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Effectiveness of the E.Y.E. visual training system in enhancing visual and reading performance in a high school for the academically at-risk

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Abstract

Background: Early work by Helmholtz2 in 1909 and later by Fincham3 in 1951 led to the idea that ocular longitudinal ·chromatic aberration (LCA) creates subtle color fringes on the eye depending on where the focus is. Essentially, under-accommodation (focus behind the retina like hyperopia) will produce a red fringe while over-accommodation (focus in front of the retina like myopia) will produce a blue fringe. These chromatic effects help to stimulate the accommodative system. The E.Y.E. device is a vision therapy-training instrument created by Dr. Jacob Liberman, and presumably makes use of this principle. The E.Y.E. device consists of a plastic thirty-six inch long plastic rod with 12 alternating red and blue led lights spaced at three and three quarter inch intervals. The aim of this investigation was to use this instrument with a sample of academically at-risk high school students and to compare their performance before and after training to a similar group of control subjects who did no training.

Methods: Twenty-nine subjects were randomly selected from a high school for academically atrisk youth. Two-thirds (n=19) of the students were chosen to undergo 4-week training session using the E. Y .E. (Exercise Your Eyes) visual training system 1 while the remaining students served as a control group (n=lO). The pre and posttest tests consisted of comprehensive battery visual skills that included acuities, refractive error, binocular function; as well as eye movement, language-processing, reading ability, and comprehension. Data were analyzed to see whether or not training with the E.Y.E. device yielded significant changes in the visual characteristics tested. In addition, an extended ADD/ADHD and medication history was also gathered for each participating subject.

Results: The only statistically significant differences noted in this study for experimental subjects following intervention were: refractive error OD (p=0.0011), refractive error OS (p=0.0002), and near phoria (p=0.01). History revealed that twenty (69%) of the participants had a prior diagnosis of ADD/ADHD, and 24 (83%), were on some form of medication during the study.

Conclusions: While an earlier prospective crossover study with the E. Y. E. device demonstrated significant improvement in a number of visual categories10 , our results were not in agreement with that earlier study. We suspect that the differences between the earlier study and our results are related to differences in methodology and subject sample. We experienced a number of challenges in working with this population, and noted problems with the training compliance of our experimental subjects. Although this may have influenced our results, likely confounders in our sample included a high rate of ADD/ ADHD, dyslexia, and very poor reading skills. It is unlikely that a limited 4-week training program with the E.Y.E. instrument, designed primarily for enhancing primarily accommodative/vergence and eye movement skills, would outweigh visual information processing performance impediments resulting from the before mentioned neurological complications.

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Effectiveness of the E.Y.E. Visual Training System in Enhancing Visual and Reading Performance in a High School for the Academically At-Risk

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BIOGRAPHIES

Matthew Earhart was born in Carson City, Nevada, and completed his Bachelor of Science degree from the University of Nevada, Reno. He is currently working towards his Doctor of Optometry degree from Pacific University College of Optometry. While at Pacific, Matthew also received his Master's of Education Visual Function in Learning degree. Upon receiving his Doctor of Optometry degree, Matthew hopes to end up practicing somewhere along the West Coast, preferably in the Pacific Northwest.

Steven Sargent was born and raised in Kamas, Utah. His undergraduate studies were completed at Snow College, where he obtained his Associates of Science, and at Utah State University where he majored in biology. He Graduated from Pacific University in May of 2005 with his Doctor of Optometry degree, and bachelors' degree in visual science. He is currently at a private practice in Kamas, Utah, and enjoys a career in optometry.

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ABSTRACT

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Results: The only statistically significant differences noted in this study for experimental subjects following intervention were: refractive error OD ($p=0.0011$), refractive error OS ($p=0.0002$), and near phoria ($p=0.01$). History revealed that twenty (69%) of the participants had a prior diagnosis of ADD/ADHD, and 24 (83%), were on some form of medication during the study.

Conclusions: While an earlier prospective crossover study with the E.Y.E. device demonstrated significant improvement in a number of visual categories[10], our results were not in agreement with that earlier study. We suspect that the differences between the earlier study and our results are related to differences in methodology and subject sample. We experienced a number of challenges in working with this population, and noted problems with the training compliance of our experimental subjects. Although this may have influenced our results, likely confounders in our sample included a high rate of ADD/ADHD, dyslexia, and very poor reading skills. It is unlikely that a limited 4-week training program with the E.Y.E. instrument, designed primarily for enhancing primarily accommodative/vergence and eye movement skills, would outweigh visual information processing performance impediments resulting from the before mentioned neurological complications.

Key Words:

- E.Y.E. Visual Training System: *developed by Dr. Jacob Liberman. The E.Y.E. device consists of a plastic thirty-six inch long plastic rod with 12 alternating red and blue led lights spaced at three and three quarter inch intervals, based on longitudinal chromatic aberration theory (LCA) and its effects on the accommodation system.*
- Academically at-risk adolescents: *students who have difficulty with learning and have not been successful in a regular school environment.*[13]
- Dyslexia: *a condition characterized by difficulty with reading and spelling.*[22]
- Accommodative facility: *ability of the eye/s to focus on stimuli at various distances and in different sequences in a given period of time.*[22]
- Vergence facility: *ability of the eyes to make fusional vergence movements in a given period of time.*[22]
- Phoria: *the tendency for the two visual axes of the eyes not to be directed towards the point of fixation, in the absence of an adequate stimulus to fusion.*[22]
- Rock: *test to measure a combination of accommodative, convergent, and oculomotor facility*[22]
- Accommodative amplitude: *the maximum amount of accommodation which the eye can exert.*[22]
- Stereopsis: *awareness of the relative distances of objects from the observer, by means of binocular vision only and based on retinal disparity.*[22]
- Visual acuity: *capacity for seeing distinctly the details of an object.*[22]
- Refractive error: *the dioptric power of the ametropia (nearsighted, farsighted, astigmatism, etc.) of the eye.*[22]
- OD (oculus dexter): *Latin for right eye.*[22]
- OS (oculus sinister): *Latin for left eye.*[22]
- OU (oculus uterque): *Latin for both eyes.*[22]

TABLE OF CONTENTS

****Subsequent to this study, the E.Y.E visual training systemhas been renamed the EYEPORT****

Introduction

The aim of this investigation was to compare baseline data to post-therapy data on the visual characteristics, reading ability, and reading comprehension of a sampling (n=29) of an academically at-risk high school population. Two-thirds (n=19) of the students were randomly chosen to undergo 4-week training session using the E.Y.E. (Exercise Your Eyes) visual training system[1] while the remaining students served as a control group (n=10). All data was then scrutinized using statistical analysis to see whether or not the E.Y.E. visual training system was useful in helping to improve the visual characteristics, reading ability, and reading comprehension of the tested student population when compared to the control group.

