A pilot study investigating the use of the Taylor Reading Plus web based on-line computerized eye movement training program to improve oculomotor control of non-reading disabled adult readers

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A pilot study investigating the use of the Taylor Reading Plus web based on-line computerized eye movement training program to improve oculomotor control of non-reading disabled adult readers

Abstract
The Taylor Reading Plus program is an eye movement training software which comprises of Core Programs such as PAVE (Perceptual Accuracy/Visual Efficiency) and Guided Reading. In this study, the Reading Plus program was used to determine if home-based computerized eye movements training could improve oculomotor skills during reading. The oculomotor skills and reading rate (with comprehension) of 70 subjects were measured during reading using the Visagraph II. The Visagraph ll provided data on reading rate, fixation, regression, and other variables for each paragraph read. Thirty of the initial 70 subjects who originally agreed to participate in this study were designated as "controls" and would receive no intervention, other than assessment. Forty subjects were designated as "experimental subjects" and would participate in ten-weeks of web based on-line PAVE and Guided Reading computerized eye movement training. Only five of the original 40 experimental subjects completed the voluntary training regimen (for a variety of reasons, described in the "discussion section" of this paper). Results from the five subjects who completed the prescribed on-line training regimen are presented in this paper in a "case report format style. Data from the five subjects is highly suggestive that PAVE and Guided Reading programs may be effective in improving oculomotor and reading skills for non-reading disabled adult readers.

Degree Type
Thesis

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A PILOT STUDY INVESTIGATING THE USE OF THE TAYLOR READING PLUS WEB BASED ON-LINE COMPUTERIZED EYE MOVEMENT TRAINING PROGRAM TO IMPROVE OCULOMOTOR CONTROL OF NON-READING DISABLED ADULT READERS

By

KIM TRAN YU CUI

A Thesis submitted to the faculty of the College of Optometry Pacific University Forest Grove, Oregon For the degree of Doctor of Optometry May 2004

Advisor:

Hannu Laukkanen, O.D., M.Ed., F.A.A.O.
Biographies of Authors

Tran, Kim

Kim grew up in Boston, Massachusetts. She graduated from the University of Massachusetts, Dartmouth with a B.S. degree in Electrical Engineering in 1988. Kim then went on to work for NASA Kennedy Space Center and Johnson Space Center for eight years as a Design Engineer. Upon graduation in May 2004, she plans to stay in Portland to practice optometry in a private multidisciplinary setting.

Cui, Yu

Yu is a visiting scholar from Xinhua Hospital, Shanghai Second Medical University, who was graduated from Ophthalmology & Optometry School, Wenzhou Medical College on 2000 with the degree of Bachelor of Medicine, major in Ophthalmology & Optometry. Yu got involved in the cooperation between Pacific University and Wenzhou Medical College, as a teaching fellow in PUCO, after completion of two-year residency of primary eye care in Department of Ophthalmology, Xinhua Hospital, SSMU. Yu will go on with practice in Optometry & Ophthalmology in China, when accomplishing the research project in visual perception area as the graduation thesis of Master degree of Science in PUCO.
Abstract

The Taylor Reading Plus program is an eye movement training software which comprises of Core Programs such as PAVE (Perceptual Accuracy/Visual Efficiency) and Guided Reading.

In this study, the Reading Plus program was used to determine if home-based computerized eye movements training could improve occulomotor skills during reading. The occulomotor skills and reading rate (with comprehension) of 70 subjects were measured during reading using the Visagraph II. The Visagraph II provided data on reading rate, fixation, regression, and other variables for each paragraph read. Thirty of the initial 70 subjects who originally agreed to participate in this study were designated as “controls” and would receive no intervention, other than assessment. Forty subjects were designated as “experimental subjects” and would participate in ten-weeks of web based on-line PAVE and Guided Reading computerized eye movement training.

Only five of the original 40 experimental subjects completed the voluntary training regimen (for a variety of reasons, described in the “discussion section” of this paper). Results from the five subjects who completed the
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Data from the five subjects is highly suggestive that PAVE and Guided Reading programs may be effective in improving oculomotor and reading skills for non-reading disabled adult readers.
Acknowledgement

We would like to thank everyone who made our thesis possible. A special thank you to our advisor Dr. Hannu Laukkanen for his guidance and support since the beginning of our project. From the planning and consulting to the last minute finishing tasks, he was there. It was great to work with and have input from a clinician so well respected in his field.

