Evaluation of a Computerized, Home-based PA/VE and Guided Reading Therapy Program and Its Influences on Reading Performance in an Adult Population

By

Stacy Bragg

Todd Hartman

Teresa Pham

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Advisor:
Hannu Laukkanen, O.D., M.Ed.

AUTHORS:

Stacy Bragg

Todd Hartman

Teresa Pham

ADVISOR:

Hannu Laukkanen, O.D., M.Ed.

BIOGRAPHIES

Stacy Bragg graduated from Mercer University, Macon, Georgia. She received a B.S. in Biology and minored in Philosophy. She hopes to return to her native Sacramento, California to practice optometry.

Todd Hartman graduated from Oregon State University, Corvallis, Oregon. He received a B.S. in Biology and minored in Chemistry. He plans on pursuing a residency in ocular disease and trauma.

Teresa Pham graduated from Boise State University, Boise, Idaho. She received a B.S. in Biology. She hopes to return to Idaho to practice optometry in the Greater Treasure Valley.

ABSTRACT

In this study the investigators set out to determine if increases in reading oculomotor efficiency could be obtained using a computerized, home-based training program in a non reading-disabled, adult population. Oculomotor efficiency improvement was determined to be an increase in reading with comprehension rate, and a decrease in number of fixations and regressions. The study population consisted of 94 subjects, most of which were optometry students. Fifty-three of the original 94 subjects were able to comply with the study protocol and produced qualifying data to be used in the statistical analysis. The investigators wished to determine whether the Reading Plus^{TM} program would be beneficial to those adults who exhibited inefficient reading eye movements, as well as those with average or above-average oculomotor skills. It was also hypothesized that in a 10-week training program, those who trained four times per week (4X) would achieve greater levels of improvement compared to the subjects who trained two times per week (2X). This study demonstrated that reading eye movement efficiency could be improved in individuals regardless of their initial reading efficiency level. Both 2X and 4X showed marked improvement in the three measures of reading efficiency, with 4X producing a larger improvement effect compared to 2X.

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INTRODUCTION

Reading is a complex process that involves the close interaction of visual function, perception and cognition. Since the late 1800s eye movements during reading have been studied to gain a better understanding of the reading process. Reading consists of a series of small, rapid eye movements (saccades) with intervening pauses (fixations). Ten to 20% of reading saccades are in a backward, right-to-left, direction (regressions). Regressions may occur to correct for the misreading of prior text, adjust for oculomotor inaccuracy, or to verify meaning.[1] Approximately 90% of the time during reading is spent in fixations, with each duration of fixation lasting from 100 to 500 milliseconds. During a fixation, five to eight characters of information are processed by the fovea (span of recognition), while peripheral information is used to direct the subsequent saccade. Shortly before, during, and shortly after a saccade, visual information is suppressed to prevent the image from persisting. During the saccades the units of visual information obtained during the fixations are integrated both temporally and spatially to form a continuous visual perception.[1] Because the fovea subtends 2-3 degrees, accurate saccades are necessary to display the text on the central retina which is necessary for efficient information processing.[2] Reading performance directly relates to oculomotor and visual processing skills. An efficient reading pattern consists of fewer fixations with a shorter duration, a larger span of recognition, and fewer regressions. Reading deficiencies may occur secondary to poor oculomotor control and/or perception.[3-8]

Reading eye movements are a part of a functional relationship between the magnocellular pathway and visual attention. There is a strong correlation between dysfunction of the magnocellular pathway and reading disability.[9-11] Breitmeyer and Ganz theorized that the magnocellular system guides the selective attention mechanism.[12] Because attention drives the saccades, a deficit in the selective attention pathways can be demonstrated in reading tasks that require eye movements.[13] Such a deficit is believed to interfere with efficient use of parafoveal information and subsequent saccadic programming. In addition, the magnocellular pathway plays a role in saccadic suppression, which may also be linked to the signal for eye movement. Therefore, deficits in the magnocellular system could manifest as abnormal saccadic suppression, which would result in a decrease in organization and integration of information.[12] Saccadic control, left to right sequencing, and motor planning are involved in reading performance, and can be adversely affected by any alteration of the magnocellular processing order, timing or rate.[14] In reading difficulty cases where there is an underlying magnocellular system deficit, oculomotor training may be of value because it emphasizes the importance of information processing to proceed in an organized fashion.[15]