E.Y.E. Training Device description

The E.Y.E. device consists of a plastic thirty-six inch long plastic rod with 12 alternating red and blue led lights spaced at three and three quarter inch intervals. Specific light wavelength is based on longitudinal chromatic aberration theory (LCA) and its effects on the accommodation system. The E.Y.E. device has an electronics box that controls which lights are turned on an off in specific patterns and time intervals depending on which program is selected. The program can be speed up to increase the rate at which the lights are turned on and off to make the exercises more difficult. Connected to the E.Y.E. device control box is a headset that relays auditory feedback, in the form of beeps. The beeps are used to indicate that a program is about to begin or when a program is over, also it is used for the fist few sessions, to help give an auditory stimulus when a light is turned on and for them to focus on that light.

Questions

- Would use of the E.Y.E. visual training system be effective in helping to improve the visual characteristics, reading ability, and/or reading comprehension of the tested student population when compared to the control group?
- If so, were the effective areas of improvement statistically significant and what do these results mean?
- If not, what explanations could account for the ineffectiveness of the E.Y.E. visual training system?

Background

Early work by Helmholtz[2] in 1909 and later by Fincham[3] in 1951 led to the idea that ocular longitudinal chromatic aberration (LCA) creates subtle color fringes on the eye depending on where the focus is. Subsequent studies[4-7] have gone into more depth and revealed more compelling evidence for this concept. Essentially, under-accommodation (focus behind the retina like hyperopia) will produce a red fringe while over-accommodation (focus in front of the retina like myopia) will produce a blue fringe. These chromatic effects help to stimulate the accommodative system. A few studies have reported contrary evidence,[8,9] but the preponderance of evidence seems to support the reflexive role of LCA in accommodative response.

Dr. Jacob Liberman made use of the LCA principle by developing the E.Y.E. device, a vision therapy-training instrument consisting of a plastic thirty-six inch long plastic rod with 12 alternating red and blue led lights spaced at three and three quarter inch intervals. As his biography states on his website[1], "Dr. Jacob Liberman received a Doctorate of Optometry in 1973, a Ph.D. in Vision Science in 1986, and an honorary Doctorate of Science in 1996 for his pioneering work with light and color. Early in his optometric training, Dr. Liberman began

exploring innovative approaches to vision and general health care. His search for a new model of wellness led him to the use of vision exercises and color as a way to assist his patients."

The E.Y.E. visual training system was originally tested in a pilot study using students at the Pacific University College of Optometry in 2003.[10] Following a 6-week crossover training regimen, improvements were seen in vergence and accommodative facility, reading ability, and timed stereo tasks.[10] Two ensuing studies of the recently renamed EYEPORT™ visual training system showed significant improvements in the number of hits by a Little League baseball team[11] and significant enhancement of visual memory, speed and span of perception and marksmanship of Maui Police Department police recruits.[12]

Subjects & Examiners

This investigation of the E.Y.E. visual training system was conducted by a third-year optometry student and a fourth-year optometry student, but with the assistance of other third-year and fourth-year optometry students. At least one licensed optometrist was present at all times during testing and assisted with data collection (e.g. carried out one or more of the tests). A small high school (grades 9th to 12th) for academically at-risk teenagers in the Portland, Oregon suburban area was selected as the site for this investigation of the E.Y.E. visual training system. Thomas Edison High School was established to serve the needs of academically at-risk students and promote both scholastic and "real-world success".[13,14]

Twenty-nine subjects from the student body at Thomas Edison High School (TEHS) agreed to participate in this study. As an incentive for participation, students were promised a small honorarium $75 if they were assigned to the experimental group or $25 if they were assigned to the control group). All subjects were informed that they would be given a series of tests to evaluate oculomotor function and visual performance as they relate to visual reaction

time, visual endurance and visual skills underlying optimal academic, on-the-job, and athletic performance. The only qualification mentioned for participation as control subject, was a willingness by the potential participant to commit sufficient time necessary to complete pre and post testing; whereas assignment to the experimental group required that plus 4 weeks of training with the E.Y.E. visual training system. All testing was done on-site at Thomas Edison High School, either in private rooms, offices, the faculty break-room, or in a hallway. All equipment and forms were provided by either Pacific University College of Optometry, or by the optometry student examiners. Before any testing was initiated, an informed consent document signed by both the parents and the subjects, was obtained for each participant.

Study design

Subject group assignment was determined by a TEHS school administrator. Of the 29 participants, nearly two-thirds (n=19) were assigned to the experimental group, while the remaining one-third (n=10), were designated as controls. At the beginning of the study, all participants were administered a series of evaluative tests; after which subjects assigned to the experimental group underwent 4 weeks of therapy using the E.Y.E. visual training system, consisting of 5 sessions a week (1 per weekday) for a length of less than 10 minutes each. The before-mentioned administrator monitored training compliance for the intervention group, plus students were encouraged to keep daily logs of their therapy completion. The ten subjects assigned to the control group did no eye training during the intervention period and only participated in the baseline and post-therapy testing. Following the intervention period, all subjects were once again evaluated post-therapy

Evaluative tests administered to all subjects

Subjects were tested in twelve different areas relating to vision. Four of these categories (visual acuities, refractive errors, phorias, and stereopsis) are typically used in school screenings as outlined in the Orinda Study[15]. In addition to these tests, this experiment took it a step further and tested all subjects in four supplementary vision categories (accommodative facility, vergence facility, Distance Rock, and accommodative amplitude). Finally, all subjects were administered a series of reading and comprehension tests (Informal Reading Inventory and Visagraph) as well as a test for dyslexia (Dyslexia Determination Test). In the final category subjects were asked whether or not they had Attention Deficit Disorder/Attention Deficit Hyperactivity Disorder (ADD/ADHD) and whether or not they were taking any medications.

The first test of the battery was to check visual acuities (VA) and contrast sensitivity (CS). The first method was to check the VA using Snellen letters with a Log Mar style chart using the subject's habitual distance correction (LogMar = 0.02 for each Bailey-Lovie letter). The right eye, left eye, and both eyes together were tested at 4 meters using equivalent 20/20 demands. Using the same style chart the near VA was tested with both eyes together, but not monocularly with the subject's near habitual correction on. The second method for eyesight measurement was with the Pelli-Robinson contrast sensitivity (CS) distance chart. CS was tested at 4 meters with the subject's habitual distance correction on. The right eye, left eye and both eyes together were tested at distance only.

Once VA and CS were measured, refractive error (RE) was sampled using the handheld Retinomax K-2 Plus.[16] This was a non-cycloplegic measure of RE and was assessed for both

right and left eyes without habitual glasses, but over contact lenses (if the subject wore contact lenses habitually).

Binocular posture was the third area tested. This was done using the cover test method at distance (4 meters) and near (40 cm) with the subject's habitual correction on, using appropriate accommodative demand targets.