We would also like to thank all subjects involved with this study, and especially Taylor Associates. This study was made possible only through the kind support of Taylor Associates who made the PAVE and Guided Reading software programs available to our subjects on-line at no cost. We also want to specifically thank Joel Terra, of Taylor Associates for all the technical support that he provided us.
Introduction

Reading is one of the most intricate processes that children and adults alike must master as it is the basic requirement for understanding all written language. Reading difficulties may be caused by a number of problems and for many years the eye movement research community tended to be divided into two camps. The majority believed that phonological factors cause reading disorders and argued that there must be "no visual deficit" in it. However, other researchers argued that visual factors must have contributed to reading disorders. It is known that dyslexic readers tend to have eye movements with longer fixation duration, shorter saccadic length, and greater number of regressions than normal readers (15). These characteristic eye movements of dyslexic readers appear similar to those of normal readers when they attempt to read a relatively difficult text. The question is whether dyslexia is the result or the cause of faulty eye movements. There is a surprisingly small proportion of research focusing on recording and analyzing eye movements of disabled readers or in assessing the results of programs designed to improve eye movements. One of those, Gilbert discovered that the ability to direct eye movements when scanning digits (number) was substantially related to oculomotor
performance in reading words for the best and the worst readers but not predictive for the average readers. Furthermore, he felt that poor oculomotor coordination is a handicap in learning to read well. This was disputed by Tinker, who felt that Gilbert had not measured this coordination satisfactorily (16). Olson reported that the eye movement patterns of the reading-disabled were erratic, showed excessive regressions, and had great irregularity in saccade lengths and fixation durations (17). Yet at the present time, most prominent eye movement researchers are convinced that reading disability is not caused by poor eye movements and instead believe the reverse to be true. Studies cited as evidence of this indicate: a dyslexic’s eye movements are normal with test that is appropriate for reading ability rather than age; dyslexics demonstrate normal eye movements when non-linguistic stimuli are used; and reading does not improve when eye movements are trained. Most of the “dyslexia cause poor eye movement” authors cite a review by Tinker, who believed eye movements to be exclusively subservient to central perceptual process, reflecting the case or difficulty of reading, along with the degree of comprehension, rather than a cause of good or poor reading (16). Conversely, several investigators steadfastly maintain that poor eye
movement ability can contribute to or cause a reading disorder. These researchers recorded eye movements binocularly, whereas those who feel that eye movements do not contribute to reading difficulties recorded only from one eye. Evidence for the viewpoint that erratic eye movements are a significant contributor to dyslexia is very cogently provided by Pavlidis (18), who demonstrated that dyslexics have worse oculomotor control than matched normal readers on eye movement tasks that are free of language, psycho-educational and intelligence factors. Moreover, a fair number of studies have been published that show a correlation between poor oculomotor skills and reading along with other studies reporting reading improvement following training. In contrast, there are ample studies showing no differences in eye movements between reading-disabled and normal achieving readers. Even so, the volume of studies and case reports indicating a reading-eye movement relationship with a subset of the reading-disabled population cannot be dismissed—except in instances of extreme philosophical bias.

According to Solan’s investigation of eye movement and comprehension therapy in the students with reading disabilities (19), the results support the notion of a cognitive link among visual attention, oculomotor readiness,
and reading comprehension. Eye movement therapy improved eye movements and also resulted in significant gains in reading comprehension. The investigator concluded that the prevalence of oculomotor abnormalities in nonreading tasks suggested that the underlying deficit in the control of eye movements observed in dyslexia is not caused solely by language problems. The data presented by Rayner (1995) lend strong support for the complementary nature of ongoing comprehension processing and the effort of lexical/cognitive development on eye movement and the effect of eye movement efficiency (oculomotor readiness) therapy on the process of reading. Persistent criticism of optometric vision therapy is that the outcomes are subjective, not quantified, and is a product of the patient wanted to “please” the therapist (20). Enhanced eye movement performance is a very common outcome of therapy, yet only recently have accurate, computerized and reliable means for quantification become widespread within the optometric community. On an individual level, eye movement recordings offer a window into the fascinating perceptual and mental processes that underlie the very complex process we call reading. According to Okumura in his study of “Oculomotor Control During Reading Improved by Vision Therapy”, Okumura investigated whether
Vision Therapy and home-based computerized eye movement training can improve oculomotor skills during reading. Eighteen Japanese-speaking college students served as subjects and were divided into three groups; Vision Therapy (VT) group, Computerized Eye Movement (CEMT) group, and control group. Subjects in VT group received full-scope VT including computerized eye movement training, subjects in CEMT group received no VT but five weeks of home-based computerized eye movement training and subjects in control group received no training at all. In his study, Okumura created a software program in Japanese language that was similar to the PAVE program that Solan used. This program required participants to count the appearances of a particular digit or letter while following a left-to-right sequential presentation of three equally spaced characters per line on the screen, starting at 40 lines per minutes and ultimately reaching 120 lines per minute. Based on this study, Okumura has found significant improvement in oculomotor control skills during reading in both VT group and CEMT group with the Japanese college students. Our study is an extension of Okumura’s study to investigate whether on-line computer training with adults specifically the optometry students can be effective in improving eye movements during reading as measured by Visagraph II. In
our study, we used the Taylor Reading Plus software as an on-line eye movement training for our subjects. Reading Plus is composed of: “Appraisals” to place students at appropriate reading levels in centrally managed Core programs such as PAVE and Guided Reading. Appraisal programs consist of the Visagraph II System and the Reading Placement Appraisal (RPA). The Visagraph II (see Figure 1 & 2) is an eye-movement recording system that measures the reading eye movement efficiency. It has been described by Taylor Associates as measuring the “Fundamental Reading Process” of subjects (visual/functional proficiency, perceptual development and information processing competence) in approximately 5-7 minutes. The Visagraph II can be used to assess reading efficiency, prescribe and evaluate corrective instruction in the form of visual perception and reading fluency development and detect visual/functional difficulties. A subject puts on goggles containing infrared emitters and sensors. Then an “easy to read” selection is read silently and aloud. During the reading/recording, the Visagraph II samples eye-movement position 60 times per second and automatically computes and analyzes various reading performance measures.

