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Comparison of eye movements before and after a speed reading course

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Abstract

The techniques of speed reading are widely used and generally accepted, but few studies have investigated whether, and how, speed-reading actually improves reading ability in the typical reader. Using the Ober2, an infrared monitoring device that accurately tracks eye movements, we measured the eye movements of 59 students. The Ober2 calculates reading speed, number of fixations per 100 words, number of words seen in each fixation, number of regressions per 1 00 words, and duration of fixation. Comprehension was assessed with ten detailed true or false questions. Approximately half of the students (n=25) participated in a speed reading class (9 hours of standard speed-reading instruction, with no out-of-class practice required). The other half (n=34) did not. After completion of the course, all60 were re-measured on the Ober2. The speed reading group improved significantly in five of the six aspects tested: reading speed, number of fixations per 100 words, span of recognition (number of words seen in each fixation), number of regressions per 100 words, and duration of fixation. Comprehension for the speed reading group showed an insignificant decrease. The control group improved insignificantly in all areas. There was large individual variation in both groups, with some readers doubling their reading speed while retaining their original comprehension. While all readers in the speed-reading group increased their reading speed, no reader exceeded a total of 734 words per minute. The goal of this study was not to substantiate the fantastic reading speeds reported by a few speed-readers; but to determine if there are measurable changes in eye movements associated with speed reading training.

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ABSTRACT

The techniques of speed reading are widely used and generally accepted, but few studies have investigated whether, and how, speed-reading actually improves reading ability in the typical reader. Using the Ober2, an infrared monitoring device that accurately tracks eye movements, we measured the eye movements of 59 students. The Ober2 calculates reading speed, number of fixations per 100 words, number of words seen in each fixation, number of regressions per 100 words, and duration of fixation. Comprehension was assessed with ten detailed true or false questions. Approximately half of the students (n=25) participated in a speed reading class (9 hours of standard speed-reading instruction, with no out-of-class practice required). The other half (n=34) did not. After completion of the course, all 60 were re-measured on the Ober2. The speed reading group improved significantly in five of the six aspects tested: reading speed, number of fixations per 100 words, span of recognition (number of words seen in each fixation), number of regressions per 100 words, and duration of fixation. Comprehension for the speed reading group showed an insignificant decrease. The control group improved insignificantly in all areas. There was large individual variation in both groups, with some readers doubling their reading speed while retaining their original comprehension. While all readers in the speed-reading group increased their reading speed, no reader exceeded a total of 734 words per minute. The goal of this study was not to substantiate the fantastic reading speeds reported by a few speed-readers, but to determine if there are measurable changes in eye movements associated with speed reading training.

INTRODUCTION

The literature is full of studies concentrating on certain aspects of reading speed, and there are some studies investigating those super-fast readers seen on TV claiming reading speeds in excess of 2000, or 200,000, words per minute (wpm). There are few studies that address the simple question "how do eye movements change as a result of speed reading training?" This study attempts to answer that question, and looks into some underlying aspects of eye movements in reading in an attempt to understand what characteristics are shared by better readers. The normal range of reading speed is 200-300 words per minute.[1,2]

Techniques for reading faster are documented as far back as the early 1900's, but became popularized in the 1960's with publicity about Evelyn Wood's Reading Dynamics Institute[2]. However, the claims of reading at extravagant rates (such as 123,000 wpm) have not been substantiated by research. The materials used, and the design of "after" tests in some speed reading classes are biased so an increased reading speed is inevitable. Still, speed reading courses do seem to improve reading speed in the average reader, even if speeds exceeding 1000 wpm are rare[2].

Carver[3,4] investigated several very fast readers (including one claiming to read 81,000 wpm) with the intention of proving or disproving claims of extremely high reading speeds and found nothing to support anyone's being able to read over 600 wpm while retaining at least 75% comprehension. However, the design of the study was not conducive to good results from the fast readers. The readers were not allowed to set their own reading rate, but instead were shown material for a given amount of time, which was then translated to a certain wpm. The subjects were not told in advance how long this would be, so could not adjust their reading strategy accordingly. Rubin and Turano[5] showed that if the reader is allowed to set the reading speed, higher speeds can be attained while retaining adequate comprehension. Many speed readers use their hands to guide their eyes across the print, but this cannot be done efficiently when the reader is not allowed to hold the material. Most speed readers do not claim to read all material equally fast, but use the techniques to read at the fastest rate reasonable considering the difficulty level of the material and the level of comprehension desired. Carver's "Rauding theory"[6] that comprehension decreases linearly as speed increases seems to be true, but only *after* a certain upper

wpm limit, which varies between individuals rather than being capped at the 400 to 600 wpm limit stated by Carver. Breznitz[7], and Breznitz and Share[8] showed that first graders comprehended 30% better while reading aloud at a fast pace than when reading at their self-pace. Masson[1] found that during skimming of material, "subjects did devote a greater degree of conceptual processing to gist-relevant statements than to irrelevant ones", and that while overall understanding was gained in skimming, retention of precise details and of irrelevant statements was reduced.

Breznitz and Share[8] studied school children reading aloud at self-paced and at accelerated rates, and found there to be "gains (in comprehension that) appear to be attributed, at least in part, to lower distractibility". They contend that the improvement is due to better utilization of short term memory. When reading faster, there is "an increase in the number of elements being held in short term memory", resulting in 30% better comprehension (and in some individual cases, 100% improvement). As well, there were fewer decoding errors when the children read faster, raising the possibility that increased comprehension was also due "simply to accuracy gains". However, this hypothesis was not supported by the data of the study. Jackson and McClelland[9] found that better readers had better short term auditory memory. They also found that better readers had faster reaction times in letter matching tasks which required long-term memory access to letter codes. They concluded that the "most important determinants...of reading speed...lie in some general, modality-independent, language comprehension skills". This is supported by Dixon, LeFevre, and Twilley[10], who found that "working memory efficiency during reading was related to comprehension", and that readers with better vocabularies were more efficient in their use of their working memory. Riley and Lowe[11] tried to determine if subvocalization slowed reading speed but increased comprehension, but could find no evidence to support or disprove either supposition.