Previous research has demonstrated that reading oculomotor efficiency can be trained in a wide range of subjects. Solan and associates have shown reading enhancement training to be effective with reading disabled sixth graders, achieving high schoolers, young adults, and older adults.[15-18] The techniques used in these studies focused on developing central visual processing speed and oculomotor skills. Rounds et al. investigated the effects of training exclusively oculomotor skills in a sample of adult poor readers. Their results indicated that reading efficiency could be improved by training oculomotor skills alone.[19] Although a conclusive direct comparison cannot be made between the two studies, it is interesting to note that the percentage of improvement was greater in the Solan study which trained visual information processing speed in addition to oculomotor skills.[17] Rounds et al. hypothesized that oculomotor training in isolation may not be enough to change the reading eye movements of adults.[19]

In this study the investigators set out to determine if similar increases in reading oculomotor efficiency could be obtained using a computerized, home-based training program in a non reading-disabled, adult population. This study population was slightly different from the previous studies in that it consisted of subjects whose reading eye movement efficiency levels spanned a large range. Relative efficiency was calculated by dividing the rate by the sum of fixations and regressions. The relative efficiency was then compared to grade level averages. The lowest grade level efficiency was 2.9, while the highest was grade level 16.4. The investigators wished to determine whether the Reading Plus™ On-line program would be beneficial to those adults who exhibited inefficient reading eye movements as well as those with average or above-average oculomotor skills.

One of the difficulties encountered with subject recruitment was that many were interested in participating, but could not guarantee compliance with the training regimen of four sessions per week for ten weeks. As a result, the investigators added another question to the study. Would decreasing the regimen from four times per week to two times per week result any difference in amount of improvement? It was hypothesized that training four times per week would result in greater levels of improvement compared to those achieved by training two times per week. For this study, three measures of the reading process were evaluated to determine whether or not training resulted in improvement. Oculomotor efficiency improvement was defined as an increase in reading with comprehension rate and a decrease in number of fixations and regressions.

METHOD

Subjects

The research program was approved by the Pacific University Institutional Review Board (PUIRB), and all participants were provided informed consent as approved by the PUIRB. All first, second, and third year optometry students who attended Pacific University College of Optometry (PUCO) and their spouses or friends were recruited to participate in the study. Ninety-four individuals (mean age: 24.8 years; range: 21 years to 40 years) agreed to participate as either an experimental or control subject. No visual performance criteria were used for eligibility. None of the subjects reported having a reading disability. Subjects were first evaluated with the Developmental Eye Movement (DEM) test.[20] The DEM test was performed twice; the first time was to familiarize subjects with the test, and the second time was to identify the existence of an oculomotor dysfunction. All of the subjects demonstrated a normal Type I behavior (H/V ratio average, 1.01 ±0.10).

Subjects were assigned to study groups based upon their perceived ability to comply with the time commitment of the study and their grade level efficiency of reading eye movements as determined by the Visagraph II recording system (Taylor Associates, 200-2 E. 2nd Street, Huntington Station, NY 11746) baseline recording average. Subjects that performed at or below grade level 10 were encouraged to enroll in the group that would train four times per week (4X) or two times per week (2X) if they were unable to commit to the 4X. Subjects that scored above grade level ten were encouraged to join the 2X if they were willing to make the time commitment, or the control (C) group if they were not motivated to participate in the training. Once reading eye movement efficiency and motivation for training were discussed, the ninety-four subjects were divided into three groups: 2X (n=42), 4X (n=25), and C (n=27).