Reading Placement Appraisal (RPA) is a 3-part computerized reading
appraisal that determines the most appropriate level of reading instructional content and automatically places subjects appropriately in Taylor Reading Plus programs. RPA can be completed by a subject in 20-30 minutes, and the result of each subject’s performance, available in either display or printout form, indicates a subject’s independent reading level, usual reading rate(s), comprehension, vocabulary study level, perceptual memory readiness and decoding competence. The Core programs consist of PAVE and Guided Reading. PAVE is a Perceptual Accuracy/Visual Efficiency Training program reportedly develops the most basic skills essential to fluent silent reading and all learning and vocational needs. According to Taylor Associates, PAVE develops (through scanning and flash activities): attention/concentration, improved visual skills, effective directional attack, rapid, accurate and orderly seeing, and a strong visual memory. Similarly, Taylor Associates describe Guided Reading as developing fluency (efficiency) in the most basic reading processes (visual/functional, perceptual and information processing) resulting in ease and comfort, adequate reading rates and improved comprehension. Timed and left-to-right scanned reading improves the subliminal reading capabilities that comprise the fundamental reading process and increases the potential for
flexibility in reading.

* The Reading Plus program is available from Taylor Associates, 200-2 East 2nd street, Huntington Station, New York 11746 (phone: 1-800-732-3758)
Figure 1. Visagraph II

Figure 2. Example output page printed by Visagraph II system.
<table>
<thead>
<tr>
<th>Name and abbreviation</th>
<th>Measurement or calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixations (FIX)</td>
<td>Number of eye pauses per 100 words read.</td>
</tr>
<tr>
<td>Regressions (REG)</td>
<td>Number of significant right-to-left eye movements (excluding return sweeps) per 100 words read.</td>
</tr>
<tr>
<td>Span of recognition (SPAN)</td>
<td>Number of words read divided by the number of fixations made.</td>
</tr>
<tr>
<td>Duration of fixation (DUR)</td>
<td>Total reading time (in seconds) divided by number of fixations made.</td>
</tr>
<tr>
<td>Reading rate with comprehension (RATE)</td>
<td>Reading rate (in words per minute) determined for all lines in the paragraph, excluding the first and last.</td>
</tr>
<tr>
<td>Grade level efficiency (GRADE)</td>
<td>An equivalent academic grade (reading from 1 to 18) determined by converting the recorded data to a grade level equivalent using norms provided by Taylor. This is a nonlinear conversion</td>
</tr>
</tbody>
</table>


Previous researchers have demonstrated that improvement in eye movements, oculomotor skills and reading comprehension can be obtained with eye movement therapy. In particular, Solan in his study of elementary school children with reading disabilities (RD) has found that eye movement therapy such as PAVE and Guided Reading improved eye movements and resulted in significant gains in reading comprehension as measured by Visagraph II.

Okumura in his study with the Japanese foreign college students, also found significant improved eye movements and oculomotor skills with vision therapy and a home-based computerized eye movement training program, similar to PAVE and Guided Reading that Solan used.

Optometric vision therapy for oculomotor and eye movement dysfunction most often involves a regimen of treatments consisting of individualized planned activities in a professional setting with guided supervision. These treatments may involve procedures that utilize highly complex instrumentation or may be relatively simple, and most often given once or twice a week for an average of three to six months. They may also be more costly and inconvenience. Therefore, this study is also aimed at providing a more convenience method of on-line computerized eye movement training where subjects can do the training at any time at their convenience and as
often as they desired to improve their eye movement and oculomotor skills and ultimately improve their level of visual functioning.

In our study, we were especially interested in quantifying the reading characteristics of a specific population of optometry students who are non-reading disabled adults or "developmentally mature" readers and eye movers to determine whether the on-line computerized eye movement therapy can be effective in improving their reading eye movements and oculomotor skills. Answers to the following questions were sought:

1. Can the on-line computerized eye movement training with PAVE and Guided Reading be effective in improving reading eye movements and oculomotor skills with non-reading disabled adult readers? (Compared to elementary school disabled readers in Solan's study and Japanese foreign college students in Okumura's study).