Beers[12] states that "good readers have several different reading rates- not just one", from which they choose "according to the purpose for reading". She reports on an accelerated reading course which was offered to ninth graders in Florida. Beers states that "significant gains were made in all areas tested" (using the Nelson-Denny Reading Test), and stated that the course would be continued in their curriculum. Brozo and Johns[13] reviewed 40 speed reading books to extract the common elements. Regarding span of recognition, 68% of the books taught methods for increasing the span of recognition; 72% of these encouraged the reader to read up to three words in each fixation, while 28% of the books

encouraged reading more than three words in each fixation. Research cited by Brozo and Johns found 19 letter-characters to be the upper limit possible during each fixation, and suggested that span of recognition is relatively fixed and limited. Regarding regressions (looking back to material already read), 68% of the books encouraged reducing the number of regressions. Brozo and Johns give a profile of a poor reader, stating that "inefficient readers make more fixations, have longer fixations, a greater number of regressions, and generally more erratic eye movement patterns".

Jackson and McClelland[9] found that better readers made fewer fixations per line than did poorer readers, but had fixation durations of about the same amount of time. They concluded that better readers extracted more information per fixation. Underwood, Hubbard, and Wilkinson[14], found a correlation between increased comprehension and decreased duration of fixation. They state that "fixation duration was highlighted as the most reliable predictor of reading ability". They do not attempt to assign causality, mentioning that faster word recognition and integration, faster syntactic parsing, and/or other faster cognitive processes need to occur in order for shorter duration of fixation to occur. Both of these studies indicate that readers who make fewer fixations do not need to make the fixations longer in order to gain the same information as a person who makes many fixations. Rounds, Manley, and Norris[15] did a study to determine the effect of four weeks (12 hours) of visual training (VT) on reading efficiency. They tested comprehension, relative efficiency (wpm/number of fixations), number of regressions, number of fixations per 100 words, duration of fixations, and span of recognition. The VT group improved significantly compared to the control group in all categories except in duration of fixation, in which the VT group improved only slightly more than the control group. The VT group showed four times more improvement in their reading speed than did the control group. Some of the techniques taught in speed reading can neutralize minor oculomotor problems, such as using the hand to help keep the eyes on track.

Sailor and Ball[16] found that peripheral vision increased in students after receiving 15.75 hours of speed reading training. Half of these speed reading students were given an additional 2.25 hours of peripheral vision training. Both groups showed an increase in both reading speed and in peripheral vision. Interestingly, although the peripheral vision training group did not have a greater increase in peripheral vision than the non-peripheral vision training group, they did have greater increases in reading speed, leading one to speculate that the peripheral vision training did play a part in increasing reading

speed. Comprehension was the same in before and after testing. In the speed reading class employed in this study, subjects were taught that a one to two second per page scan can preset the mind to absorb the upcoming information. That is, in a brief glance readers can know the basic topic of the material, and can determine, for example, whether they are reading ocular science or a gothic romance. Quickly previewing the material may make it faster and easier to access related information stored in the subject's brain. If this is the case, picking up an occasional word from the line below could enhance reading efficiency. Pollatsek, Raney, Lagasse, and Rayner[17] found no evidence that "visual search is more efficient" when information is presented on the line below the line upon which the subject is fixating. They did, however, find that if the lower line consisted of non-word-like letter combinations, reading rate decreased. They also found that some subjects could identify target words in the line below the line of fixation. Henderson and Ferreira[18] investigated whether the level of difficulty of the upcoming parafoveal word affects the eye movement behavior on the currently fixated word, and they found that fixation on a given word was not affected by the nature of the next word. It is widely accepted that readers in English tend to process more information to the right of the fixation than to the left of fixation. Haberlandt, Schnieder, and Graesser[19] found that slow readers tend to fixate at the end of each sentence, a less efficient method than that used by faster readers who fixate at the end of each line. Stated another way, fast readers paused longer at physically defined locations, whereas slower readers paused longer at linguistically defined locations. Fast readers also "chunk" information more efficiently than do slower readers[19], and can continue reading additional words even if they do not immediately understand what they have just read, utilizing working memory to continue processing the previously read words. Both of these techniques, chunking and reading in physically defined segments, are taught in speed reading.

An interesting study regarding reading speed is the research of Rubin and Turano[5] who determined that the limiting factor in reading speed is the time involved in preparing to make saccadic eye movements. They presented words consecutively in a single spot on a screen, at a rate determined by the reader. If material was presented at a pace set by the reader in a manner that relieved the need for saccadic eye movements, a mere 70 msec/word was required to understand material, with a pause equal to one word duration at the end of each sentence. This compares to 170 msec/word recorded as the fastest duration of fixation in normal reading, and to the 250 msec/word required by Rubin and Turano's

subjects in normal reading. This indicated that over two thirds of the time spent on each fixation is not needed for receiving information, but rather is somehow required for programming the saccade. In presenting text without saccades, best comprehension was gained at rates of at least 350 wpm, but rates of more that 1600 wpm (the maximum possible) were found, with excellent recall and comprehension. Print size became more important when saccades, which are the speed-limiting factor in normal reading, were removed. Print between 4 to nine times larger than the subject's minimum resolvable print size allowed for the fastest reading speeds. For reading rates of 70 msec/word, complete concentration is required. None of the subjects felt comfortable reading 1650 wpm, even though their comprehension was 75% or better. One could extrapolate that even minor difficulties in eye movements can cause great reductions in reading speed. None of the various studies cited here address our question: What is the effect of speed reading training on eye movements?

METHODS

Subjects were selected by advertising a speed reading course that would normally cost $400 for only $25 to be offered on the Pacific University campus (appendix 1). Since the subjects had to pay $25 to participate in the study, it was hoped that this would dissuade non-motivated subjects. All subjects were required to read and sign an informed consent document prior to participating (appendix 2).

The speed reading group consisted of 25 subjects (14 females and 11 males) ranging in age from 20 to 43 years, with a mean age of 28. The subjects were undergraduate students, optometry students, and non-students. Thirty individuals were initially recruited to be subjects; however, four of the subjects failed the entrance criteria and one speed reading student, at the end of the study, read straight down the page instead of accross, and the eye movement recording system couldn't analyze the data. The control group consisted of 34 subjects (21 females and 13 males) ranging in age from 21 to 43 years, with a mean age of 26. Control subjects were optometry students and non-students.

The entrance criteria included having near monocular habitual visual acuity of at least 20/40 (mean = 20/23), heterophoria at near based on near cover test, and smooth and accurate ocular motility with no gaze restrictions based on bead skills and results from an initial test on the Ober2, Model B-120[a] .