The fourth category that was tested was depth perception. This was accomplished using the Super Selwyn stereo test[17]. The subjects wore their habitual near correction with polarized lenses in place. The first of the two 67 cm tests was intended to familiarize the subject with the test but the data was not used for analysis, while the second test was used as data for this study This test is traditionally performed at 40 cm, but by increasing the distance to 67 cm, we created an extra demand for the depth perception which allowed us to test the limits of the subjects even further in an attempt to reach their threshold. While it is true that the disparity is quantified as Disparity = (PD x d)/D^2, where PD = pupillary distance, d = depth interval, and D is the viewing distance, the value d *simulated* in the stereogram increases in proportion to viewing distance. Therefore, when we change our viewing distance from 40 cm to 67 cm, simulated d changes, and the amount of retinal disparity decreases by a factor of 1.67X. For example, by going from 40 cm to 67 cm, we increased the demand from 20" (arc seconds) to 12" (arc seconds).

The fifth category that was tested was accommodative facility[18]. This was accomplished by using +/- 2.00 D flippers at 40 cm for 1 minute binocularly, using a three column sheet. The subject was required to make sure the letters were clear before calling out the first letter of the column, and then continuing on with the next set of letters. Suppression was tested before testing using the polarized bar reader and polarized glasses with +/- 2.00 flippers in place. If the subject suppressed with either plus or minus lens the facility testing was not completed.

Suppression was also checked after accommodative testing using the same method as before facility testing.

The sixth category that was tested was vergence facility[18]. Testing was done using the three column sheet and an 8^{Δ} BI/BO flipper at 40 cm. The subject was required to call out the first letter of each set of three, but they had to make sure the letters were clear and single before calling them out. Suppression was checked before and after the test using the Polaroid bar reader with polarized lenses and the BI/BO lens in place. If the subject suppressed then the test was not administered.

The seventh test that was administered was a combination of accommodative and vergence facilities (Distance Rock Test)[19]. The first half of the test required the subject to alternate reading 20/80 letters at distance (6 meters) then at near (40 cm) then back to the distance letters and so on and so forth for 30 seconds. The second part of the test requires the subject to do the same thing as before except with a 20/25 letter demand. The Distance Rock Test is scored on the basis of the number of cycles per minute the subject is able to do, and the number of mistakes that the subject made (e.g., loss of place, wrong letter called out, etc.).

The eighth category that was tested was accommodative amplitude. This was done by using the Donder's push-up method with the subject wearing their habitual near correction (spectacles or contact lenses). This test was administered to the right eye, then left eye and then binocularly. The subject was pushed to either blur or breaking points as end points of the test.

The ninth category that was tested was reading eye movement efficiency with computerized eye monitoring techniques using the Visagraph. The reading level was established by having the subject read a paragraph and checking for number of words incorrect and amount of difficulty the subject demonstrated. Once the appropriate reading level was found, then three

separate test recordings were gathered from each subject. The first was thrown out, and the last two were kept and averaged together to establish a mean grade level and reading comprehension level.

The tenth category that was tested was to establish an approximate reading level. This was done using the Informal Reading Inventory by Burns and Roe 6th edition.[20] This test establishes a reading level via grade leveled words which the reader is required to read quickly and accurately. Once the reading level is determined, the subject is then required to read a story at this level. Each word that is missed or pronounced incorrectly counts against them. If the subject is unable to attain an expected percentage of words correct at this level, then the reading level is decreased until the proper reading level is found. The subject is then tested at the proper reading level, and then he/she is administered reading comprehension questions about the story. Subjects must achieve a minimum of 75% comprehension in order for the level to count. This establishes a reading level and reading competency useful for tracking improvement and determining the effects of improvement with intervention and is referred to as the student's "Instructional Level."

The eleventh category of assessment was decoding language processing or dyslexia. This was done using the Dyslexia Determination Test by Griffin and Walton 2nd Edition.[21]

The twelfth category included an extended history obtained from both the subjects and their school regarding their status of having a diagnosis of ADD/ADHD. Whether or not the students had ADD/ADHD, they were also asked if they were taking any form of medication used to treat the condition.

E.Y.E. Training Protocol with Intervention Group

The Exercise Your Eyes program (E.Y.E. program) consisted of 20 days of intervention with the eye device. For each session, five exercises were performed. These exercises relied upon three different programs (1,2 or 3) and different orientations of the rod of lights. The exercise program sequence ranged from 1-3, depending on the specific session. Sessions 1-6 was set on program 1 with auditory stimulus feedback. Sessions 7-12 were set on program 2 with auditory stimulus. Sessions 13-20 were set on program 3 with no auditory stimulus. Programs 1-3 differ by which colored lights are stimulated in which pattern. Each day the program is speed up by 1 level until the program is changed to the next level, when it begins anew starting with the lowest speed, and then the speed is progressively increased throughout that level. For some of the testing red and blue filter glasses are worn. The red and blue filters cancel out the specific color. For example, the red filter cancels the blue light so the blue light is not seen by the eye wearing the red filter and and vice versa. For program 1, the red/blue glasses are worn for the first five exercises but not for the last exercise. For Program 2 the red/blue glasses are worn 1 minute before the program begins but they are removed for the 5 exercises. For program 3 the red/blue glasses are not worn at all. The five exercises that are done each day (regardless which program is selected), consists of different rod orientations i.e., horizontally (x-axis), vertically (y-axis), obliquely at 135 degrees, obliquely at 45 degrees, and lastly on the z-axis (looking straight out). In between each exercise the subjects were instructed to close their eyes, relax and gently breathe. After 1 minute the E.Y.E. would give two beeps to indicate that the relaxation period was over, then provide a 10 beep count down for the next exercise to begin.

Results

Data from 29 subjects attending a high school for academically at-risk students were included in this data analysis. Tables 1, 3, 5, and 7, show the baseline data collected for the control subjects for the basic vision screening tests compared to the follow-up data collected for the control subjects once the experimental group completed their E.Y.E. visual training system sessions. The visual acuities (distance OD, OS, OU and near OU) are listed in LogMar units (0.0 = 20/20 and each individual letter is 0.02). Refractive error (OD, OS) are recorded in Diopters and distance and near phorias are also listed (negative numbers indicate exophoria). The final category is timed stereopsis using the Super Selwyn stereo test. The Super Selwyn is designed with two sets of wirt circles (ten boxes per set, three circles per box), which gradually get more difficult to see (increasing arc seconds) and a third set of random dot circles which tests global stereopsis. The subject is required to wear polarized glasses in order to determine which of the three circles in each box appears to stand out. Data is recorded for how many seconds it took each subject to complete one set of ten stereopsis boxes. Following each table, the results of an unpaired two-tailed t-test comparing the baseline to follow-up data are listed. No significant differences were noted from baseline to follow-up testing.