2. If improvements were seen in adults following PAVE and Guided Reading on-line training, which of the reading characteristics (fixations, regressions, span of recognition, duration of fixations, and rate with comprehension) would change after ten weeks of training as measured by the Visagraph II?
There are many factors, which have not yet been clarified in terms of the correlation between eye movement skills and reading comprehension. We hope this study can be the first step toward the clarification.
Subjects

Thirty optometric students between the ages of 23 and 38 and 10 non-optometric students served as subjects for our study: 26 were males (mean age, 26.0 years; SD, 6.0) and 14 were females (mean age, 22.0 years; SD, 1.9). All of them denied ever been diagnosed as reading disabled or dyslexic, and all read at a level sufficient to have completed college in the U.S. Each subject demonstrated at least 20/30 near Snellen equivalent at 40 cm (with correction if required) and gave informed consent for participation in this project.
Methods

This study was designed to compare 2 groups of subjects, a computerized eye movement training (CEMT) group and a matched control group. Subjects in the CEMT group were to receive 10 weeks of on-line, web based computerized eye movement training designed to enhance reading and eye movement skills. Subjects in the control group were to receive no comparable training or intervention, only diagnostic evaluations at two predetermined time intervals.

All subjects in the CEMT group were examined for oculomotor skills during reading with the Visagraph II both before and after training. All subjects in the control group were to be examined with the Visagraph II twice, the second measurement eight weeks or more weeks after the first measurement. Data from both the CEMT and the control groups were to be analyzed for any changes in the following factors: fixations, regressions, span of recognition, duration of fixation, reading rate with comprehension, and reading comprehension (correct answers to the ten comprehension questions following the eye movement recording).

All subjects in CEMT group had a Visagraph II recorded as a baseline measure prior starting on the Reading Plus training program. After an
orientation to the Taylor Visagraph II system, each subject was comfortably seated and asked to hold the Taylor text 40 cm from the eyes at an angle of approximately 30 degrees down from vertical.

Goggles were placed over the subject's near correction (when indicated) and adjusted for interpupillary distance by centering the pupils through the apertures as the subject viewed a near target (see Figure 4).

Instructions to each subject followed the protocol listed in the Visagraph II Manual, and Taylor Paragraph Booklet. Each of the subjects read three 100-word, Level 10 (college level) selections from the Visagraph II reading selection book. Since most of our subjects were optometry students and familiar with the "Braille" story, this particular story was excluded from the story selections that were administered to the optometry student subjects. After reading each story, the subjects answered ten comprehension questions related to that story from memory. If fewer than six questions were answered correctly in any selection, an additional trial was administered. The first "trial" reading selection, was necessary to validate the reading level as well as to familiarize the subjects with the feel of the goggles. The "trial" story was read either silently or aloud but always excluded from any data analysis. Subjects were directed to read the second selection silently but to
read the third paragraph aloud. Eye movement recordings from the last two readings were collected and analyzed.

The training procedures used in this study follow those as described in the Reading Plus user's manual.

After an orientation to the Taylor Reading Plus system, subjects then were allowed to log on to the Reading Plus website. The subjects first completed a Reading Placement Appraisal (RPA). RPA results served to determine the need for a reading improvement program and as an effective means to place subjects in an appropriate reading improvement course of study. The RPA consists of three parts:

Part I – Content Level/Rate Determination

Part II - Comprehension Level

Part III - Vocabulary Level

A detailed descriptions of RPA’s Part I, II, and III, PAVE, and Guided Reading are described in Appendix A.

Following the 10-week training program, subjective performance questionnaires (via phone) were administered to determine the perceived benefits of the on-line training specifically reading rate improvement, rate of comprehension improvement, ease of reading, and reading efficiency after
ten weeks of training. Each of the subjects was asked to rank on a five-point scale any subjective changes noted in reading. The five-point scale ranged from (1=Strongly Agree, 2=Agree, 3=Neutral, 4=Disagree, 5=Strongly Disagree). For reason of curiosity sake we included whether the subjects aware of any improvement in the following: fixations, regressions, span of recognition, duration of fixation, rate with comprehension and correct answers (see Table 4).
Figure 3. Methods Flow Diagram

CEMT Group

Visagraph II Assessment in Oculomotor Control Skills During Reading and Reading Rate with Comprehension

Control Group

Daily home-based computerized eye movement training for 10 weeks

Visagraph Assessment in Oculomotor Control Skills During Reading and Reading Rate with Comprehension
Figure 4. Subject wearing Visagraph goggles reading Taylor paragraph
Results

Originally, 40 subjects agreed to participate in this study. Each subject was asked to systematically log on-line (a minimum of 40 times over ten weeks) and complete the PAVE and Guided Reading programs. In addition, each subject was asked to complete pre & post training Visagraph II assessments. Although forty subjects completed the pre-training Visagraph II measurements and agreed to do the training; unfortunately, only five subjects followed through and completed the PAVE and Guided Reading training.