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[a] LearnMaster. 7810 S.W. 66th Ave. Portland, Ore. 97223 (503) 245-6418

At the start of the study, all subjects were scheduled for a 20 minute session in which they were given a series of tests to determine if they met the entrance criteria. They were then tested on the Ober2, a state of the art infrared eye movement recording system used for clinical assessment of reading eye movements. Subjects who wore spectacles had their prescription duplicated using trial lenses in the lens wells of the Ober2 test goggles. The subject wore the infrared goggles while reading hard copy text. Eye movement information detected by the goggle sensors is relayed to a 486 PC computer for analysis and display. The manufacturer of the Ober2 states that the Ober2 is sensitive to less than 5 minutes of arc horizontally, but it was tested by an end user at 9 minutes of arc. The "normal sized" text character spans approximatly 15 minutes of arc horizontally.[20]

In the study, the subjects were instructed to read a passage as fast as they could, but for good comprehension. Each passage contained approximately 120 words which required approximately 20-40 seconds to complete depending on the subject. The passage was printed in 14 point Times Bold, with high contrast black print on white paper. The computer analyzed fixations/100 words, span of recognition, regressions/100 words, duration of fixation, and words/minute. The subjects were then given 10 true/false questions to answer concerning the passage they had just read and a comprehension score was determined for each subject. At the initial test session, each subject was tested twice on the Ober2. Test 1a was run first, immediately followed by test 1b. This dual testing was done for two reasons. First, the results from test 1a were used as part of the entrance criteria to ensure each individual had fairly accurate eye movements that didn't hinder reading ability. The second reason for test 1a was to familiarize the subjects with the Ober2, and thus counter any learning or familiarity effects between the results at the beginning and end of the study. The data from test 1a were not used in any pre-to-post analysis; only the results from test 1b were used as the pre-speed-reading course data. All results were recorded on a data form (appendix 4).

The study subjects were required to attend a minimum of three speed reading classes, each lasting three hours. These courses were taught by a professional instructor who had taught speed reading for over 20 years to students of all ages and education levels. During these classes, subjects were given intense instruction on methods to improve their reading speed while maintaining or improving their comprehension. The instructor taught the subjects various techniques to incorporate into their

reading habits, and ran many drills to teach the subjects how to use these techniques properly. They were also advised, but not required, to use the techniques whenever they were reading, whether it was for work, school, or pleasure. There were two additional classes offered that stressed study skills, and were used to review the speed reading techniques that had been taught during the first three classes. Attendance was optional for these last two classes. The control subjects continued their regular daily life and were instructed not to alter their reading style during the duration of the study.

Six weeks after data were gathered from tests 1a and 1b, the speed reading course was completed, and test 2 was run. Factors such as illumination, setup, and instructions given were identical to the initial testing setup. The same criteria were analyzed by the computer for test 2 (post-speed reading course data) as were analyzed for test 1b (the pre-speed reading course data). The results from test 1b were then compared to the results from test 2 to determine any effects associated with the speed reading training.

All of the passages and questions were of the same difficulty level. They were college level passages included in the Ober2 software. A copy of one passage that was used in the study, and the 10 T/F questions used to determine each subject's comprehension score, can be found in appendix 4.

RESULTS

All comparative data were subjected to analysis using two-way ANOVA procedures, with pre/post training (repeated measures) and group assignment being the main factors. Table 1 summarizes these results. After comparing the data gathered from tests 1b and 2, it was found that those subjects who took the speed reading course significantly decreased their number of fixations, number of regressions, and fixation duration. While the control group also showed decreases, they were not significant. It was also found that the speed reading group showed a significant increase in span of recognition and reading speed, as compared to insignificant increases in these areas by the control group. The control group's comprehension scores went up slightly while the class group's comprehension scores went down slightly; this variable had a significant interaction.

			Pre-Data		Post-Data		Significance		
Variable	Units	Group	Mean	Std. Dev.	Mean	Std. Dev.	Group	Repeated Measure	Interaction
Fixations/	Number of	Speed	94.6	19.5	71.0	21.7	F=2.541	F=39.98	F=22.233
100 words	Fixations	Control	93.0	21.5	88.4	18.5	P=0.1165	P=0.0001	P=0.0001
Span of	Number of	Speed	1.10	0.2	1.54	0.49	F=5.287	F=38.927	F=30.265
Recognition	Characters	Control	1.13	0.2	1.18	0.25	P=0.0252	P=0.0001	P=0.0001
Regressions/	Number of	Speed	16.88	10.1	6.16	5.2	F=0.860	F=34.056	F=21.307
100 words	Regressions	Control	14.18	8.8	12.38	7.3	P=0.2577	P=0.0001	P=0.0001
Duration of	Time in	Speed	0.241	0.03	0.228	0.02	F=1.096	F=5.273	F=3.057
Fixation	Seconds	Control	0.244	0.03	0.241	0.04	P=0.2995	P=0.0254	P=0.0858
Words per	Number of	Speed	277.6	63.8	404.5	140.9	F=6.058	F=35.193	F=27.238
Minute	Words/min	Control	280.6	69.1	295.9	80.3	P=0.0169	P=0.0001	P=0.0001
Comprehension	Percentage	Speed	80.8	15.8	73.6	16.0	F=0.158	F=0.870	F=4.125
		Control	77.6	13.3	79.4	15.9	P=0.6924	P=0.355	P=0.0469

Table 1. Descriptive data by group and condition with statistical significance of main effects and interaction.

Referring to Figure 1, it can be seen that the speed readers decreased their number of fixations/100 words by 23.6 fixations as compared to a 4.6 fixation decrease by the control group. The main effect for group assignment is not significant. The main effect for the repeated measure, fixations/100 words, improved significantly ($F=39.98$, $p<0.0001$) and, most importantly there was a significant interaction ($F=22.233$, $p<0.0001$) indicating greater improvement for the speed reading group.

Span of recognition is inversely related to the number of fixations one makes when reading. The larger the span of recognition (the more characters one can see during a fixation) the less fixations one has to make. Figure 2 shows an increase in span of recognition of 0.44 words for the speed readers and 0.05 words for the control group. For span of recognition, both main effects were significant (group $F=5.287$, $p<0.0252$; repeated measure $F=38.927$, $p<0.0001$) as was the interaction ($F=30.265$, $p<0.0001$) indicating significantly greater improvement by the speed readers.

Number of regressions decreased for both groups as can be seen in Figure 3. The speed reading group decreased by an average of 10.72 regressions/100 words while the control group

decreased by only 1.8 regressions/100 words. The main effect for group was not significant, but was significant for the repeated measure ($F=34.067$, $p<0.0001$). The interaction was also significant ($F=21.307$, $p<0.0001$) suggesting that the speed reading group improved more.