Fifty-three of the original 94 subjects (56.4%) produced qualifying data. At the end of the 10 week study, six subjects had withdrawn from both 2X and 4X, citing inability to adhere to the training regimen time commitment. Compliance was assessed at 10 weeks, and nineteen 2X subjects, four 4X subjects, and six C subjects failed to comply with the assigned training regimen or were unable to return for subsequent testing at the appropriate time intervals. Individual performance was monitored with utilization of the Reading Plus™ administrator privileges. The investigators communicated with the subjects at regular intervals to help ensure compliance. The data from the subjects who were unable to comply with the training or testing protocols was not included in the statistical analysis.

The baseline differences in all three reading eye movement efficiency measures between C and 2X were not statistically significant when compared using analysis of variance (ANOVA). However, C and 4X were significantly in average number of fixations, while 2X and 4X differed significantly in average number of fixations and reading rate. The initial reading eye movement characteristics of the subjects who successfully completed the study are shown in Table 1.

	AVG. FIXATIONS (SD)		AVG. REGRESSIONS (SD)		AVG. RATE (SD)	
C (n=21)	85.857 (16.2)		8.929 (6.7)		281.762 (58.0)	
2x (n=17)	89.647 (23.2)		10.206 (11.5)		295.235 (95.7)	
4x (n=15)	108.967 (22.2)		17.300 (13.0)		224.667 (46.4)	
	mean difference	p-value	mean difference	p-value	mean difference	p-value
C vs. 2X	-3.790	0.8504	-1.277	0.9310	-13.473	0.8400
C vs. 4X	-23.110	0.0062*	-8.371	0.0664	57.095	0.0629
2X vs. 4X	-19.320	0.0351*	-7.094	0.1642	70.569	0.0230*

Table 1. Summary of initial reading efficiency characteristics and inter-group comparisons.
*Statistically significant difference.

Procedures

After the initial DEM testing, the reading eye movements of each subject were objectively measured with the Visagraph II recording system. If habitual correction was needed for reading, the goggles were placed over the correction. Each of the subjects read three Level 10 passages from the Visagraph II reading selection book. The first passage was read to familiarize the subjects with the entire process of reading with goggles and answering ten comprehension questions. The data from the second and third passages was recorded and averaged to establish the baseline measurements to which future measurements would be compared.

The 2X and 4X subjects each received an individual login number and password to the Reading Plus™ Online Program (Taylor Associates/Communications, Inc., 200-2 E. Second Street, Huntington Station, NY 11746), and could access the program from anywhere at anytime to participate in a training session. Before starting the training sessions, subjects were required to complete a Reading Placement Appraisal (RPA™), which determined the independent reading level, reading rate and vocabulary level to ensure placement at an appropriate level in the program. Each training session lasted approximately 35 minutes. For each session, if necessary, habitual correction was used by the individual subjects. The first ten minutes consisted of Perceptual Accuracy/Visual Efficiency (PA/VE) training. VE training was comprised of scan activities, which assigned a target lowercase letter for the subject to count as three random lowercase letters per line were presented in a left-to-right manner. The initial scanning rate was 40 lines per minute, and following each exercise the accuracy of the subject's count determined the rate of the subsequent scan exercise. If the subject was correct, the rate increased. However, if the subject was incorrect, the rate remained the same for one more exercise and would decrease if he/she was incorrect again. After five sets of scan exercises, subjects engaged in PA training, which was comprised of flash/tachistoscopic activities. Initially, five lowercase letters were flashed at once in 1/10th of a second. The student was then required to type back the correct letters in the correct sequence as presented. The program would automatically increase or decrease the number of symbols to be flashed based upon performance at previous levels. Subjects performed one set of ten flash activities.

