills, rather than age, were the best predictor of caption utilization. Eye scanning behavior for both caption reading and paragraph reading appeared to develop when reading skills were at the first grade level, as measured by the Stanford Test of Reading Comprehension.

Introduction

Most people who are deaf usually use visual skills to partially compensate for their hearing loss. One of the most important of these visual skills is reading. Much information that is typically heard can also be accessed in printed form.

A prime example of using reading skills to compensate for hearing loss is the closed-captioned television system that allows people to read the audio dialogue of a television program. Since the first closed-captioned program was broadcast on March 16, 1980, the number of closed-captioned television programs has grown exponentially, and by 2006, almost all programs will be closed-captioned.

The average child watches about 30 hours of television per week, and children who are deaf watch just as much television as their hearing peers do. Reading captions on television programs has become an important pastime for most deaf children. Many of them spend more time reading television captions than material printed on paper.

Of course, printed material continues to be an important source of information for children who are deaf. They read newspapers, books, magazines, and other printed sources just as hearing children do, but for children who are deaf, the value of printed material goes farther and provides information that they cannot obtain by listening.

The act of reading requires certain eye movement skills. There is a wealth of research that documents how hearing people move their eyes when they read material printed on paper. Articles by Watts (1990) and Rayner (1997) give a good summary of this. Unfortunately, there appears to be no research that demonstrates how deaf people move their eyes when reading printed material. It is usually assumed that they move their eyes on printed material in the same way as hearing people, but this is not documented.

As was recognized in the early pioneering work of O'Bryan (Unpublished, 1976) for the Caption Center at WGBH, reading captions is a very different task from reading material printed on paper. The scanning motions of reading a printed page are much simpler than the scanning motions needed to follow both a moving television picture and the changing captions on that picture. Unfortunately, the early work of O'Bryan was not continued. There were no further studies of eye movement and television captioning until Shroyer did some unpublished work in the early 1990s. He experimented with delaying the caption display until subjects had a chance to scan the picture. His basic finding was that the delay made no difference. More recently, the eye movements of adult caption television viewers were explored in two studies by Jensema (1999, 2000). This work demonstrated that watching television is primarily a complex reading task and that viewers spend about 85% of their viewing time looking at the captions.

Jensema's work showed that the eye movement of caption viewers varies with both the material being viewed and the characteristics of the viewer. For example, an interesting, action-filled picture may cause a viewer to spend more time looking at the picture and less time looking at the captions. As another example, a deaf person who depends primarily on speech reading for communication may spend relatively more time looking at the television character's lips.

Much more research on eye movement and captioning needs to be done. Perhaps the most urgent need is for studies of how deaf children who are beginning to read view captioned television and how this relates to their overall reading skill development. Understanding this process could have a very significant impact on the teaching of reading skills to such children, as well as to the rendering of captions on television.

The present report gives the results of a three-year study of the development of eye movement and reading skills in young deaf school children. The overall goal of the project was to

determine the relationship between eye movement development and reading of captioned media and printed materials.

Method

This research study was carried out at the Western Pennsylvania School for the Deaf (WPSD) in Pittsburgh, Pennsylvania over a three-year period. WPSD was selected because it is an excellent school with deaf students who come from a variety of socio-economic backgrounds. WPSD provided the project with a large room to serve as a research lab. The school also provided assistance in obtaining parental permissions, organizing data collection, and locating test scores and demographic data in school records. Permission was obtained to collect eye movement data from a total of 71 students.

For a number of years before this project, Dr. Carl Jensema and his staff at IDRT had been using an EyeGaze system for captioned television research. This eye movement measuring system was purchased in 1997 and IDRT programmers extensively modified the system's software for television research. The system was used for the first two years of data collection at WPSD.