The original intent of this study was to statistically compare pre & post reading eye movements data of subjects who participated in the training versus matched control subjects. Meaningful statistical analysis with a sample size of only five is not realistic, therefore the results from those five subjects is presented qualitatively as follows.

Listed below is a short descriptive profile for each subject, followed by: Table 1, reading eye movement normative data expected for college level subjects (Taylor Reading Eye Movement Norm) and mean pre & post Visagraph II values from the five subjects; Table 2, individual subject Visagraph II pre & post training data (for subject 3, the pre & post values of
the first reading selection were taken rather than the second due to some inconsistent errors of the Visagraph II measurements); Table 3, percentage change in Visagraph II data; Table 4, subjective questionnaire results; Figure 5, frequency distribution graphs for the data in this study illustrating Visagraph II results.

Subject 1: 24 year old Asian-American female. She is currently a third year optometry student at Pacific University College of Optometry (PUCO). She denied having dyslexia or ever being diagnosed as reading disabled and showed a 20/20 visual acuity at near (40cm) Snellen equivalent.

Subject 2: 25 year old Caucasian male. He is currently a fourth year optometry student at PUCO. He denied having dyslexia or ever being diagnosed as reading disabled and showed a 20/20 visual acuity at near (40cm) Snellen equivalent.

Subject 3: 30 year old Caucasian male. He is currently a fourth year optometry student at PUCO. He denied having dyslexia or ever being diagnosed as reading disabled and showed a 20/20 visual acuity at near (40cm) Snellen equivalent.

Subject 4: 26 year old African-American male. He is currently a fourth year optometry student at PUCO. He denied having dyslexia or ever being
diagnosed as reading disabled and showed a 20/20 visual acuity at near (40cm) Snellen equivalent.

Subject 5: 35 year old Asian female. She is currently a fourth year optometry student at PUCO. She denied having dyslexia or ever being diagnosed as reading disabled and showed a 20/20 visual acuity at near (40cm) Snellen equivalent.

Objective results were collected and compared between the first measurement before the ten weeks of on-line training and the second measurements after ten weeks of on-line training.

Marked improvement was suggested by our data for all reading characteristic categories: fixations, regressions, span of recognition, duration of fixations, and rate with comprehension. An exception was reading comprehension, or the number of correct answers following each reading selection. When comparing the number of correct answers, three out of five subjects did not improve at all; one subject improved 39.3%, and the other improved 11.1%, respectively. Regressions improved the most across the five subjects while duration of fixations improved the least across the five subjects.

Subjective performance questionnaires (via phone) were administered to determine the perceived benefits of the on-line training after ten weeks of
on-line training. Each of the five subjects was asked to rank on a five-point scale, any subjective changes noted in reading. Responses ranged from “strongly agreed” to “strongly disagreed”. Categories included: fixations, regressions and reading rate with comprehension. Three of the subjects disagreed that the on-line training improved in their duration of fixations. The subjects overall were neutral in reporting any improvement with their ability in span of recognition and correct answers for comprehensive questions.
Table 1. Taylor National Norms\textsuperscript{18} and the Mean scores in this study of the five subjects Pre & Post Training

<table>
<thead>
<tr>
<th>Reading Level Demand</th>
<th>Taylor National Norms\textsuperscript{18}</th>
<th>Mean Scores Pre-Training</th>
<th>Mean Scores Post-Training</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixations/100 words</td>
<td>90</td>
<td>101.4</td>
<td>90.2</td>
</tr>
<tr>
<td>Regressions/100 words</td>
<td>15</td>
<td>11.2</td>
<td>6.0</td>
</tr>
<tr>
<td>Span of recognition</td>
<td>1.11</td>
<td>1.076</td>
<td>1.172</td>
</tr>
<tr>
<td>Duration of fixation</td>
<td>0.24</td>
<td>0.288</td>
<td>0.248</td>
</tr>
<tr>
<td>Rate with comprehension (words/min)</td>
<td>280</td>
<td>231.6</td>
<td>283</td>
</tr>
</tbody>
</table>

Table 2. Results of eye movement data Pre and Post ten weeks of on-line training as measured by the Visagraph II

Raw scores

<table>
<thead>
<tr>
<th></th>
<th>Subject 1</th>
<th>Subject 2</th>
<th>Subject 3</th>
<th>Subject 4</th>
<th>Subject 5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
</tr>
<tr>
<td>FIX Left</td>
<td>140</td>
<td>116</td>
<td>98</td>
<td>94</td>
<td>65</td>
</tr>
<tr>
<td>FIX Right</td>
<td>142</td>
<td>115</td>
<td>97</td>
<td>94</td>
<td>65</td>
</tr>
<tr>
<td>REG Left</td>
<td>12</td>
<td>12</td>
<td>17</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>REG Right</td>
<td>17</td>
<td>12</td>
<td>16</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>SPAN Left</td>
<td>0.71</td>
<td>0.86</td>
<td>0.7</td>
<td>1.06</td>
<td>1.54</td>
</tr>
<tr>
<td>SPAN Right</td>
<td>0.70</td>
<td>0.87</td>
<td>0.98</td>
<td>1.06</td>
<td>1.54</td>
</tr>
<tr>
<td>DUR Left</td>
<td>0.28</td>
<td>0.27</td>
<td>0.25</td>
<td>0.22</td>
<td>0.40</td>
</tr>
<tr>
<td>DUR Right</td>
<td>0.27</td>
<td>0.26</td>
<td>0.25</td>
<td>0.22</td>
<td>0.40</td>
</tr>
<tr>
<td>RATE</td>
<td>151</td>
<td>180</td>
<td>246</td>
<td>283</td>
<td>228</td>
</tr>
<tr>
<td>GRADE</td>
<td>4.1</td>
<td>6.9</td>
<td>8.3</td>
<td>13.1</td>
<td>13.5</td>
</tr>
</tbody>
</table>