Tables 2, 4, 6, and 8, show the baseline data collected for the experimental subjects for the basic vision screening tests along with the follow-up data collected for the experimental subjects once they completed their E.Y.E. visual training system sessions. The visual acuities (distance OD, OS, OU and near OU) are listed in LogMar units (0.0 = 20/20 and each individual letter is 0.02). Refractive error (OD, OS) are recorded in Diopters and distance and near phorias are also listed (negative numbers indicate exophoria). The final category is timed stereopsis using the Super Selwyn stereo test. As described earlier, the Super Selwyn is designed with two

sets of doughnut circles (ten boxes per set, three circles per box), which gradually get more difficult to see (increasing arc seconds) and a third set of random dot circles which tests global stereopsis. The subject is required to wear polarized glasses in order to determine which of the three circles in each box appears to stand out. Data is recorded for how many seconds it took each subject to complete one set of ten stereopsis boxes. Following each table, the results of an unpaired two-tailed t-test comparing the baseline to follow-up data are listed. The only statistically significant differences of this study noted from baseline to follow-up testing were seen here. These categories were: refractive error OD ($p=0.0011$), refractive error OS ($p=0.0002$), and near phoria ($p=0.01$).

Tables 1 to 8. Control & experimental subjects vision screening battery @ baseline and @ follow-up:

Table 1. Controls. *baseline and follow-up*

SUBJECT	DVA-OD	DVA-OD	DVA-OS	DVA-OS	DVA-OU	DVA-OU
C1	0.1	0	0.14	0.16	0.04	0.02
C2	-0.08	-0.1	-0.1	-0.1	-0.16	-0.2
C3	-0.2	-0.12	-0.18	-0.18	-0.2	-0.18
C4	0.2	0.2	0.32	0.34	0.16	0.18
C5	-0.16	-0.06	-0.12	-0.16	-0.16	-0.16
C6	-0.08	-0.1	-0.08	0	-0.1	-0.08
C7	-0.04	-0.08	-0.04	-0.04	-0.04	-0.18
C8	0.28	0.2	-0.08	0	-0.1	0
C9	-0.22	-0.24	-0.18	-0.24	-0.22	-0.28
C10	0.06	0.16	0.22	0.06	-0.04	-0.06
MEAN	**-0.01**	**-0.01**	**-0.01**	**-0.02**	**-0.08**	**-0.09**

Table 2. Experimentals. *baseline and follow-up*

SUBJECT	DVA-OD	DVA-OD	DVA-OS	DVA-OS	DVA-OU	DVA-OU
E1	0.26	-0.16	0.32	-0.18	0.3	-0.18
E2	0.04	0	0	-0.06	-0.04	-0.06
E3	-0.2	-0.2	-0.2	-0.2	-0.18	-0.2
E4	-0.08	-0.14	-0.2	-0.18	-0.18	-0.14
E5	-0.14	0.2	0	0.1	-0.1	0.14
E6	0.64	0.54	0.6	0.56	0.48	0.36
E7	0.08	0.12	0.06	0.06	0.02	-0.06
E8	-0.04	-0.08	-0.16	-0.06	-0.08	-0.22
E9	-0.1	-0.08	-0.1	0	-0.1	-0.04
E10	0.04	0.14	0.02	0.04	0.02	0.04
E11	-0.1	-0.18	-0.06	-0.1	-0.08	-0.16
E12	0.36	0.32	0.18	0.36	0.08	0.14
E13	0.12	0.24	0.06	0.24	0.04	0.08
E14	0.14	-0.1	-0.1	-0.02	-0.1	-0.06
E15	-0.06	-0.04	-0.2	-0.22	-0.1	-0.16
E16	0.02	-0.02	-0.02	-0.04	0	-0.06
E17	-0.1	0.02	-0.26	0.12	-0.26	-0.04
E18	-0.08	-0.14	-0.08	-0.06	-0.18	-0.14
E19	-0.08	0.02	0	-0.04	-0.08	-0.06
MEAN	**0.04**	**0.02**	**-0.01**	**0.02**	**-0.03**	**-0.04**

Table 3. Controls. *baseline and follow-up*

SUBJECT	NVA-OU	NVA-OU	RE-OD (DIOPTERS)	RE-OD (DIOPTERS)	RE-OS (DIOPTERS)	RE-OS (DIOPTERS)
C	-0.26	-0.2	4.375	4.5	3.5	3.25
C	-0.3	-0.3	0.625	-0.25	0.5	0
C	-0.3	-0.3	0.5	0.25	0.75	0.375
C	-0.02	0.02	0.625	-0.5	0.625	-1.625
C	-0.3	-0.3	1.375	0.375	0.375	0.125
C	-0.3	-0.3	0	0.25	0.125	0.125
C	-0.28	-0.3	0.625	-2.75	0.875	-1.375
C	-0.26	-0.06	0	-1.25	-0.125	-1.5
C	0	-0.3	-1.125	0.75	-1.25	1
C	-0.24	-0.28	-0.875	-1.125	-0.375	-0.875
[illegible]	**-0.25**	**-0.23**	**0.613**	**0.025**	**0.500**	**-0.050**

Table 4. Experimentals. *baseline and follow-up*

SUBJECT	NVA-OU	NVA-OU	RE-OD (DIOPTERS)	RE-OD (DIOPTERS)	RE-OS (DIOPTERS)	RE-OS (DIOPTERS)
E	-0.3	-0.3	-1.375	-1.375	-1.125	-2.375
E	-0.28	-0.3	0.87	-0.375	1	-0.625
E	-0.28	-0.28	-1.125	-0.375	-1.375	-0.25
E	-0.3	-0.28	0.5	-0.75	0.375	-0.625
E	-0.22	-0.3	0.75	-1.375	0	-3
E	-0.28	-0.3	-2.375	-3.25	-2.375	-2.875
E	-0.3	-0.2	-0.625	-1.125	-0.375	-2.5
E	-0.3	-0.3	-1.125	-1.625	-1.125	-1.75
E	-0.3	-0.18	0.625	-0.5	0.125	-0.625
E	-0.3	-0.2	-0.5	-2.25	-1.125	-2
E	-0.3	-0.26	-0.125	-0.625	0.375	-0.5
E	-0.3	-0.18	-1.125	-2.625	-0.875	-2.625
E	-0.3	-0.26	-0.75	-2	-0.75	-1.75
E	-0.22	-0.3	1.25	0.125	0.625	-0.625
E	-0.3	-0.26	-1.375	-2.625	-0.5	-1.625
E	-0.26	-0.3	-0.25	-1	-0.375	-0.75
E	-0.3	-0.3	0.125	-2	0.125	-2.125
E 8	-0.26	-0.28	0.75	-0.75	0.375	-1
E	-0.26	-0.3	0.125	-1.875	-0.125	-1.75
[illegible]	**-0.28**	**-0.27**	-0.503	**-1.388**	-0.375	**-1.546**