The EyeGaze system purchased by IDRT utilized Windows 3.1 and by 2001 was considered outdated. Rather than try to upgrade a technically obsolete system, the IDRT staff designed and programmed a completely new eye movement system. This new eye movement system was developed under a different project (SBIR Phase II contract ED-01-CO-0116) and refined through use at WPSD. The new system was used for data collection during the third year of the WPSD project. The main difference is that the new IDRT system is much less expensive (the equipment costs $3,000 to build vs. $17,900 to buy a similar commercially-made system) and is specifically designed for captioned television research applications. The two systems use the same

mathematical approach to eye movement measurement and have the same degree of accuracy, so the WPSD data from each of the three years are comparable.

Figure 1 shows a graphic of how eye movement is measured. A subject sits approximately two feet from a computer monitor. Visual material is shown on the monitor screen and the subject looks at it. An infrared camera is mounted below the screen and this camera has an infrared light that reflects off the eye of the subject. Figure 2 shows a typical image taken by the infrared camera. The position of the reflected light dot on the eye image allows computation of where the subject is looking on the computer screen. The horizontal and vertical coordinates for the screen position are recorded in a computer file. This recording of eye position is done 30 times a second.

After the eye position coordinates are recorded, they can be graphed on top of the visual material. For example, Figure 3 shows a graph of a subject's eye movements during about three seconds of a video clip.

It is also possible to graph the eye movements on a plain white background and the shape of this graph can often be used to make inferences. For example, Figure 4 shows the eye movement graphs for two different subjects who watched the same captioned video clip. The first subject was not reading the captions, and the second subject was reading them.

The visual materials for this study consisted of five video clips taken from cartoon programs. Each clip was approximately one minute long. In the first year, each subject watched four video clips. In the second and third years, two video clips were shown to each subject. The eye movements of each subject for each video clip were recorded on a separate file.

In addition to the video clips, the subjects were also shown a short, simple paragraph on the computer screen. This paragraph had a second grade reading difficulty level and was selected from among a collection of such paragraphs used by optometrists to test visual acuity for reading. As