Figure 4 shows the change in the duration of fixation. The speed reading group decreased fixation duration by 0.013 seconds as compared to a 0.003 seconds decrease by the control group. For fixation duration, the main effect for group was not significant; however, it was significant for the repeated measure ($F=5.273$, $p<0.0254$). The interaction was not significant. It was not expected that this variable would change significantly, as it was thought that increased spans of recognition would require the same or longer fixation duration as was necessary with a shorter span of recognition.

The reading speed increased in both groups as can be seen in Figure 5. The speed reading group's reading speed went up significantly by 126.9 wpm, whereas the control group's reading speed went up only slightly by 15.30 wpm. Both main effects for reading speed were significant (group $F=6.058$, $p<0.0169$; repeated measure $F=35.193$, $p<0.0001$) as was the interaction ($F=27.238$, $p<0.0001$). This undoubtedly shows that the speed reading group had significantly greater improvement.

Figure 6 shows the change in comprehension scores between the two groups at the beginning and end of the study. The control group's comprehension score increased slightly by 1.8%. The speed reading group showed a 7.2% decrease in their comprehension score. Neither of the main effects, group or repeated measure, were significant for the comprehension variable; however, there was a significant interaction ($F=4.125$, $p<0.0469$) reflecting the different directional effects of the two groups.

Overall, results obtained from paired t-tests for the control group show no significant changes in the tested factors of fixations/100 words, span of recognition, regressions/100 words, length of duration, reading speed, or comprehension score. However, results for the speed reading group from paired t-tests show significant values for decrease in fixations ($p = .0001$), increase in span of recognition ($p = .0001$), decrease in regressions ($p = .0001$), decrease in fixation duration ($p = .0039$), and increase in reading speed ($p = .0001$). The slight decrease in the class comprehension score was not significant ($p = .0981$).

DISCUSSION

The results of this study indicate that speed-reading techniques can be beneficial to the typical reader. Significant improvements for the speed-reading group were found in five of the six variables measured: number of fixations per one hundred words decreased by 25%, span of recognition increased by 40%, number of regressions decreased by 64%, duration of fixation decreased 5%, and reading speed increased by 46%. There was a decrease in comprehension of 7.2% which was not significant. For the control group, insignificant improvements were found in all six variables measured: number of fixations per one hundred words decreased by 5%, span of recognition increased by 4%, number of regressions decreased by 13%, duration of fixation decreased 1%, reading speed increased by 5%, and comprehension increased by 1.8%. There was much individual variation.

Number of fixations per one hundred words decreased 25% for the speed reading group, vs. 5% for the control group. Since two thirds of each fixation is used not for information processing but for programming the next saccade, reducing the number of fixations, and reducing the number of regressions, will result in faster reading speeds. In the speed reading group, 24 of 25 subjects showed a decrease in the number of fixations per one hundred words (for an average of 25% fewer fixations), as compared to 21 of 34 of the control group subjects (for an average of 5% fewer fixations), with the greatest improvement in the speed reading group being 53 fewer fixations per 100 words, from 125 fixations per 100 words to 72 fixations per 100 words. The fewest fixations for one hundred words being 38. In the control group, the greatest improvement was a decrease of 48 fixations per 100 words, from 167 fixations per 100 words to 119 fixations per 100 words. The fewest fixations among the control subjects for one hundred words was 57.

Span of recognition increased by 40% for the speed reading group, vs. a 4% increase for the control group. The more characters (letters) a reader can recognize in each fixation, the fewer the fixations needed to cover the material. The study by Pollatsek et al[17] showed that there is a direct relationship between peripheral vision and reading speed, but their research did not show that peripheral vision training itself increased reading speed. Of the speed reading group, 24 of 25 subjects showed an increased span of recognition (40% larger span of recognition), as compared to 21 of 34 of the control group subjects (4% larger span of recognition). The greatest improvement in the speed reading group

was an increase of 1.26 more words read with each fixation, with the starting span of recognition being 1.37 words read per fixation and the ending span of recognition being 2.63 words read with each fixation. The most characters per fixation read by the speed reading group was 2.63 words per fixation. The greatest improvement in the control group was an increase of 0.48 more words read with each fixation, with the starting span of recognition being 0.85 words read per fixation and the ending span of recognition being 1.33 words read with each fixation. The most characters per fixation read by the control group was 1.75 words per fixation.

Number of regressions decreased by 64% for the speed reading group, vs. 13% for the control group. The reduction in regressions may be related to the use of the hand as a pacer, which would compel the eyes to continue forward to keep up with the hand. Again, due to the time involved in programming and completing saccadic eye movements, any reduction in eye movement will lead to increased reading speed, if all other variables are held constant. The elimination of redundant eye movements will improve reading speed. Of the speed reading group, 23 of 25 showed a decrease in the number of regressions (64% fewer regressions), as compared to 22 of 34 of the control group (15% fewer regressions), with the greatest improvement in the speed reading group being a reduction of 29 fewer regressions per 100 words, a decrease from 34 regressions per 100 words to 5 regressions per 100 words. The fewest regressions in the speed reading group was 0 regressions. The greatest improvement in the control group was a reduction of 17 fewer regressions per 100 words, a decrease from 44 regressions per 100 words to 27 regressions per 100 words. The fewest regressions in the control group was 1. With the theory that fewer regressions might increase comprehension, due to fewer breaks in continuity of information intake, the data were analysed correlating comprehension with 10 or greater reductions in regressions per 100 words, with 15 or greater reductions in regressions per 100 words, and with 20 or greater reductions in regressions per 100 words. There was no consistency in the data and the sub-groups were too small for any conclusions to be drawn.

Duration of fixation decreased 5% for the speed reading group, vs. 1% for the control group. We had not anticipated this, but rather, were speculating that we would instead see either a slight increase or no change, considering that the reader would be processing more information with each fixation if increased span of recognition was found, as it was. The decrease in fixation duration may be, in part, due

to more efficient saccades, as the Ober2 does not measure duration of saccadic motion and duration of fixation separately. Of the speed reading group, 16 of 25 showed a decrease in duration of fixation, as compared to 15 of 34 of the control group, with the greatest improvement in the speed reading group being a reduction of 0.07 seconds, from a starting duration time of 0.28 sec and a finishing duration of 0.21 sec. The shortest duration of fixation for the speed reading group was 0.18 sec. For the control group, the greatest improvement was a reduction of 0.04 seconds, from a starting duration time of 0.26 sec to a finishing duration of 0.22 sec. The shortest duration of fixation for the speed reading group was 0.19 sec. It is interesting to remember Rubin and Turano's[5] research which indicates that only 0.07 sec is required to comprehend material, and the rest of the fixation time is used to program the saccade. The fastest saccade they found in their study was 0.17 sec, with 0.25 sec being the average.