Following PA/VE training, subjects engaged in one session of guided reading, which lasted approximately 25 minutes. The guided reading lessons consisted of a key vocabulary introduction, free reading, guided reading, and a comprehension check. For the free reading portion, the passage was displayed in full screen at a rate of 750 words per minute (wpm) until the screen was full. Subjects were allowed to read at their usual reading rate and advance the screen manually. After approximately four minutes of free reading, the subjects continued reading the passage as it was presented one line at a time. At a usual reading rate of less than 300 wpm, a scanning slot with a left-to-right presentation was utilized. At 300 wpm and greater, the passage was presented without the scanning slot. Guided reading rates were automatically increased on subsequent sessions when comprehension scores of 70% or greater were achieved.

After five weeks, all subjects returned for Visagraph II testing to track progress at the midpoint of the study. Each subject read two passages, and the results were recorded and averaged. Subjects continued with their respective protocols for another five weeks. At the end of 10 weeks, Visagraph II testing was performed for a third time using the same procedures as used in the midpoint testing.

RESULTS

Three factors were analyzed to investigate improvement in reading eye movement efficiency: number of fixations, number of regressions, and reading with comprehension rate. Table 2 summarizes the absolute reading measures at the beginning, midpoint and conclusion of study for the three groups. For the overall 10-week change, a one-way repeated measures analysis of variance (ANOVA) using a two-tailed test of significance was performed with the amount of training received as the between group factor. An ANOVA was performed for each reading efficiency measure. Scheffe post-hoc analysis of mean difference was utilized in determining p-values. These results are demonstrated in Table 3.

There was a significant decrease in the number of fixations in both 2X ($p=0.0383$) and 4X ($p<0.0001$) compared to the control group. There was also a significant difference in the amount of improvement by 4X compared to 2X ($p=0.0130$). The average decrease in number of fixations by 4X was nearly twice as much as the average decrease shown by 2X. After 5 weeks of training, 2X group decreased the average number of fixations by 80% from the baseline level. This decrease accounted for 89% of the group's average total change. By comparison, the 4X demonstrated a 68% decrease in average number of fixations from the baseline average, which accounted for 93% of the group's average overall change. Figure 1.1 plots the number of fixations measured at the beginning and at each five week interval. A paired t-test indicated that there was not a significant difference between the average changes in number of fixations measured at five weeks versus 10 weeks for both 2X and 4X.

The 2X group did not demonstrate a significant difference ($p=0.4809$) in the decrease of the average number of regressions when compared to the control group. However, the 4X decrease in average number of regressions was significantly different from both C and 2X (p=

0.0001 and p=0.0077, respectively). In the 2X group, during the second 5 weeks of training the average number of regressions actually increased by 11.6% from the average recorded after the first five weeks. For 4X, the average number of regressions was exactly the same at 10 weeks as it was at five weeks. Figure 1.2 demonstrates the rate of change in number regressions for each group.

The average change in reading with comprehension rate was significantly different for both the 2X and 4X (p=0.0246 and p=0.0002, respectively) compared to that of C. There was not a significant difference between the increase in average rate between the 2X and 4X. At ten weeks, 2X demonstrated an average increased reading rate of 111 wpm, with 85% of this improvement being demonstrated at the five week testing interval. The 4X group showed an increase in average rate by 168 wpm, with 76% of this improvement evident at the midpoint. A paired t-test indicates that there was a significant difference between the decrease in rate measured at five weeks compared to ten weeks for 4X, but not for 2X. The change in reading rate for each group is shown in Figure 1.3.

	C (n=21)			**2X (n=17)**			**4X (n=15)**		
WEEK	**0**	**5**	**10**	**0**	**5**	**10**	**0**	**5**	**10**
FIXATIONS (SD)	85.95 (16.2)	78.17 (13.2)	79.48 (13.5)	89.65 (23.2)	72.12 (15.9)	70.12 (18.8)	108.97 (22.2)	75.40 (16.2)	72.90 (22.8)
REGRESSIONS (SD)	8.93 (6.7)	6.40 (4.7)	7.35 (5.1)	10.21 (11.5)	5.56 (7.9)	6.21 (7.5)	17.30 (13.0)	6.27 (7.5)	6.27 (9.3)
RATE (SD)	281.76 (58.0)	320.14 (71.6)	317.43 (79.0)	295.24 (95.7)	389.85 (122.4)	406.26 (149.8)	224.67 (46.4)	352.97 (74.3)	392.63 (110.7)

Table 2. Average Visagraph II measurements of control and experimental groups at beginning, midpoint, and conclusion of 10 week study.