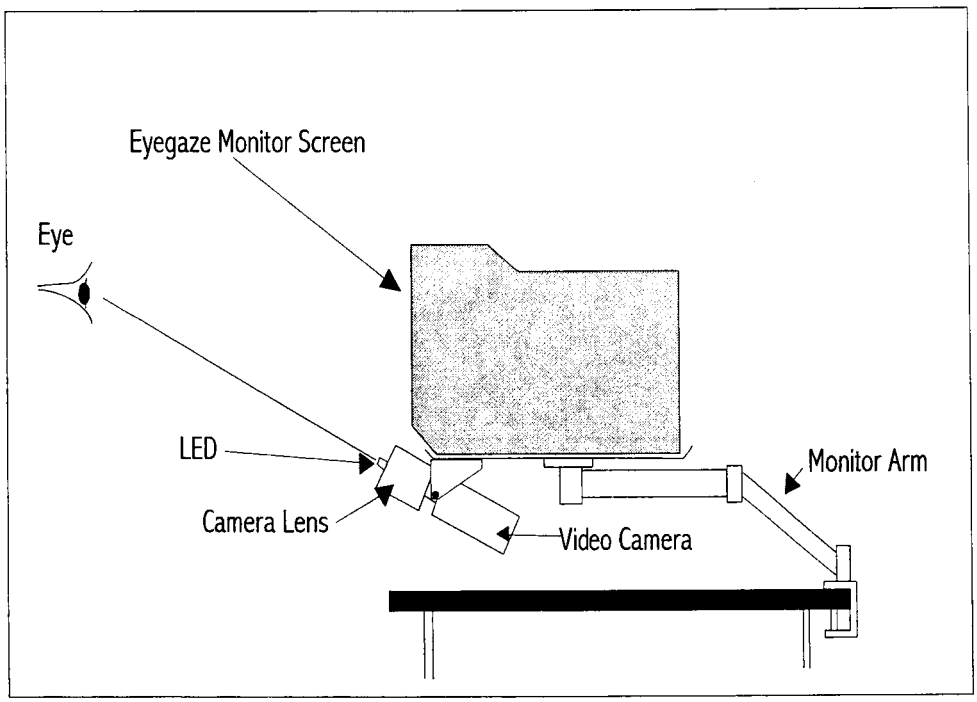


Figure 1
Eye Movement Equipment Setup

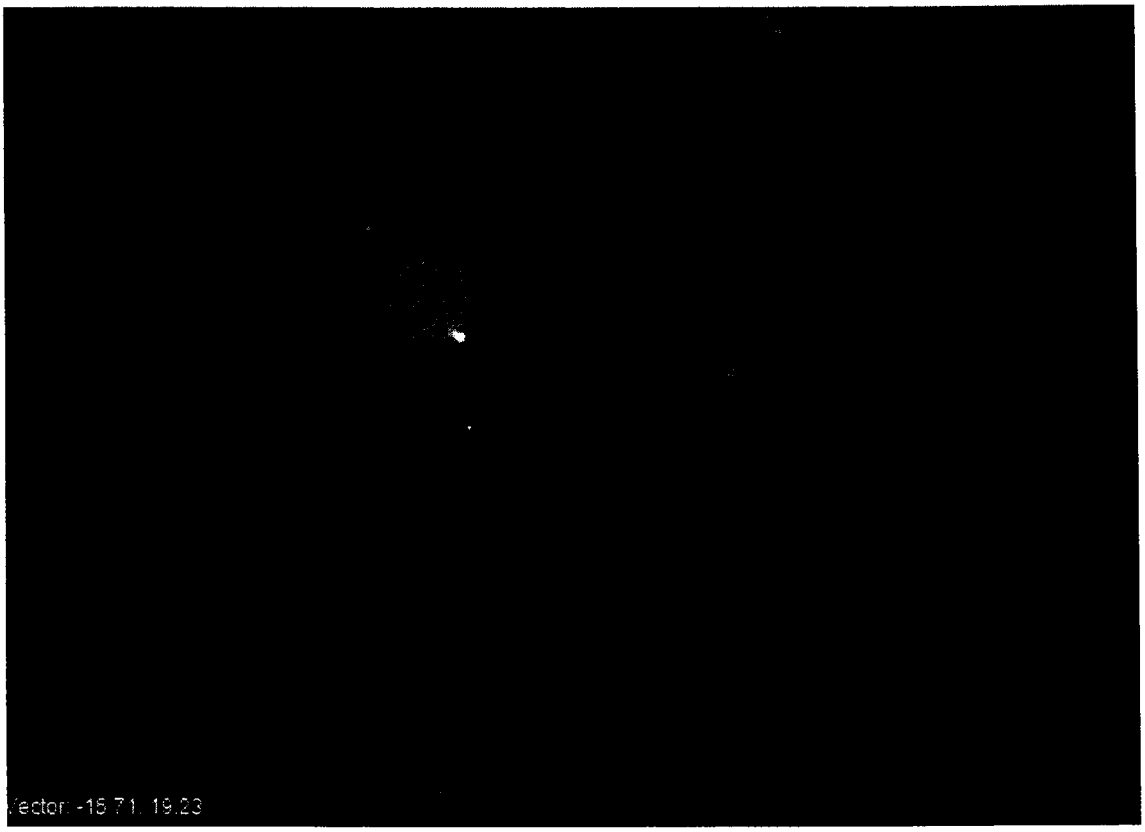