Reading speed increase is related to the improvement in the eye movement components of reading. Fewer fixations and fewer regressions will lead to a faster reading speed. Rubin and Turano[5] found that the visual system uses over two thirds of the duration of fixation time to program for a saccade, rather than to gain information. A shorter duration of fixation will also lead to less time being required to complete a passage. A larger span of recognition allows the reader to fixate fewer times but still read the entire passage. Of the speed reading group, 24 of 25 showed an increased reading speed (46% faster), as compared to 21 of 34 of the control group (5% faster). For the speed reading group, the greatest increase in reading speed was 436 words per minute (wpm), from a starting speed of 298 wpm to a final speed of 734 wpm. The fastest speed for a speed reading group subject was 734 wpm. For the control group, the greatest improvement was an increase of 147 wpm, from 379 wpm to 526 wpm, with the fastest reading speed in the control group being 526 wpm.

Comprehension decreased for the speed reading group by 7.2%, and increased for the control group by 1.8%. The changes in comprehension were slight, but were statistically significant when the two groups were compared to each other in a two way ANOVA. Speed reading subjects reported that when reading faster they felt that they concentrated better and daydreamed less. In the testing situation they may have sacrificed comprehension in order to show an increase in reading speed. For the speed reading group 24 of 25 showed an increase in reading speed. Of those 24 whose reading speed increased, 8 individuals showed improved comprehension, 3 maintained the same comprehension score,

and 13 had decreased comprehension scores. In the control group, 21 of 34 showed an increase in reading speed. Of these 21, 4 individuals showed improved comprehension, 7 maintained the same comprehension scores, and 10 showed decreased comprehension. Of the speed reading group over all, 16 of 25 showed a decrease in comprehension, as compared to 12 of 34 of the total control group.

Of the 9 speed readers who showed equal or improved comprehension, reading speed improved an average of 127 wpm, number of fixations decreased an average of 23.8 fixations per 100 words, span of recognition increased an average of 0.4 words read per fixation, number of regressions decreased an average of 13 regressions per 100 words, and duration of fixation decreased by an average of 0.014 sec (see Table 2). The comprehension rate of this group (speed readers whose comprehension either stayed the same or improved) increased by an average of 10%, or one more correct answer than before. There is an improvement of 15%, or 1.5 more correct answers for the speed reading group if only those with increased comprehension are considered without including those who maintained the same comprehension. Of the 16 speed readers who showed reduced comprehension, average changes are as follows: reading speed improved 126.6 wpm, number of fixations decreased by 23.12 fixations per 100 words, span of recognition increased by 0.47 words read in each fixation, number of regressions decreased by 9.3 regressions per 100 words, and duration of fixation decreased by 0.012 sec. The comprehension rate of this group (speed readers whose comprehension decreased), decreased by an average of 17%, or 1.7 more incorrect answers than before.

For the control group, the 22 who had equal or increased comprehension showed these averages: their reading speed improved by 6.9 wpm, number of fixations *increased* by 1.45 fixations per 100 words (all other sub-groups showed a decrease), span of recognition *decreased* by 0.0036 words per fixation (all other sub-groups showed an increase), number of regressions decreased by 0.09 regressions per 100 words, and duration of fixation decreased by 0.0059 sec. (see Table 2). The comprehension rate of this group (control group whose comprehension either stayed the same or increased), increased by an average of 11.4%, or 1.14 more correct answers than before. There is an improvement of 18.5%, or 1.85 more correct answers for the control group if only those with increased comprehension are considered without including those who maintained the same comprehension. The 12 subjects in the control group who had a decrease in comprehension showed these averages: their

reading speed improved by 30.9 wpm, number of fixations decreased 15.6 fixations per 100 words, span of recognition increased by 0.159 words read in each fixation, number of regressions decreased by 4.9 regressions per 100 words, and duration of fixation *increased* by 0.019 sec (other sub-groups showed a decrease). The comprehension rate of this group (control group whose comprehension decreased), decreased by an average of 15.8%, or 1.58 more incorrect answer than before.

	compre-hension	reading speed	# of fixations per 100 words	span of recognition	# of regres-sions per 100 words	duration of fixation
Speed reading group whose comprehension remained equal or improved. (9 of 25)	1 more correct*	127 wpm faster	23.8 fewer	0.4 word larger	13 fewer	0.014 sec shorter
Speed reading group whose comprehension decreased. (16 of 25)	1.7 fewer correct	126.6 wpm faster	23.12 fewer	0.473 word larger	9.3 fewer	0.0119 sec shorter
Control group whose comprehension remained equal or improved. (22 of 34)	1.14 more correct*	6.9 wpm faster	*1.45 more*	*0.0036 word smaller*	0.09 fewer	0.0059 sec shorter
Control group whose comprehension decreased. (12 of 34)	1.58 fewer correct	30.9 wpm faster	15.58 fewer	0.159 word larger	4.9 fewer	*0.019 sec longer*

Table 2. Summary of average changes in both groups when separated by comprehension scores.
*There is an improvement of 1.5 more correct answers for the speed reading group, and 1.85 more for the control group if only those with increased comprehension are considered, instead of both those who maintained the same comprehension and those who improved.

For the speed reading group, both those with increased comprehension and those with decreased comprehension improved in all five areas. The improvements for both sub-groups of the speed reading group are similar. Notably, those speed readers with increased comprehension had a greater reduction in the number of regressions per 100 words than did the speed reading sub-group with decreased comprehension. For the control group, those with equal or increased comprehension had an increase in the number of fixations per 100 words and had a reduced span of recognition as compared to their entrance test. Those control sub-group subjects with decreased comprehension had a longer duration of fixation than they had shown in the initial test, but their reading speed increased more than that of the control sub-group with equal or increased comprehension. For the speed reading group, both those with increased comprehension and those with decreased comprehension increased their reading speed by about 127 wpm. About two thirds of the speed reading group had an average 17% decrease in

comprehension, but the individual who had the greatest increase in speed (436 wpm faster, for a final reading speed of 734 wpm) had 90% comprehension in both the initial and the final test.

Based on the results of this study, speed reading techniques can benefit the typical reader by increasing reading speed, but with somewhat decreased comprehension for some. Of course, the reader can select to read slower when greater comprehension is required. Other techniques taught in the speed reading course, but not previously discussed in this paper, aid in study efficiency. These include previewing the material prior to reading by looking first, for example, at the table of contents, and then spending one to two seconds on each page, drawing the eyes down the page with the hands, paying attention particularly to the structure and organization of the material, bold print titles, and occasional proper nouns and other single words in order to "set the scene". This allows the mind to begin to access stored knowledge on the topic, which helps to increase comprehension.