	AVG. FIXATIONS (SD)		AVG. REGRESSIONS (SD)		AVG. RATE (SD)	
C (n=21)	-6.476 (14.0)		-1.593 (5.8)		35.667 (64.5)	
2x (n=17)	-19.529 (14.4)		-4.000 (4.9)		111.029 (84.2)	
4x (n=15)	-36.067 (17.4)		-11.033 (7.4)		167.967 (101.1)	
	mean difference	p-value	mean difference	p-value	mean difference	p-value
C vs. 2X	13.053	0.0383*	2.407	0.4809	-73.675	0.0261*
C vs. 4X	29.590	<0.0001*	9.440	0.0001*	-132.300	<0.0001*
2X vs. 4X	16.537	0.0130*	5.409	0.0077*	-56.937	0.1601

Table 3. Average overall change measured at 10 weeks and inter-group comparison of overall change. *Statistically significant difference

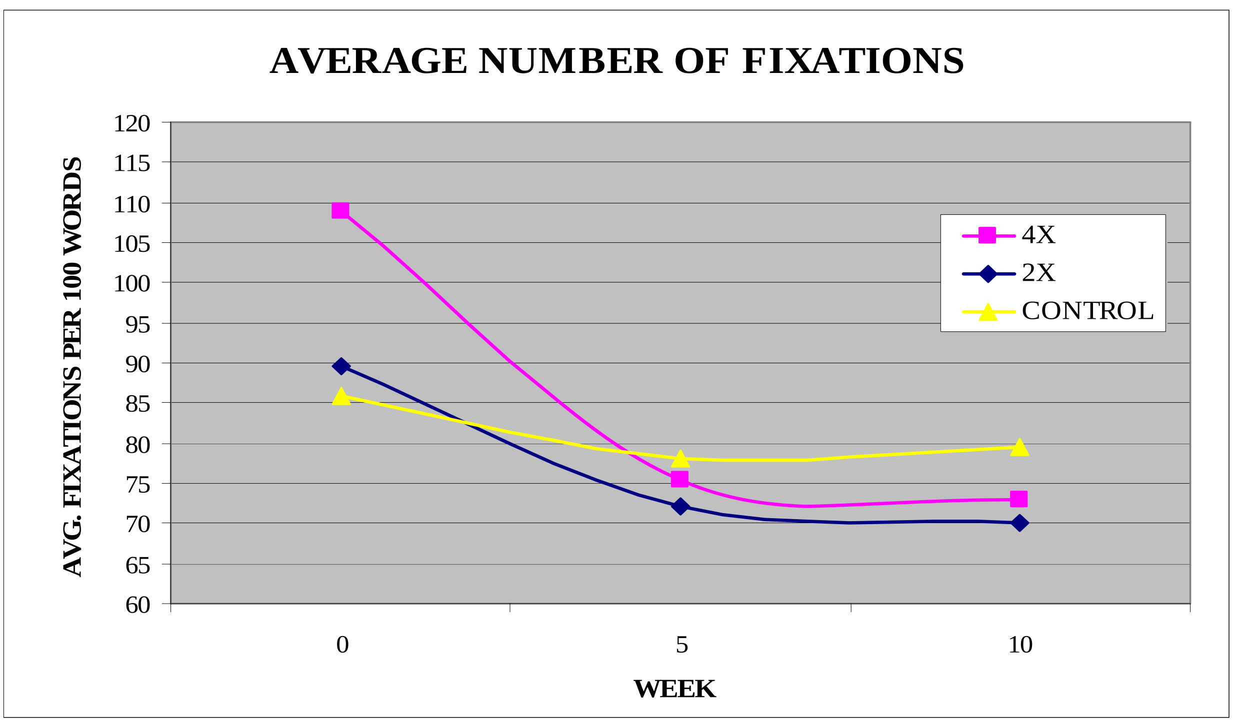

Figure 1.1. Representation of change in average number of fixations for control and experimental groups.