Figure 2
Infrared Image

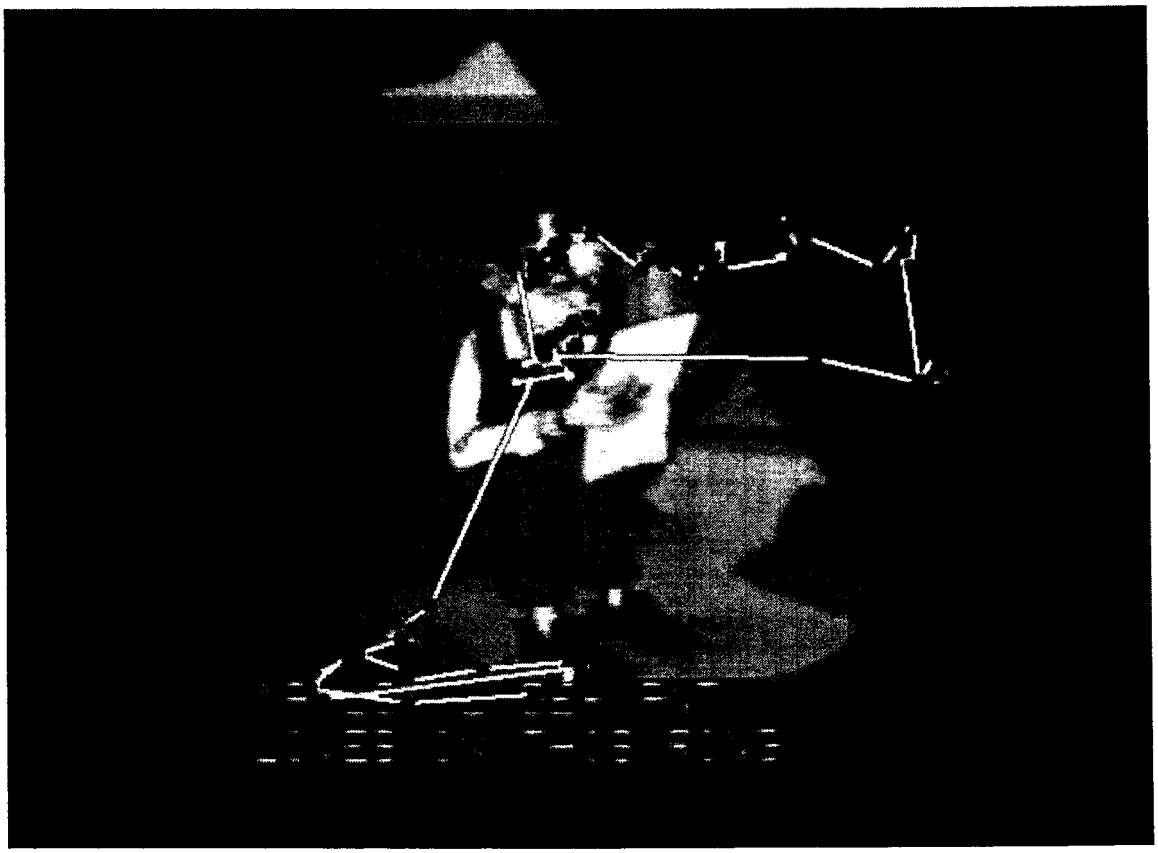
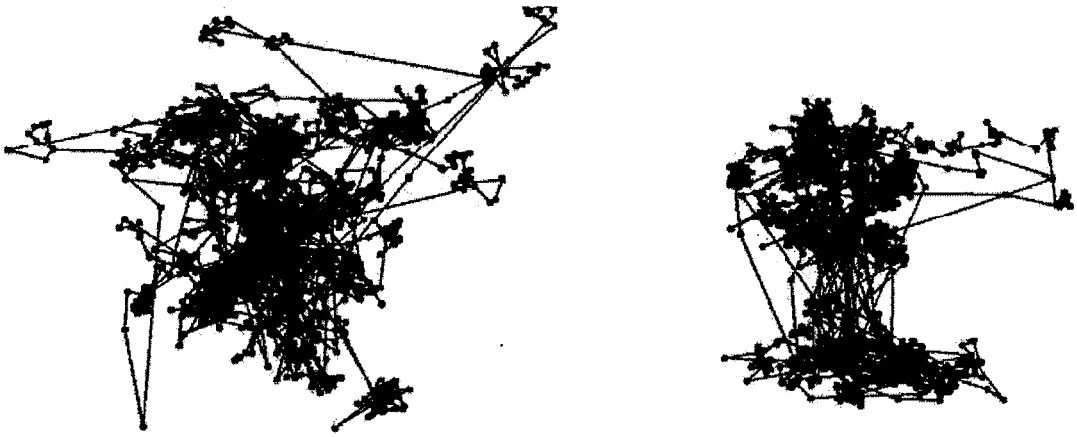