There are many areas for future study related to enhancement of reading speed. The area to emphasize in training faster reading is increasing span of recognition, as this seems to be the limiting factor in reaching faster reading speeds (in those with accurate eye movement control), in light of the research showing the large percentage of each fixation which is involved in programming saccadic eye movements rather than in gaining information. As well, there has yet to be an unbiased study to substantiate or disprove the claims of reading speeds in excess of 2000 wpm. Imaginative researchers could easily adapt existing technology to this pursuit.

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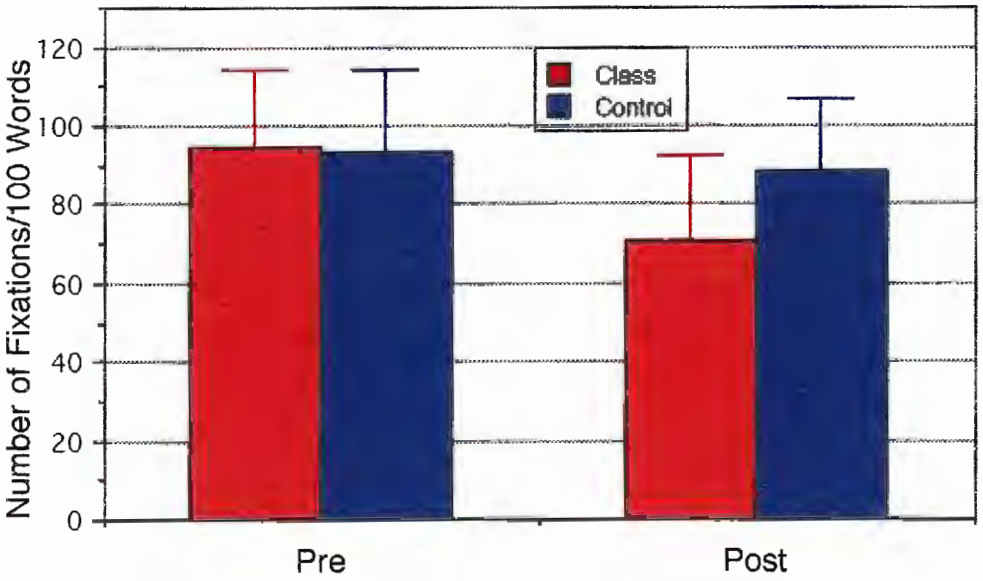

Figure 1. Changes in fixations for each group pre and post, with the error bars representing one standard deviation.

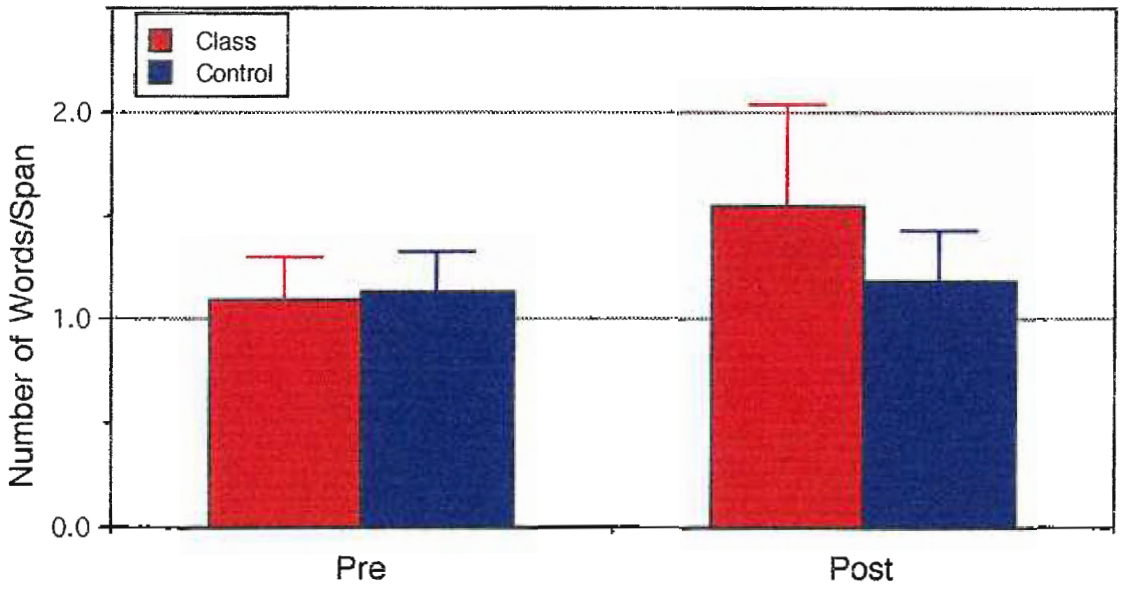

Figure 2. Changes in span of recognition for each group pre and post, with the error bars representing one standard deviation.

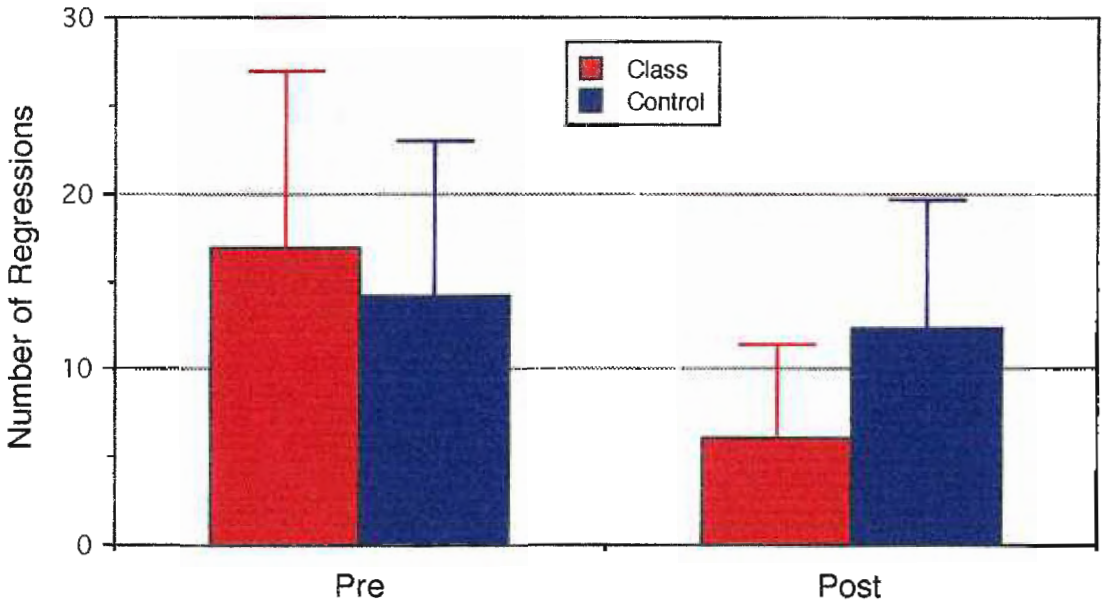

Figure 3. Changes in the number of regressions for each group pre and post, with the error bars representing one standard deviation.