31
Table 3. Percentage of improvement of the five subjects after ten weeks of on-line training

<table>
<thead>
<tr>
<th></th>
<th>Subject 1</th>
<th>Subject 2</th>
<th>Subject 3</th>
<th>Subject 4</th>
<th>Subject 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIXATION</td>
<td>17.1%</td>
<td>4.08%</td>
<td>3.07%</td>
<td>18.65%</td>
<td>11.5%</td>
</tr>
<tr>
<td>REGRESSION</td>
<td>29.4%</td>
<td>62.5%</td>
<td>40%</td>
<td>47.05%</td>
<td>80%</td>
</tr>
<tr>
<td>SPAN OF RECOGNITION</td>
<td>21.13%</td>
<td>51.43%</td>
<td>1.3%</td>
<td>22.66%</td>
<td>13.28%</td>
</tr>
<tr>
<td>DURATION OF FIXATION</td>
<td>3.57%</td>
<td>12%</td>
<td>32.5%</td>
<td>3.22%</td>
<td>4.76%</td>
</tr>
<tr>
<td>RATE WITH COMPREHENSION</td>
<td>19.2%</td>
<td>15.04%</td>
<td>49.56%</td>
<td>17.36%</td>
<td>25.3%</td>
</tr>
<tr>
<td>CORRECT ANSWERS</td>
<td>39.3%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>11.1%</td>
</tr>
</tbody>
</table>

Table 4. Subjective questionnaire results of the five subjects on the improvement after ten weeks of on-line training

<table>
<thead>
<tr>
<th></th>
<th>Subject 1</th>
<th>Subject 2</th>
<th>Subject 3</th>
<th>Subject 4</th>
<th>Subject 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIXATION</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>REGRESSION</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>SPAN OF RECOGNITION</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>DURATION OF FIXATION</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>RATE WITH COMPREHENSION</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>CORRECT ANSWERS</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

1=Strongly Agree; 2=Agree; 3=Neutral; 4=Disagree; 5=Strongly Disagree;
Figure 5. Frequency distribution graphs for the data in this study illustrating Visagraph II results (the number of fixations, regressions, span of recognition, duration of fixation, and rate with comprehension.

The Number of Fixation-Left (Fixations/100words)

The Number of Fixation-Right (Fixations/100words)

Regression-Left (Regression/100words)
Regression-Right (Regression/100words)

Span of Recognition-Left (words)

Span of Recognition-Right (words)
Discussion

Previous research conducted in both clinical and laboratory settings suggested that eye movements therapy resulted in improved eye movements and oculomotor skills (19). This current pilot study was designed to investigate the potential effects of on-line training with PAVE and Guided Reading upon reading eye movements skills and oculomotor performance with non-reading disabled adult readers; specifically a group of optometry students. Previously, Solan has reported significant improvements in these areas with elementary school children using these computer programs (19). Okumura reported similar reading eye movements improvements with a group of Japanese college students using a program very similar to the one used by Solan (21).

This study was designed to explore whether developmentally mature eye movers and readers (optometry students) would also demonstrate this “improvement effect”. Another key difference of this study to the previously mentioned two, is that for each training computer session, each subject was required to log on the web and/or to download the appropriate PAVE and Guided Reading programs to his/her personal computer from the Taylor Associates website.
Subjects in this study were given scheduling recommendation guidelines, and general information on how to complete their individual training; however, they were free to log on whenever it was convenient for them to do so and complete their training sessions.

Reading is one of the most intricate processes that require extremely high visual demands. It entails recognition, decoding, and phonological and syntactic awareness of hundreds of wiggly and straight lines we called printed words. An integral component of reading is moving one’s eyes across the page of text. Based on the results of previous studies we hypothesized that on-line eye movement therapy with PAVE and Guided Reading could improve eye movements and oculomotor skills of non-reading disabled adult readers.