Figure 3
Eye Movement During Three Seconds of Video



Non-Reader Reader

Figure 4
Eye Movement of Two Subjects Watching the Same Captioned Video Clip

with the captioned video clips, a graph of the eye movements on the paragraph can be used to indicate whether a subject is displaying reading behavior. For example, Figure 5 shows the graph for two different subjects who looked at the same paragraph on a computer screen. The first subject was not reading the paragraph, while the second subject clearly showed the eye scanning behavior associated with reading.

The subjects in this study were given a vision-screening test to assure that they had vision correctable to a normal level. A professional optometrist did this vision screening. The subjects were then shown captioned video clips and a printed paragraph. The eye movement data from each of these items was recorded into computer files. Since eye position measurements were made 30 times a second, a considerable amount of data was generated for each subject.

The eye movement of each subject on each video clip and printed paragraph was both played back on top of the stimulus material and graphed on a blank screen. The graphs on the blank screen were printed out and bound into a book for later reference.

Two researchers watched the eye movement graph being played back on top of the stimulus material and also examined the blank screen printouts. These two examiners graded the subject as "reading," "some reading," and "no reading," indicating that the subject always, sometimes, or never displayed the kind of eye scanning behavior associated with reading. It is important to remember that eye movement is not the same thing as actually reading and understanding the material. On the other hand, understanding of print materials cannot happen until appropriate eye scanning behavior takes place.

In addition to the eye movement data, demographic and academic data was gathered on each subject. This included age, sex, hearing loss, age at onset of loss, cause of hearing loss, number and

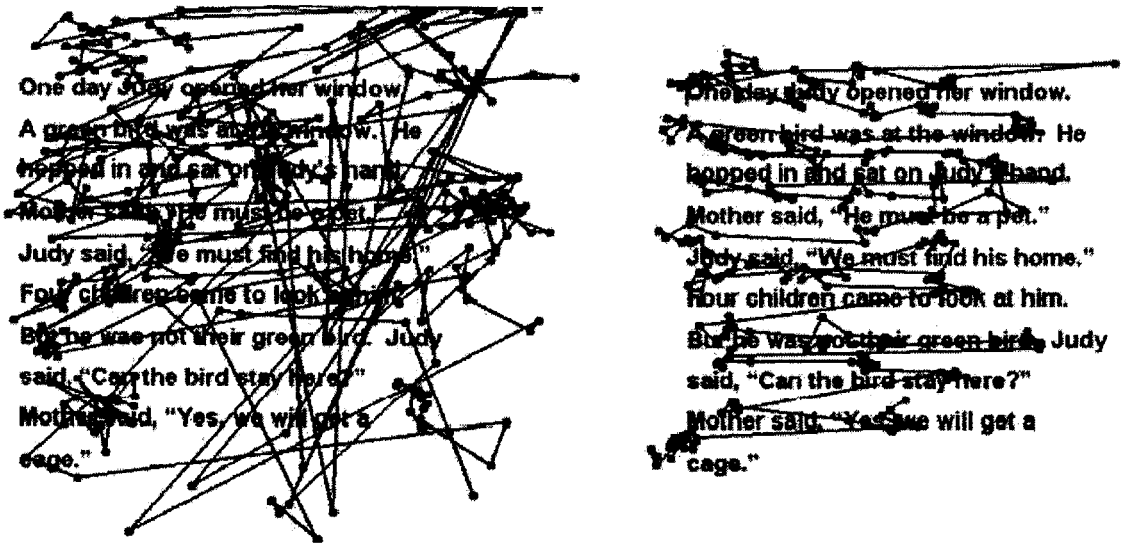


Figure 5
Eye Movement of Two Subjects Looking at a Paragraph

age of siblings, birth order, parent hearing status, intelligence level, and SAT reading grade equivalent.