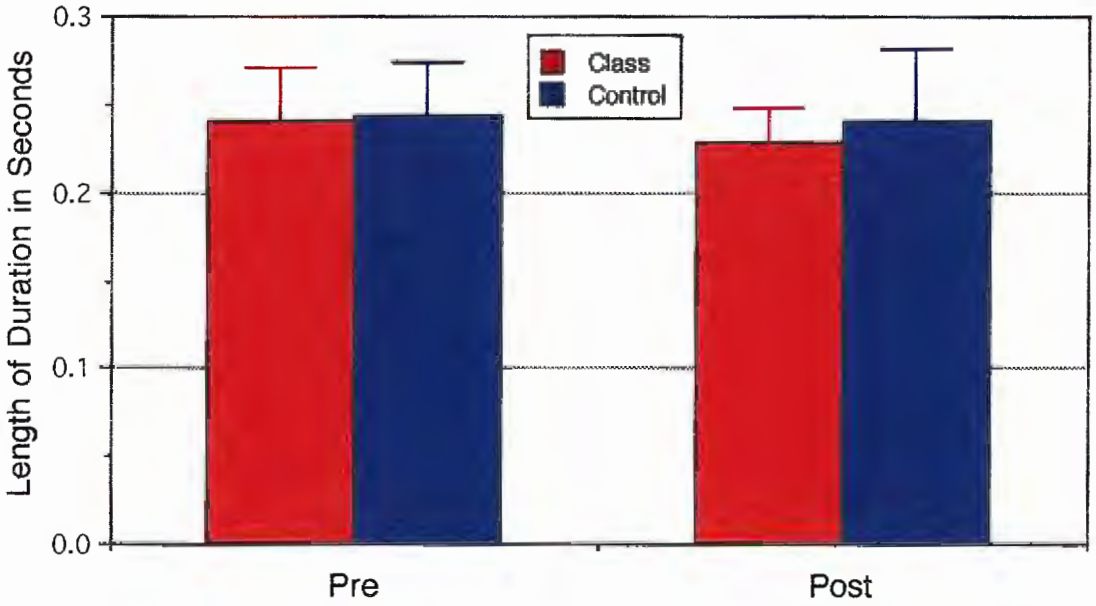

Figure 4. Changes in fixation duration for each group pre and post, with the error bars representing one standard deviation.

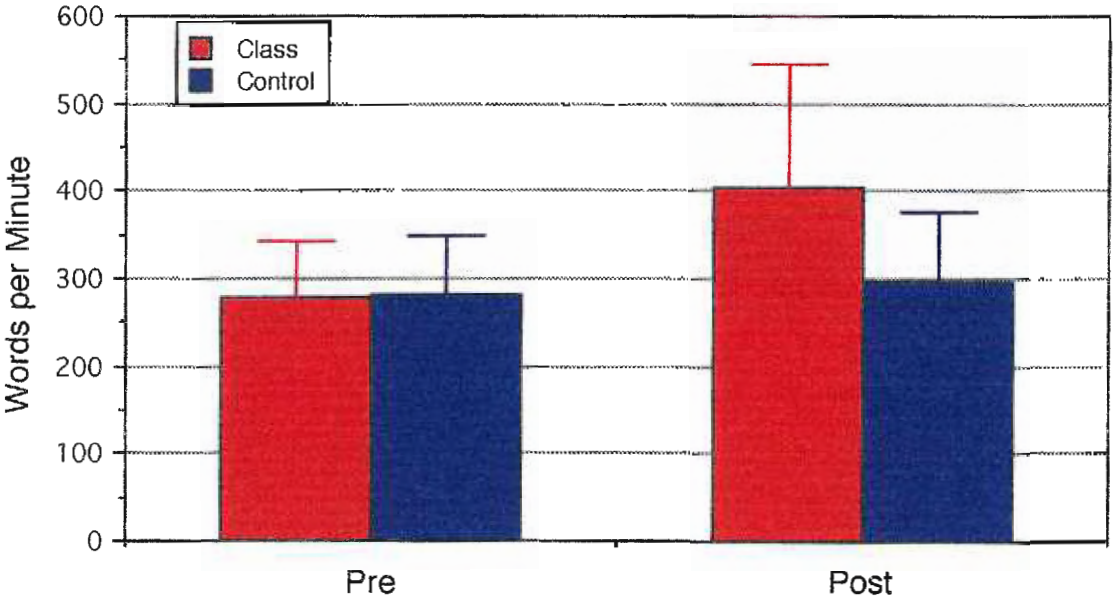

Figure 5. Changes in reading speed for each group pre and post, with the error bars representing one standard deviation.