Table 5. Controls. *baseline and follow-up*

SUBJECT	D PHORIA	D PHORIA	N PHORIA	N PHORIA
C	-6	-2	-6	-22
C	0	0	0	-12
C	0	0	-4	0
C	0	0	5	5
C	0	0	-4	-7
C	0	-6	0	-10
C	0	0	-2	0
C	0	0	0	0
C	0	0	-6	-2
C	0	-4	0	0
	-1	-1	-2	-6

(-) = exophoria, (+) = esophoria

Table 6. Experimentals. *baseline and follow-up*

SUBJECT	D PHORIA	D PHORIA	N PHORIA	N PHORIA
E	0	-2	-4	-10
E	0	0	-4	-10
E	0	0	0	0
E	0	0	0	-4
E	0	0	-6	-8
E	0	0	-2	-4
E	0	0	-8	-4
E	0	0	-2	0
E	0	-6	-4	-8
E	0	0	-2	-14
E	0	0	-2	-12
E	0	0	0	-8
E	2	-2	0	-20
E	0	0	-2	-2
E	0	0	0	0
E	0	0	0	0
E	0	0	0	0
E	0	0	-8	-8
E	0	0	0	-6
	0	-1	-3	-7

(-) = exophoria, (+) = esophoria

Table 7. Controls. *baseline and follow-up*

SUBJECT	T-STEREO1 (sec)	T-STEREO1 (sec)	T-STEREO2 (sec)	T-STEREO2 (sec)	STEREO THOLD (sec)	STEREO THOLD (sec)
	17	15	33	30	9	8
	15	11	22	9	9	10
	12	12	16	14	10	10
	29	11	0	35	4	7
	14	16	16	22	5	7
	26	24	17	15	7	6
	21	13	23	16	8	10
	10	11	17	22	8	8
	4	8	8	7	10	10
	18	10	17	14	7	10
MEAN	**17**	**13**	**19**	**18**	**8**	**9**

Table 8. Experimentals. *baseline and follow-up*

SUBJECT	T-STEREO1 (sec)	T-STEREO1 (sec)	T-STEREO2 (sec)	T-STEREO2 (sec)	STEREO THOLD (sec)	STEREO THOLD (sec)
	9	16	18	11	9	6
	13	15	28	28	9	6
	7	7	11	10	9	9
	9	X	11	22	7	2
	30	13	16	18	10	10
	9	14	17	18	7	8
	14	12	20	21	10	9
	20	20	25	20	7	7
	18	19	35	30	10	7
	12	10	13	15	9	10
	18	12	19	24	6	10
	12	12	20	25	7	8
	12	16	12	14	7	8
	15	12	16	20	8	9
	8	7	11	12	9	9
	12	15	8	13	8	6
	8	8	8	9	10	10
	16	12	20	16	9	10
	9	13	14	16	6	9
MEAN	**13**	**13**	**17**	**18**	**8**	**8**

X = for unexplained reasons, no data was available for this particular test

Tables 9, 11, and 13, list the data collected from the control subjects for the supplementary vision tests that were performed at baseline and at follow-up. Accommodative and vergence facilities are listed according to the number of cycles per minute (cpm). Distance and Near Rock numbers are also recorded as cycles per minute. Accommodative amplitude (OD, OS, OU) is recorded in centimeters (cm). Contrast sensitivity (OD, OS, OU) is recorded in LogMar units. Following each table, the results of an unpaired two-tailed t-test comparing the baseline to follow-up data are listed. No significant differences were noted from baseline to follow-up testing.

Tables 10, 12, and 14, list the data collected from the experimental subjects for the supplementary vision tests that were performed at baseline and at follow-up. Accommodative and vergence facilities are listed according to the number of cycles per minute (cpm). Distance and Near Rock numbers are also recorded as cycles per minute. Accommodative amplitude (OD, OS, OU) is recorded in centimeters (cm). Contrast sensitivity (OD, OS, OU) is recorded in LogMar units. Following each table, the results of an unpaired two-tailed t-test comparing the baseline to follow-up data are listed. No significant differences were noted from baseline to follow-up testing.

Tables 9 to 14. Control & experimental supplementary vision tests @ baseline and @ follow-up:

Table 9. Controls. *baseline and follow-up*

SUBJECT	ACC FAC	ACC FAC	VERG FAC	VERG FAC	ROCK 20/80	ROCK 20/80	ROCK 20/25	ROCK 20/25
C	10	12	15.5	13	15	11	7	5
C2	22.5	17.5	7.5	16	9	11	9	11
C3	18	13	8.5	10.5	11	11	10	9
C4	10.5	13.5	10	9.5	9	11	5	X
C5	8	8	7.5	6	15	7	13	8
C6	10	14	10	10	15	15	11	12
C7	15.5	15	12	9.5	7	11	7	7
C8	13.5	9.5	9.5	8	13	13	5	X
C9	14.5	14.5	8.5	8	15	16	12	13
C10	6	X	9.5	X	12	12	7	X
MEAN	**13**	**13**	**10**	**10**	**12**	**12**	**9**	**9**

X = for unexplained reasons, no data was available for this particular test

Table 10. Experimentals. *baseline and follow-up*

SUBJECT	ACC FAC	ACC FAC	VERG FAC	VERG FAC	ROCK 20/80	ROCK 20/80	ROCK 20/25	ROCK 20/25
E1	suppr.	13.5	suppr.	7.5	3	9	0	9
E2	suppr.	8.5	suppr.	8.5	6	9	9	9
E3	15.5	16.5	15.5	12	13	17	10	9
E4	13.5	13	9	4	15	15	11	12
E5	11	19	13.5	13	16	X	12	X
E6	14.5	suppr.	12	suppr.	0	X	0	X
E7	suppr.	suppr.	suppr.	suppr.	10	10	9	X
E8	15	suppr.	20.5	suppr.	10	13	9	11
E9	10	10.5	8.5	5.5	11	9	10	8
E10	13	12	9.5	7.5	15	12	9	7
E11	11	19.5	5.5	14	14	16	14	14
E12	17.5	17.5	14	12	9	X	0	X
E13	8.5	9.5	9	9.5	13	X	15	X
E14	16.5	17	15	12.5	12	14	10	12
E15	17	21.5	15.5	16	13	16	9	10
E16	16.5	16	10	15	14	13	11	7
E17	15	10.5	7	7.5	11	17	10	5
E18	11	6	11.5	14	16	9	10	5
E19	8.5	8	5	3	9	9	5	6
MEAN	**13**	**14**	**11**	**10**	**12**	**13**	**9**	**9**

suppr. = patient suppressed during testing and was unable to perform that particular test
X = for unexplained reasons, no data was available for this particular test