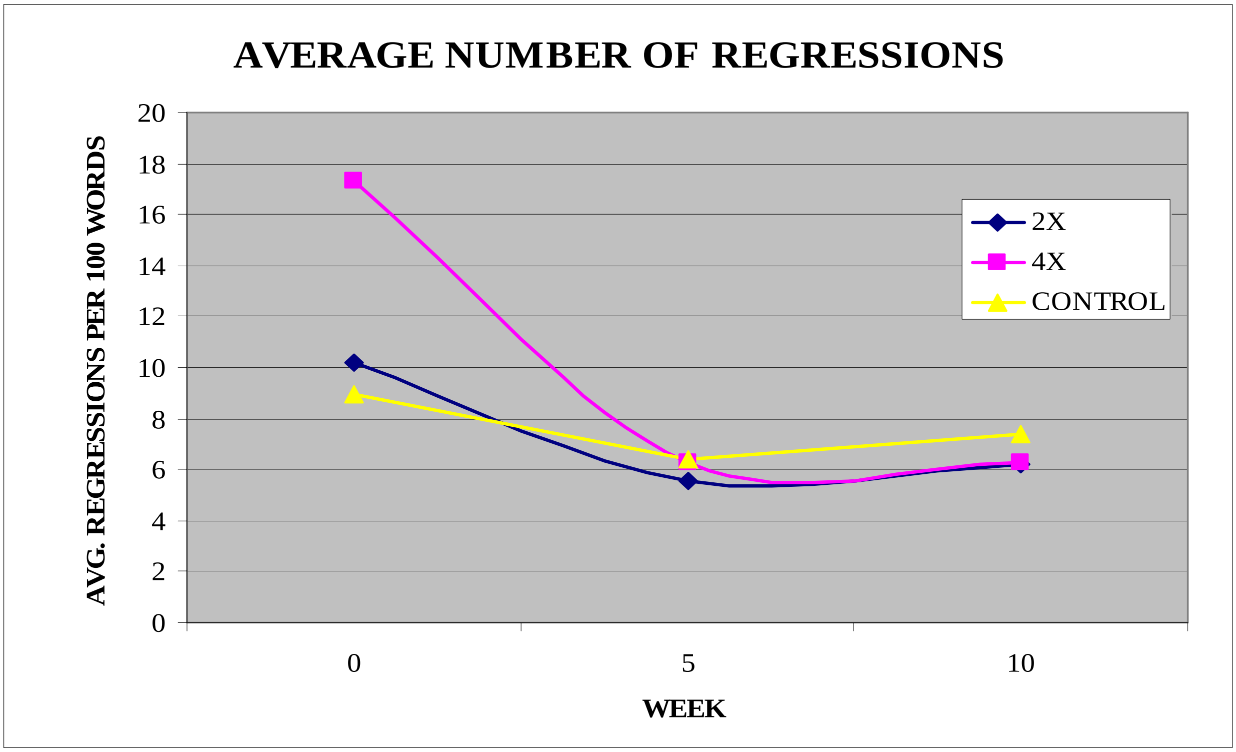

Figure 1.2. Representation of change in average number of regressions for control and experimental groups.