The eye movement evaluations were compared with the demographic and academic data. The purpose of this was to determine when caption scanning and paragraph reading eye behavior began and what factors related to it.

Results

During the first year, data was collected from 23 students. The mean age was 6.1 years and the age range was 4.1 to 9.7 years. Most of these children could not read, and an analysis of their eye movement data indicated that 18 out of the 23 students (78%) were not looking at the captions. Two students (9%) were sometimes looking at the captions, and three (13%) consistently showed eye movements associated with caption reading. The project staff had selected subjects ranging in age from four to nine years because the staff thought the subjects would become aware of captions around age 4 or 5 and would strive to read them until they were fully using them around age nine. This did not happen. Age did not seem to be a particularly good indicator of how captions were used, and the project was clearly not covering the full range of caption utilization.

For Year 2, the subject pool was expanded to include students of all ages at WPSD. A sample of 70 students was selected and usable caption viewing eye movement data were obtained from 65 of these students. The mean age was 11.4 years, with a range of 5.1 to 20.2 years. Among these students, 23 (35%) were not reading, 8 (12%) were sometimes trying to read, and 34 (52%) were reading captions.

Finally, for Year 3 of the project, the staff retested as many Year 2 subjects as possible. Several students had left the school or were absent on the data collection days. Usable eye

movement data was obtained from 60 students. The mean age was 11.7 years, with a range of 6.1 to 19.1 years. Among these students, 15 (25%) were not reading, 5 (8%) were sometimes trying to read, and 40 (67%) were reading captions. As expected, there was an overall increase in the use of captions from one year to the next.

Age appeared to have only moderate relation to reading captions. The other demographic variables appeared to have little connection to caption reading. Data on intelligence obtained from school records were of limited value because each student's intelligence was simply categorized as "superior," "above average," "average," and "low average."

The variable that proved to be the best predictor of a subject's use of captions was the Stanford Test of Reading Comprehension (9^{th} Edition) reading grade equivalent score. These test scores were from an April 15, 2002 administration of the test and were available for 55 students. The mean score was 3.9 grade equivalent, with a range of 1.3 to 12.0. Among the 15 students for whom reading grade equivalent scores were not available, all were between 5 and 7 years of age and, according to school personnel, were not given the Stanford test because they were unable to read at even a beginning level.

Stanford Test of Reading Comprehension grade equivalent scores were compared with the Spring 2002 eye movement data. A cross-tabulation comparing the evaluation of caption reading with Stanford reading grade equivalent scores is shown in Table 1. The table is based on 65 subjects for whom complete data was available. None of the non-readers consistently looked at the captions. All of the subjects with reading grade equivalent scores of 3.0 or more consistently looked at the captions.

A second cross-tabulation was done to compare paragraph reading eye movement with Stanford reading grade equivalent scores. This cross-tabulation is given in Table 2 and is based on

Table 1
Caption Viewing at Different Reading Grade Equivalent Levels

	Reading Grade Equivalent									
	Non-Reader		1.0 - 1.9		2.0 - 2.9		3.0+		All subjects	
	n	%	n	%	n	%	n	%	n*	%
Did not look at captions	13	87	9	56	1	11	0	0	23	35
Sometimes looked at captions	2	13	5	31	1	11	0	0	8	12
Consistently looked at captions	0	0	2	13	7	78	25	100	34	52
Total	15	100	16	100	9	100	25	100	65	100

* Missing data on five subjects.

Table 2
Paragraph Viewing at Different Reading Grade Equivalent Levels

	Reading Grade Equivalent									
	Non-Reader		1.0 - 1.9		2.0 - 2.9		3.0+		All subjects	
	n	%	n	%	n	%	n	%	n*	%
Not reading	15	100	9	56	0	0	0	0	24	36
Some reading	0	0	2	13	0	0	0	0	2	3
Reading	0	0	5	31	10	100	26	100	41	61
Total	15	100	16	100	10	100	26	100	67	100

* Missing data on three subjects.

data from 67 subjects. Below the first grade reading level, no student displayed eye scanning behavior that could be associated with paragraph reading. At the second grade reading level and above, all students displayed paragraph reading behavior. The eye movement skills required to read a paragraph appear to develop during the first grade.