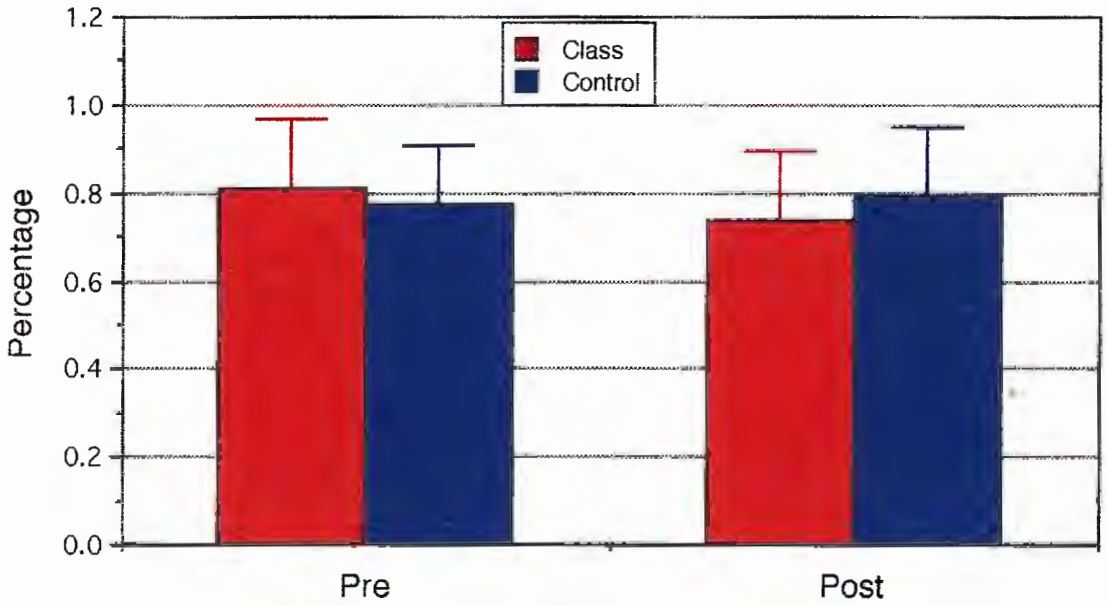

Figure 6. Changes in comprehension for each group pre and post, with the error bars representing one standard deviation.

Speed Reading Seminar

Have you always been curious about speed reading? Now is your chance. Marci Pieper and Tammie Calef are doing a thesis in which we will measure eye movements before and after a 15 hour speed reading seminar. The class will be offered Tuesday nights, from 5:30 to 8:30, for five weeks, from October 11th through November 8th. We will measure your eye movements before (sometime during the week of October 3-7) and after (prior to Thanksgiving break) the class. This should take about 20 minutes. The class will be taught here at Pacific by Sharon Williams, who has taught speed reading for many years. The regular cost for her seminar is $400.00, but she is offering this course for $25.00 (just enough to cover materials) because she is excited to see documentation of the changes in eye movements due to the speed reading course. Class enrollment is limited to 35, and will be on a first come first enrolled basis. You *must* attend all five weeks (slackers will be shot), but there will be no requirement of homework outside of the class, except to try to utilize the techniques during regular studying.

If you want to take the class, let Tammie (357-1791) or Marci (357-7759) know by 30 September, either by phone or by a note.

Informed Consent Form

Institution

A.	Title of project:	Analysis of Eye Movements Before and After Speed Reading Instruction
B.	Principal investigators:	Tammie Calef 357-1791 Marci Pieper 357-7759
C.	Advisors:	Bradley Coffey OD 357-6151 ext.2280 Scott Cooper OD 357-6151 ext. 2271
D.	Location:	Pacific University
E.	Date:	Fall, 1994

1. Description of project

The goal of this study is to document the changes in eye movements after a 15 hour seminar in speed reading. The subject's eye movements will be measured before and after the subject attends the seminar using the Ober, a state of the art instrument which records exactly where the eyes look, and which can analyze how many characters are recognized with each fixation of the eyes, measure reading speed, and test for comprehension, among other things. The seminar will be the standard 15 hour course in speed reading, using the established techniques. It is expected that the reading speed will increase drastically, and that the eye movements will be faster, and that more information will be taken in with each fixation of the eyes.

2. Description of risks

The testing included in the diagnostic evaluation consists of visual tests which are routinely used in diagnostic testing at the Pacific University Family Vision Centers. No experimental procedures are included. As such, risk to subjects is no greater than that associated with a routine visual examination.

3. Description of benefits

The information gained from this study will provide necessary data regarding the effects of standard speed reading techniques on eye movements.

4. Alternatives advantageous to subjects

Subjects could buy a book on speed reading and do a self-guided course, and guess if their eye movements have changed as a result of the self education.

5. Record-keeping

Records of this project will be maintained in a confidential manner and no name-identifiable information will be released.

6. Compensation and medical care

All efforts have been made to eliminate risk of injury to subjects. In the unlikely event that a subject is injured in this study, it is possible that no compensation or medical care will be provided by the investigators or by any organization associated with the study.

7. Offer to answer any inquiries

The investigators will be happy to answer any questions that may arise at any time during the course of the study. If the answers are not satisfactory, please call Dr. James Peterson (357-0442). During participation in the project you are not a Pacific University clinic patient or client for the purposes of the research and all questions should be directed to the researchers and/or the faculty advisor who will be solely responsible for any treatment (except for an emergency). You will not be receiving complete eye, vision, or health care as a result of participation in the project; therefore, you will need to maintain your regular program of eye, vision, and health care.

8. Freedom to withdraw

Subjects are free to withdraw their consent and to discontinue participation in project or activity at any time without prejudice toward them.

I have read and understand the above information and I am in agreement with the personal obligations of the consent.

Printed name:_____ Date of birth:_____
Signature:_____ Date:_____
Address:_____ Phone:_____
_____
_____
Name of nearest relative (not living with you):_____Phone:_____

NAME:_____

ENTRANCE CRITERIA DATE_____

Near VA_____

Ocular Motility_____

Cover Test_____

OBER 1a Fixations/100 Words_____

Span of Recognition_____

Regressions/100 Words_____

Duration of Fixation_____

Words/Minute_____

Comprehension score_____

OBER 1b DATA DATE_____

Fixations/100 Words_____

Span of Recognition_____

Regressions/100 Words_____

Duration of Fixation_____

Words/Minute_____

Comprehension score_____

OBER 2 DATA DATE_____

Fixations/100 Words_____

Span of Recognition_____

Regressions/100 Words_____

Duration of Fixation_____

Words/Minute_____

Comprehension score_____

Questions

1. Paganini was born in 1784. (Yes)
2. He began violin lessens when he was eleven years old. (No)
3. Violin teachers finally told Paganini they could not improve his technique. (Yes)
4. Paganini began to give violin lessons. (No)
5. He often practiced passages for fifteen hours at a time. (No)
6. He began touring professionally at the age of thirteen. (Yes)
7. Audiences were astonished by his force and speed. (Yes)
8. He could play whole compositions on one string alone. (Yes)
9. He composed violin music so difficult that he alone could play it. (Yes)
10. It was not until after his death that his music was appreciated. (No)

Paganini was one of the world's greatest violinists. Born in 1784, Paganini began violin lessons early in life. When he was eleven years old, violin teachers told him they could do no more to improve his technique. Paganini began to study strenuously on his own, practicing passages for ten hours at a time. He began professional tours when he was thirteen. Audiences were moved to tears by his rendition of quiet melodies and astonished by his force and speed. To show his virtuosity, he played entire selections on the fourth string alone. He took great delight in composing music so technically difficult that he alone could play it. His later life was a series of triumphant tours.