Intuitively, with mature readers, and presumably skilled eye movers such as optometry students, one would not expect a great deal of improvement because these subjects would be near the “normative developmental plateau” for visual skills where only marginal improvement are seen with further increases in college grade level and age. Interestingly, even given the limited number of participants, we were surprised by how suggestive our results were of eye movement improvement (as a result of the on-line training). Fixations, regressions, span of recognition, duration of fixations,
reading rate with comprehension, and overall reading efficiency, were very suggestive of an "improvement effect". An "improvement effect" was also suggested by the responses to a subjective questionnaire related to "noticeable effects" following the on-line training. All five subjects felt there were some significant improvements in one or more parameters of their eye movements or oculomotor skills following the training.

Obviously, the small number of subjects in this study precludes meaningful statistical analysis. This was the most serious and frustrating limitation of this pilot study. However, while the number of participants in this study was limited, the striking objective and subjective results beg further investigation. This study should first be expanded to include a larger number of non-reading disabled adults readers to permit meaningful statistical analysis of whether the "improvement effect" suggested in this preliminary investigation of only optometry students, is in fact repeatable. In addition to a larger sample, follow up should include more random sampling of non-disabled adult readers. Ideally, future studies would include a sample population that more closely mirrors the actual demographics of adult readers in the U.S. If reading eye movement improvement is possible with developmentally mature eye movers via PAVE and Guided Reading programs with non-reading disabled adults, then
logically its use with poor adult readers and reading disabled adults should investigated as well.

Future research should investigate the potential variations in eye movement behaviors for different reading conditions—for example, when one reads aloud versus when reads silently. According to Okumara (21) in his study with the Japanese college students, he has found that when subjects read aloud their eye movement characteristics: (fixations, regressions, span of recognition and duration of fixations) tended to show less improvement than when those same subjects read silently. However, their reading rate with comprehension, plus comprehension itself (the number of correct answers following each reading passage) was better when read aloud, rather than when they read silently.

Unfortunately, the applicability of any findings generated from this investigation is severely limited by the modest size of the sample group who completed the requisite training. Why did so few subjects who agreed at the beginning of this study to do the training, not follow through? We have conjectured several reasons but ultimately, the meager incentives we offered for participation were insufficient to generate the enthusiasm necessary for follow through; hence the small size of our experimental group. We feel the inadequate level of subject participation may have been directly related to
the limited resources we had available for conducting this project. When recruiting potential subjects at the outset, the only incentive we could offer busy optometry students was the intangible promise of potentially better intrinsic eye movements and reading skills in exchange for 40 sessions (10 weeks) of training time.

Another flaw in our recruitment plan was trying to attract third-year optometry student during the spring semester. During spring semester, most third-year P.U.C.O. students are very busy finishing the classroom requirements of their last didactic year in professional school, plus senior thesis projects. In addition, third-year students are also preparing to move onto different preceptorship sites around the country. At a large number of these remote preceptorship sites, there is no internet access, so precepting students are unable log onto the Taylor Associates web site and complete the on-line training. In retrospect, if we were to repeat this study, we would offer better incentives for participation, alter our recruiting strategy, and chose subjects whose on-line training could be more easily, carefully, and effectively be monitored.

Based upon the trends evident in this pilot study, we believe that web based, on-line, PAVE and Guided Reading therapy programs show great promise for improving eye movement and reading skills with adults motivated to
complete the recommended training. Additional and more comprehensive studies are strongly recommended to confirm or disprove this premise.
References


21. Tomohito Okurama. Use of Taylor Visagraph II to Evaluate Eye Movements During Reading of Japanese Text

22. Tomohito Okurama. Oculomotor Control During Reading Improved by Vision Therapy.
APPENDIX A: Specific Methodology for RPA, PAVE and Guided Reading

Subjects began with Part I, reading at grade level or one level below his/her reading level. A maximum of seven 100-word reading selections were presented. The level and number of selections varied based on the accuracy of each subject’s comprehension. Five literal comprehension questions followed the reading of each selection. Subjects next proceeded to Part II – A 300-word selection that was read at one level below the subject’s independent reading level (based on Part I). Ten questions were then completed follow the reading selection. Subjects’ performance on Part II would confirm the independent reading level indicated by Part I, or suggest a lower independent reading level, or call forth a second 300-word selection at an even lower level (two levels down from the initial part II selection to gain additional information about the most appropriate independent reading level which is termed “Assigned Reading level”. A subject’s final “Assigned Reading Level” was determined after the completion of part II. Each subject then proceeded to Part III – Vocabulary Level. Starting at a subject’s “Assigned Reading Level” of Part I, each subject completed from twenty to sixty items starting with vocabulary items from his/her
independent reading level. The subject continued until four errors were made on a given vocabulary level. The outcome is the suggested vocabulary study level. Pressing “quit” after RPA allowed the subjects to exit from the RPA program.

Next, the subject was allowed to enter the PAVE (Perceptual Accuracy/Visual Efficiency) program. Once entered, the subject was immediately offered “Scan and Flash” pretests followed by training.