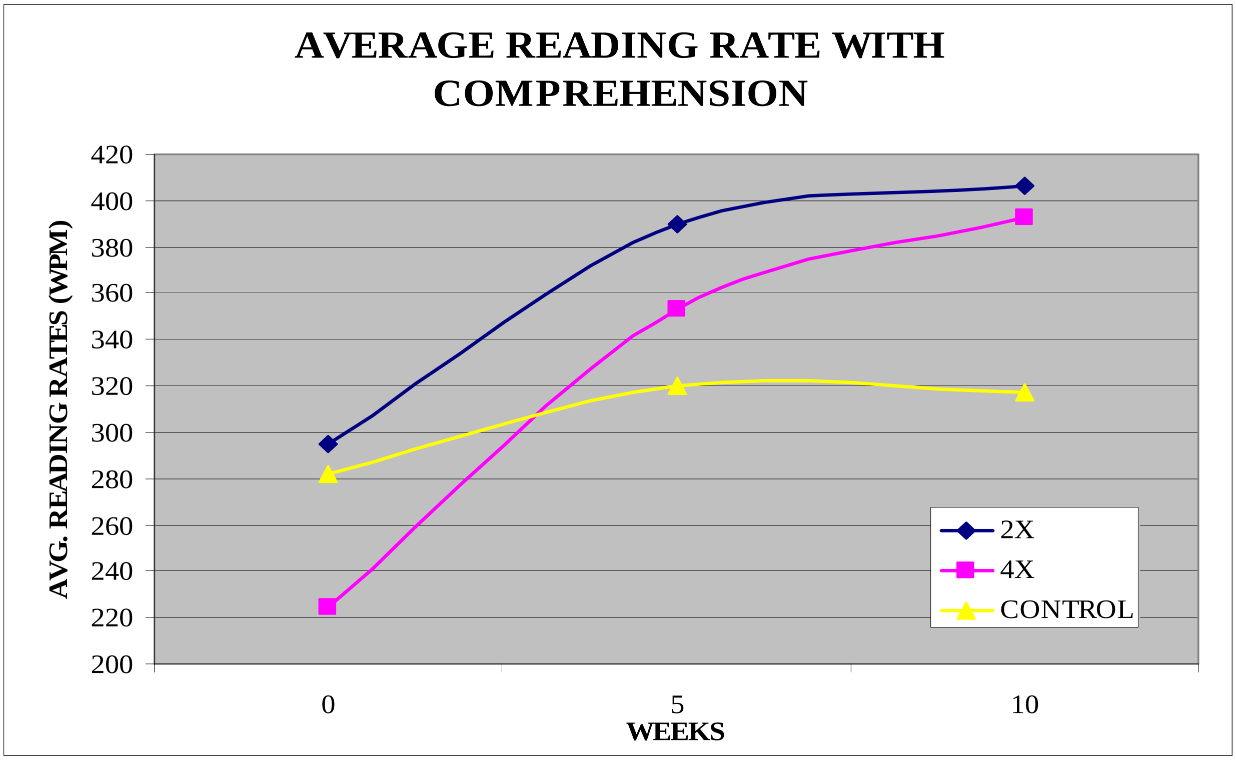

Figure 1.3. Representation of change in average reading rate for control and experimental groups.

DISCUSSION

Tachistoscopic and scanning training have long been used to improve attention, ocular motility, coordination, directional attack, visual memory, and fixation accuracy.[21] All of the aforementioned skills are required for efficient and fluent reading, and can be improved with such eye movement training. In addition to flash and scan training, controlled reading is another tool that has been used successfully to improve reading eye movement efficiency. Today's computerized guided readers have evolved from a long line of controlled reading devices that first started with the Metron-O-Scope of the 1930s. Taylor Associates' on-line version of their Reading Plus™ program appears to effectively utilize modern computer technology to build upon the previous successes of the flash, scan, and controlled reading activities.

The authors' original intent was to evaluate the efficacy of the on-line version of eye movement training program in an adult population, and compare the results to previous studies which utilized the more traditional in-office methods. However, after a thorough literature review, it was discovered that there was little published research involving non reading-disabled adult readers and eye movement therapy. At that point the authors switched the focus of their study to determine if reading eye movements could be improved and, if so, to what degree. The authors also set out to determine if the amount of oculomotor training could directly impact the amount of improvement.