Table 11. Controls. *baseline and follow-up*

SUBJECT	A.A. OD	A.A. OD	A.A. OS	A.A. OS	A.A.OU	A.A.OU
C1	8	8	8	8	5	4
C2	7	8	7	8	6	4
C3	7	6	8	6	5	4
C4	5	5	5	5	4	4
C5	7	8	9	10	5	6
C6	11	8	11	8	9	7
C7	4	5	4	5	4	6
C8	8	6	8	10	5	6
C9	5	5	6	5	4	3
C10	4	5	4	5	3	5
MEAN	7	6	7	7	5	5

Table 12. Experimentals. *baseline and follow-up*

SUBJECT	A.A. OD	A.A. OD	A.A. OS	A.A. OS	A.A. OU	A.A. OU
E1	6	7	5	6	5	4
E2	7	4	9	4	7	3
E3	8	8	9	8	7	6
E4	9	12	9	12	6	10
E5	8	X	8	X	8	X
E6	4	3	5	3	4	3
E7	7	6	7	6	5	4
E8	5	5	8	5	5	4
E9	8	9	8	8	7	7
E10	4	6	4	6	3	4
E11	6	5	5	5	5	3
E12	4	6	4	7	4	4
E13	13	4	11	4	7	3
E14	7	4	8	4	5	3
E15	3	5	4	5	2	3
E16	5	5	5	5	3	5
E17	5	3	4	3	3	3
E18	4	7	4	6	3	6
E19	8	5	7	5	2	3
MEAN	7	6	7	6	5	4

X = for unexplained reasons, no data was available for this particular test

Table 13. Controls. baseline *and follow-up*

SUBJECT	CS-OD	CS-OS	CS-OS	CS-OS	CS-OU	CS-OU
	0.15	0.81	0.07	0.16	0.81	0.93
	1.25	1.19	1.24	1.08	1.2	1.28
	1.2	1.25	1.27	1.05	1.27	1.24
	-0.02	0.91	-0.1	0.78	0.06	1.18
	0.75	0.56	1.09	0.78	1.09	1.3
	1.03	1.15	0.99	0.89	1.2	1.27
	0.82	0.44	0.78	0.55	1.12	1.08
	-0.1	0.37	0.6	1.27	0.99	1.27
	1.19	1.22	1.17	1.17	1.29	1.23
	0.57	0.52	0.44	0.28	0.84	0.67
MEAN	**0.68**	**0.84**	**0.75**	**0.80**	**0.99**	**1.15**

Table 14. Experimentals. baseline *and follow-up*

SUBJECT	CS-OD	CS-OD	CS-OS	CS-OS	CS-OU	CS-OU
	0.02	1.06	0.49	1.14	0.79	1.24
	0.96	1.18	0.71	1.19	1.07	1.29
	1.23	1.26	1.28	1.25	1.27	1.28
	1.21	1.15	1.26	1.26	1.26	1.24
	0.94	1.09	0.7	1.02	1	1.2
	-0.01	0.67	-0.01	0.49	0.08	1.19
		1.23	0.61	1.24	0.57	1.28
	1.2	1.14	1.2	1.27	1.27	1.29
	1.19	1.06	0.99	0.97	1.19	1.1
	0.65	0.54	0.53	0.65	0.87	0.76
	1.29	1.23	0.96	1.14	1.2	1.27
	-0.1	0.29	0.03	0.27	0.09	0.83
	1.25	0.29	1.18	0.15	1.28	0.46
	0.07	0.51	0.96	1.13	1.04	1.23
	0.88	0.84	1.16	1.05	1.26	1.26
	0.9	0.77	0.94	0.8	1.16	1.04
	0.96	0.6	1.07	0.38	1.13	0.86
	1.06	0.99	0.97	0.98	1.1	1.13
	0.76	0.89	0.8	0.89	1.17	1.17
MEAN	**0.79**	**0.88**	**0.83**	**0.91**	**0.99**	**1.11**

Tables 15, 17, and 19, list the data collected from the control subjects for the reading and dyslexia tests that were performed at baseline and at follow-up. The grade level of each student in high school at the time of testing is listed first. Table 15 shows the level of reading material that the student read at for the Visagraph followed by how efficiently they read the material as indicated by their eye movements. Visagraph reading comprehension is recorded as the percentage correct. The Informal Reading Inventory (IRI) "Instructional Level" is detailed in Table 17 (see Methods for description), along with the IRI comprehension.

Finally, the grade level established by the Dyslexia Determination Test (DDT) is expressed in Table 19 and whether or not the test indicated the student to be dyslexic. The three graded categories of dyslexia are: dysphonesia (P) which is a "deficit in visual-symbol and sound integration, and the inability to develop phonetic word analysis-synthesis skills;" dyseidesia (E) which is a "deficit in the ability to perceive whole words as visual gestalts and match them with auditory gestalts;" and dysphoneidesia (PE) which is a "deficit in grapheme-phoneme integration and in the ability to perceive whole words as visual gestalts and match them with auditory gestalts (mixed dysphonetic and dyseidetic)."[17] Following each table, the results of an unpaired two-tailed t-test comparing the baseline to follow-up data are listed. No significant differences were noted from baseline to follow-up testing.

Tables 16, 18, and 20, list the data collected from the experimental subjects for the reading and dyslexia tests that were performed at baseline and at follow-up. The grade level of each student in high school at the time of testing is listed first. Table 16 shows the level of reading material that the student read at for the Visagraph followed by how efficiently they read the material as indicated by their eye movements. Visagraph reading comprehension is recorded as the percentage correct. The Informal Reading Inventory (IRI) "Instructional Level" is detailed

in Table 18 (see Methods for description), along with the IRI comprehension. Finally, the grade level established by the Dyslexia Determination Test (DDT) is expressed in Table 20 and whether or not the test indicated the student to be dyslexic. As mentioned earlier, the three graded categories of dyslexia are: dysphonesia (P), dyseidesia (E), and dysphoneidesia (PE). Following each table, the results of an unpaired two-tailed t-test comparing the baseline to follow-up data are listed. No significant differences were noted from baseline to follow-up testing.