Scan (Visual Efficiency) Training – Prior to each exercise a target (number, uppercase or lowercase letter) was assigned. Next, three random numbers or letters per line were presented in left-to-right drills at predetermined rates. Each time the target appeared, the subject was instructed to press the “spacebar”, which resulted in a reinforcing color or type change for each correct response. In addition, each subject was required to track and silently count the number of target appearances and later entered that count. Following each exercise, the accuracy of a subject’s count would determine the scanning rate for the next exercise. If the count was correct, the scanning rate would increase by 10 letters per minute (lpm). If the count was incorrect, the scan rate dropped 5 lpm. After the scan test, randomly assigned numbers, and uppercase and lowercase letters presented at increasingly higher rates.
Flash (Perceptual Accuracy) Training – Once selected by the subject, the first step in Flash training was a test to determine the optimum number of elements that could be flashed during the first Flash training session that would follow. Each lesson consists of ten Flash exposures of numbers/letters to see, remember, and type. The lesson was not recorded unless all ten exposures were completed. Subjects could choose numbers or letters for Flash training by clicking on the appropriate button. A set of one to nine numbers would flash for 1/10th of a second. When three or fewer elements were flashed, a set of three foils was displayed to assist the subject in remembering what had just been seen. Subjects responded by typing in the blank box. Typing errors could be corrected by using the “backspace”. The final screen for the exercise displayed the results. The subject could click the Go On button to do another Flash exercise, or click the “Scan” button to begin Scan training. A subject was permitted two errors out of each series of 10 flashes to advance to one more element. A subject could engage in as many Flash lessons as he/she chose. Usually however, only one lesson of ten exposures was undertaken during each PAVE training session. One Flash lesson typically lasted from four-to-five minutes depending upon the rapidity of the subject’s responses. Pressing “Quit”
would allow a subject to exit from the PAVE program, concluding the training session.

Next, the subject entered into the Guided Reading program. Each Guided Reading program consists of the following sections:

1. Lesson Selection
2. Keywords
3. Preview the Story
4. About the Story
5. Part A
6. Part B
7. Questions
8. Progress Report

1. Lesson Selection – Subjects were given the opportunity to choose a story from a list of stories contained within the level. Subjects could select stories in any order, however, we recommended that subjects progress chronologically through the stories because the content within each story on a given level got progressively more difficult as the lesson progressed. Stories that the subject had completed were marked with an "X". Subjects could complete a lesson already completed by selecting it, which would allow repetition of the lesson again.
2. Keywords – After making a lesson selection, the subject would be presented with the keyword activity. A series of words that were critical to the lesson were flashed to the subject after which the subject was asked to type in the word. These words had been determined to be high frequency words that were most appropriate for his/her content level. The subject was given the opportunity to make two mistakes before the word was filled in automatically.

3. Preview the Story – This section provided a brief overview of the selected story before the subject began a timed reading of the story. One multiple-choice question and then several True/False questions would follow.

4. About the Story – Certain stories contained “About the Stories” presentations that helped clarify proper names that would be included in the story.

5. Part A – Free reading (non-timed) 3-4 minutes. Each lesson contained a story that was broken into two sections Part A and Part B. Part A presented the story in a line-by-line build up format in order to allow the subject an independent reading experience that was measured. Prior to a rate track assignment, the rate at which Part A was presented depended upon the subject’s assigned reading level. After the subject had been assigned a rate track, Part A was presented at a rate 30% faster than the last successful Part
B rate. (A comprehension score of 70% or higher was considered a successful lesson.)

6. Part B – Guided Reading (4-5 minutes). The second part of the lesson story was presented in a guided form that encouraged the subject to develop proper eye-movements that would increase reading effectiveness. The Part B text was displayed with a guided slot when the subject’s words per minute (wpm) rate was 299 or less. At 300 wpm to 399 wpm, subjects would be presented with a guided line instead of a masked slot. At rates of 400 wpm and higher, subjects would read line-by-line presentations. The part B rate of presentation was determined by the rate at which the subject completed Part A. Once a subject completed a lesson and scored 70% or better comprehension, the subject was placed onto a “rate track”. The rate track, in conjunction with subject performance determined the rate of presentation of Part B in subsequent lessons. Through the use of the “change rate” button, subjects were allowed to change their rate up to a value that was up 20% higher than the rate they were currently set at.

7. Questions – Ten multiple-choice comprehension questions (skills coded) followed each lesson. The subject could click the “Reread” button to review any portion of the selection relevant to the question. Also, if the subject made an incorrect response, the reread portion would appear automatically.
The question would be displayed again for the subject to make a response, but the question was counted as incorrect. The subject’s first incorrect choice was removed as an option. If a subject quit during question selection, location was book-marked, ensuring a correct return to the proper question the next time the Guided Reading program was opened.

8. Progress Report – After all the questions had been answered, a final summary was presented to the subject, which included the previous lesson completed. The rate at which the subject read Part A, Part B, and the comprehension score percentage, and the number of rereads that they initiated, were presented. The system would cue the subject with auditory alerts if it detected that the subject was having difficulty.