However, learning to read at the first grade level is not necessarily a one-year process. As shown in Table 3, the process of learning first grade reading skills often lasts several years for children who are deaf. Learning appropriate eye scanning behavior for reading captions is also likely to stretch over several years. In 2001, data was collected from 23 young subjects. Of these, 18 (78%) were not looking at captions. Two years later, in 2003, 12 (52%) of the 23 students were still not demonstrating caption-scanning behavior.

Comparison of Table 1 and Table 2 suggests that development of caption viewing and paragraph scanning eye movement skills develop together. This is confirmed in Table 4, which gives a cross-tabulation of caption viewing and paragraph reading. Among 24 students who did not read a paragraph, 19 (79%) did not look at captions. Among 39 students who read the paragraph, 33 (85%) consistently looked at captions. Caption reading and paragraph reading skills appear to evolve together. A student who reads a printed paragraph is also very likely to read captions.

Discussion

Captioned television programs are complex reading material. The viewer is required to obtain information from both a moving picture and words flashed on the screen. A deaf viewer who is watching captioned television can be expected to split his or her attention between the picture and the captions according to some personal formula that maximizes the information gained.

Table 3
Cross-Tabulation of Age by Reading Grade Equivalent

	Not	Reading Grade Equivalent												
Age	Reading	1	2	3	4	5	6	7	8	9	10	11	12	Total
5	9	2												11
6	5	2	1											8
7	1	2												3
8		3												3
9		2	4											6
10		4	1											5
11														0
12			2	1	1									4
13		1	1	1	1		1							5
14			1	3	1			1	1		1			8
15							1	1						2
16				1					1			1		3
17				2	1	1				1			2	7
18				2										2
19			1			1								2
20				1										1
Total	15	16	11	11	4	2	2	2	2	1	1	1	2	70

Table 4
Caption Viewing Vs. Paragraph Reading

	Paragraph			
Captions	Not Reading	Some Reading	Reading	Total*
Did Not Look at Captions	19	2	2	23
Sometimes Looked at Captions	4	0	4	8
Consistently Looked at Captions	1	0	33	34
Total*	24	2	39	65

* 5 of the 70 subjects had missing data.

If a person cannot read, the captions will not provide information, and attention will focus on the picture. In the present study (See Table 1), non-readers seldom looked at captions.

As basic reading skills are learned (i.e. first grade reading), more and more attention shifts to captions since more and more information is obtained from this source. As reading skill reaches a level where captions become a reliable source of information (i.e. second grade and above), people who are deaf tend to consistently watch captions whenever they appear on the screen.

The basic process of looking at words for the purpose of reading is taught in the first grade. In Table 2, non-readers were not scanning to read. At the first grade reading level, some students were scanning to read, while others were not. At the second grade reading level and above, all students were showing the scanning behavior associated with reading. Clearly, caption reading and paragraph reading are closely correlated. Both depend on the subject having basic reading skills that are generally acquired at the first grade academic level.

Captioned television is reading material, just as books and magazines are reading material. Captioned material has an advantage over printed reading material in the sense that it provides animated pictorial information to accompany what is read. Unfortunately, captioned videos are usually used in schools as supplementary material for science, social studies and other subjects. They are seldom used as a primary source of material for the process of teaching reading.

Much more work needs to be done to develop ways of using captioning to teach basic reading skills. The process of learning first grade reading skills frequently takes several years for children who are deaf. These children begin watching captioned television long before they can read the captions. The reading material is already in front of the student. Educators need to find better ways of taking advantage of the situation and use captions as a part of the process of teaching children to read.