Tables 15 to 20. Control & experimental subjects reading and dyslexia tests @ baseline and @ follow-up:

Table 15. Controls. baseline *and follow-up*

SUBJECT	TEHS GRADE PLACE-MENT	VISAGRAPH GRADE LEVEL / EYE MOV'T EFFICIENCY LEVEL	VISAGRAPH GRADE LEVEL / EYE MOV'T EFFICIENCY LEVEL	VISAGRAPH READING COMP.	VISAGRAPH READING COMP.
C1	10	7 / 1.3	7 / 4.45	100%	80%
C2	10	10 / 11.9	10 / 7.5	75%	70%
C3	10	10 / 10.95	10 / 5.4	70%	90%
C4	9	10 / 5.15	10 / 4.1	90%	95%
C5	10	10 / 5.25	10 / 3.4	80%	85%
C6	10	10 / 5.15	10 / 4.45	90%	95%
C7	9	10 / 12.55	10 / 11.95	60%*	80%
C8	11	10 / 5.95	10 / 5.05	55%*	85%
C9	10	7 / 7.45	10 / 3.95	85%	95%
C10	9	6 / 1.55	6 / 1.25	75%	95%
MEAN	10	**9 / 6.72**	**9.3 / 5.15**	**78%**	**87%**
PT=II		0.33			

Table 16. Experimentals. baseline *and follow-up*

SUBJECT	TEHS GRADE PLACE-MENT	VISAGRAPH GRADE LEVEL / EYE MOV'T EFFICIENCY LEVEL	VISAGRAPH GRADE LEVEL / EYE MOV'T EFFICIENCY LEVEL	VISAGRAPH READING COMP.	VISAGRAPH READING COMP.
E1	10	10 / 4.85	10 / 5.3	50%*	70%
E2	9	10 / 8.3	10 / 3.85	85%	80%
E3	9	10 / 12.05	10 / 11.9	85%	95%
E4	11	7 / 1	7 / 1	85%	95%
E5	10	10 / 4.7	10 / 3.15	100%	70%
E6	9	10 / 2.65	10 / 3.85	85%	90%
E7	9	10 / 12.1	10 / 5	90%	70%
E8	12	10 / 10.5	10 / 15.25	60%*	60%*
E9	12	7 / 9.3	7 / 1.55	75%	55%*
E10	12	10 / 4.75	10 / 4.65	75%	75%
E11	12	10 / 4.05	10 / 2.75	65%*	65%*
E12	11	10 / 4.75	10 / 2.55	90%	85%
E13	10	4 / 7.55	10 / 10.5	35%*	50%*
E14	9	4 / 3.75	7 / 2.6	65%*	70%
E15	11	10 / 4.15	10 / 11.2	70%	90%
E16	10	10 / 10.95	10 / 3.3	90%	95%
E17	11	10 / 1.3	10 / 1.55	95%	90%
E18	12	7 / 1	7 / 1.6	65%*	75%
E19	11	10 / 10.05	10 / 11.65	85%	80%
MEAN	11	**9 / 6.20**	**9.4 / 5.43**	**76%**	**77%**
PT=II		P = 0.33	P = 0.52		

**for unexplained reasons, Visagraph recordings were not repeated with these six subjects until the recommended 70% comprehension score was attained.*

Table 17. Controls. baseline and follow-up

SUBJECT	TEHS GRADE PLACE-MENT	IRI INSTR. LEVEL	IRI INSTR. LEVEL	IRI READING COMP	IRI READING COMP.
C1	10	5	6	80%	80%
C2	10	8	10	80%	75%
C3	10	11	11	75%	75%
C4	9	12	12	75%	75%
C5	10	12	12	75%	95%
C6	10	12	12	75%	75%
C7	9	11	12	80%	85%
C8	11	12	12	75%	75%
C9	10	12	12	75%	75%
C10	8	3	6	80%	80%
MEAN	10	10	11	77%	79%

PIT<=0 | 3.87 | 0.00

Table 18. Experimentals. baseline and follow-up

SUBJECT	TEHS GRADE PLACE-MENT	IRI INSTR. LEVEL	IRI INSTR. LEVEL	IRI READING COMP.	IRI READING COMP.
E1	10	10	10	75%	75%
E2	9	12	12	75%	80%
E3	9	12	12	85%	80%
E4	11	9	11	95%	75%
E5	10	5	10	90%	75%
E6	9	12	12	75%	80%
E7	9	11	10	75%	75%
E9	12	11	11	80%	75%
E10	12	7	6	75%	75%
E11	12	11	10	85%	80%
E12	12	11	9	75%	80%
E13	11	10	11	100%	75%
E14	10	4	10	75%	75%
E15	9	4	6	75%	75%
E16	11	12	12	75%	75%
E17	10	11	12	75%	75%
E18	11	12	6	75%	95%
E19	12	9	6	75%	80%
MEAN	11	12	12	75%	75%
	11	10	10	79%	78%

PIT<=0 | 3.87 | 0.00

Table 19. Controls. baseline and follow-up

SUBJECT	TEHS GRADE PLACE-MENT	DDT GRADE LEVEL	DDT GRADE LEVEL ▼=decrease from baseline ▲=increase ►=no change	DYSLEXIC? P, E, PE, or no	DYSLEXIC? P, E, PE, or no ▼=decline ▲=improvement ►=no change
C1	10	X	10►	E	E►
C2	10	12	10▼	no	no►
C3	10	12	10▼	no	no►
C4	9	>12	9▼	no	no►
C5	10	4	10▲	PE	PE►
C6	10	12	10▼	no	E▼
C7	9	12	9▼	no	no►
C8	11	8	11▲	PE	PE►
C9	10	12	10▼	E	no▲
C10	9	8	9▲	E	PE▼
MEAN	10	9	10	N/A	N/A

X = for unexplained reasons, no data was available for this particular test

Table 20. Experimentals. baseline and follow-up

SUBJECT	TEHS GRADE PLACE-MENT	DDT GRADE LEVEL	DDT GRADE LEVEL ▼=decrease from baseline ▲=increase ►=no change	DYSLEXIC? P, E, PE, or no	DYSLEXIC? P, E, PE, or no ▼=decline ▲=improvement ►=no change
E1	10	12	10▼	no	no►
E2	9	>12	9▼	no	no►
E3	9	12	9▼	no	no►
E4	11	12	11▼	no	PE▼
E5	10	8	10▲	no	no►
E6	9	12	9▼	E	PE▼
E7	9	>12	9▼	no	no►
E8	12	12	12►	P	P►
E9	12	12	12►	P	PE▼
E10	12	12	12►	P	no▲
E11	12	12	12►	PE	PE►
E12	11	12	11▼	E	E►
E13	10	12	10▼	no	PE►
E14	9	12	9►	P	PE▼
E15	11	>12	11▼	no	no►
E16	10	12	10▼	E	PE▼
E17	11	12	11►	no	PE▼
E18	12	12	12►	no	PE▼
E19	11	>12	11▼	no	no►
MEAN	11	12	11	N/A	N/A

Table 21 includes data on Attention Deficit Disorder/Attention Deficit Hyperactivity Disorder (ADD/ADHD). To further supplement our study, ADD/ADHD information was collected from the school and from the students themselves, revealing twenty students of the twenty-nine students with the condition (69%). When asked about medications, we were informed that twenty-four students were on some sort of treatment (83%), whether or not they had ADD/ADHD. For side-by-side comparison, a list of the subjects with visual problems is also included.