With ten weeks of computerized, home-based training in PA/VE and Guided Reading therapy, it is evident that the reading oculomotor efficiency can be improved in adult readers by training two or four times per week, regardless of initial reading skill level. Our subject groups displayed a wide range of reading grade level efficiencies, yet all participants in each group demonstrated some degree of improvement. The grade level reading efficiency improvement ranged from one to 239 percent. The largest percentage of improvement was achieved by one of the subjects in 4X. Her grade level reading efficiency went from grade 3.95 to 13.4. She was able to reduce the number of fixations and regressions by 62 and 28, respectively, and her reading rate increased by 148 wpm. The largest percentage of efficiency improvement in 2X was 170 percent. This subject went from grade level 3.0 to 8.1, and increased her reading rate by 69 wpm.

Noteworthy improvements were also found with subjects whose reading efficiency was at or closer to college level at the start of the training program. One subject in 4X started at a grade level efficiency of 13.5 and improved his reading rate by 235 wpm, placing him at a grade level efficiency of 16.7. By comparison, one of the subjects in 2X with the same starting efficiency rating improved his reading rate by 225 wpm, and his grade level efficiency increased to 16.4. Even the study's most efficient reader was able to increase his reading rate from 597 wpm to 810 wpm, resulting in an increase in grade level efficiency from 16.4 to 18.0 with training two times per week.

In comparison to the control group, both 2X and 4X showed marked improvements in reading eye movement efficiency. When comparing the two experimental groups, 4X showed a greater amount of improvement. However, the reading rate change difference was not statistically significant. This is surprising since the improvement in the number of fixations and regressions were significant. Because the number of fixations and regressions directly affect the reading rate, it might be intuitive to expect that the difference in reading rate should have also been significant. One possible explanation is that at the baseline, there was already a statistically significant difference between the reading rate of 2X and 4X. Another potential explanation might be the rate of 4X was significantly lower than 2X at the start of the training program, so

4X would have had to increase the reading rate to a greater degree in order to achieve significance. When looking at the individual data compared to the averages, it seems that there may be a significant difference in percentage change of reading rate found for 4X compared to 2X.   For example, in 4X, nine out of 15 subjects increased their reading rate by 60 percent or more. Of these nine, four individuals increased their reading rate by more than 120 percent. By comparison, only two out of 17 subjects in 2X were able to increase their reading rate by more than 60 percent, with the highest percentage increase being 98 percent. This large difference in percent change between 2X and 4X could be explained by the individual participants and their relative level of motivation. Because each subject self-selected their group, the 4X subjects displayed a greater desire and level of commitment to improve their reading efficiency. It is conceivable that this group had more room for improvement. It is difficult to conclude which factor had more of an impact on the results of this study.

A possible criticism of this study design was that at baseline there were differences in the means of the reading efficiency measures. Ideally, subjects would have been randomized into groups with an overall composition similar to one another. However, due to factors beyond the researchers control, subjects were not willing to be randomly placed into groups. It was predicted that a higher rate of non-compliance with the training regimens would have occurred if the subjects were randomly assigned to groups. It could be argued that control group assignment of motivated individuals, who could potentially benefit from eye movement and perceptual training, would have been unethical. It seems likely that the greater improvement in reading efficiency displayed by 4X versus 2X is a combination of factors, including the idea that 4X had more room for improvement and had a greater intrinsic motivation.

One last interesting trend that was evident in analyzing the plotted data was the fact that for both 2X and 4X the greatest percentage of overall improvement that was achieved within the first five weeks of training. A follow-up to this study is being conducted at this time to re-evaluate the subjects several months after the cessation of training. It will be interesting to see if the improvements made by 2X and 4X in reading eye movement efficiency are lasting or if there is any degree of regression to an inefficient reading eye movement behavior.

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