Table 21. Visual problems, ADD/ADHD, or meds. = *yes*

SUBJECT	VISUAL PROBLEMS	ADD/ADHD	TAKING MEDS
1	yes	no	no
2	yes	no	no
3	yes	yes	yes
4	yes	yes	yes
5	yes	yes	yes
6	no	yes	yes
7	no	yes	yes
8	no	yes	yes
9	yes	yes	yes
10	yes	yes	yes
11	no	yes	yes
12	no	yes	yes
13	no	yes	yes
14	yes	yes	yes
15	yes	yes	yes
16	no	no	yes
17	no	no	yes
18	yes	no	no
19	yes	no	no
20	yes	no	yes
21	yes	yes	yes
22	no	yes	yes
23	yes	yes	yes
24	yes	yes	yes
25	no	yes	yes
26	no	yes	yes
27	no	yes	yes
28	yes	no	yes
29	yes	no	no
RESULTS:	17 yes	25 yes	24 yes
PERCENTAGE:	59%	86%	83%

Special Subject Circumstances

While working with this population throughout the study a few things became very apparent that we had not factored in, such as the very high incidence of ADD/ADHD and dyslexia. Another nagging problem was the limited availability of training equipment, lack of training supervision, and an abundance of extracurricular activities that interfered with many subject's availability for training. This combination of difficulties impacted our ability to complete our study protocol as it was originally designed.

ADD/ADHD: ADD/ADHD diagnosis was obtained via a self-reported questionnaire. Twenty of our twenty-nine subjects reported having been previously diagnosed with ADD/ADHD. This was a much higher incidence than we anticipated. We strongly suspect that ADD/ADHD may be a confounder in situations where experimental subjects are expected to motivate themselves to self-start and to enthusiastically participate in monotonous but self-directed training.

Dyslexia: While testing for Dyslexia using the Dyslexia Determination Test (DDT), the data indicated 13 of 29 subjects showed some form of dyslexia. A diagnosis of dyslexia arguably diminishes the prospects for reading improvement for almost every type of intervention.

Availability to training Equipment: All of the EYE training was completed in a single room at TEHS. A controlled training environment was necessary to fulfill the specific requirements of the EYE study training protocol. In order not to conflict with the normal school activities EYE training had to very carefully scheduled during normal school hours. Because of the already busy TEHS normal didactic schedule, only narrow windows of training opportunity with access to the training equipment were available to participating experimental subjects.

Supervision: During the EYE training, supervision was necessary to monitor whether training was being completed, to help keep the students on track, and to answer questions as they arose. This study was originally designed as double-blind study, which meant that the examiners would not be involved with the training, only with testing. One individual staff member of the school was designated as the training supervisor. This was very helpful because he was always at the school and had easy access to the students. We later learned that the supervisor had difficulty keeping track of the students due to the myriad of individual schedules. In addition, there were reported difficulties with student's willingness to communicate with the supervisor about their training. The training was also monitored by having the subjects turn in training time log-sheets. We visited TEHS one day during the designated training time to monitor progress but to our surprise, we found that some of the individuals had teamed up as partners training as a joint team rather than individually as prescribed. Some individuals did not read the day's instructions on which specific activities they were suppose to complete that day, or specifically how they were to be completed.

Extracurricular Activities: As mentioned above, all subjects were attending TEHS as normal students, which meant normal academic schedule in parallel with extracurricular activities such as basketball, tennis, track, plus weekend scholastic retreats. These extracurricular activities further limited the students' ability to do their EYE training. EYE training was scheduled for a 4-week period with 5 days a week participation needed to complete the protocol. Unfortunately, a noteworthy number of EYE training sessions were missed due to conflicts with school activities. The originally prescribed training period had to be extended in order to acquire sufficient subject participation. In addition, the designated testing period also to be extended

because of schedule conflicts. These complications may have impacted the effectiveness of the training.

Discussion

While analyzing our data we realized that the areas in which we expected to get an increase from the training activities we did not, and in some of the other areas that we did not expect to get an increase we did. The only two categories to reach significant change in our data were: right and left eye refractive error, and near phoria. Significant change in these categories seems a bit perplexing. These are not thought to be visual functions that are amenable to change via training. Pre/post differences in habitual correction wear is our best explanation for the RE change. Some subjects wore their habitual correction during the baseline testing and not at post-testing, and vice versa. We surmise that inter-examiner measurement differences were responsible for the near phoria change. Different examiners were responsible for gathering baseline and post testing phoria data.

As mentioned before, a prior prospective masked study with college students training with the E.Y.E. device resulted in significantly improved accommodative facility, vergence facility, reading fixations, and reading comprehension.[10] We were unable to replicate those improvements in this study. The question is why? We believe that part of this may have to do with differences between the two training group participants. In the antecedent study, the 40 optometry student participants were self-motivated, closely monitored, and committed to completion of the prescribed training without interruption (zero training days missed). In contrast, the twenty-nine students in our study were not as tightly monitored, not as committed, and experienced quite a number of training breaches. Training discontinuity may have been a

likely factor contributing to our largely negative results. Other confounders such ADD/ADHD, dyslexia, unavailability of training equipment, limited supervision, and extracurricular activity interference (see above "Special Subject Circumstances") may have also played a role.

One of the original goals of our study was to investigate potential changes in reading ability from E.Y.E. training. Would having the eyes work more proficiently potentiate the speed and accuracy of reading? Given the results of the antecedent study, we anticipated reading improvement in at least a portion of our subjects, but realized that subtle changes would be difficult to detect. We incorporated three forms of reading evaluation (Dyslexia Determination Test, Informal Reading Inventory, and Visagraph) to try and survey reading skills. Surprisingly, we found large baseline to post-test fluctuations in Visagraph efficiency and IRI results--both in positive and negative directions. In our opinion, this is further evidence for the notion that our sample had very atypical reading skills unlike those found in a typical teenage population. The Dyslexia Determination Test indicated that 5 of our 9 control subjects, and 8 of our 20 experimental subjects demonstrated significant language processing difficulties, or some form of dyslexia. This is an astonishingly high incidence within such a small sample--what are the odds? Although Visagraph II results from the antecedent study hint that E.Y.E. training can improve reading skills of some individuals; the same inference cannot be drawn from our study. Given the high number of "dyslexic" subjects in the current study (whose reading skills were unlikely to respond to E.Y.E. training), it is not inconceivable that E.Y.E. training could improve reading skills with a non-dyslexic population. This question can only be answered by future research.

Prior to initiating this study, we felt the TEHS student body would serve as a great resource for investigating potential E.Y.E. training changes. As inexperienced investigators we learned that in pilot studies with a very limited budget, there are many unforeseen obstacles to

executing high quality clinical research. We also learned that there are unpredictable major challenges to working with special populations. Although we were disappointed by the variability in our data, and surprised that the promising antecedent study results were not replicated, it would be very improbable that a three-hour training program (designed to primarily treat accommodative/vergence and eye movement problems) could overcome the effects of ADD/ADHD, dyslexia, or a severe reading difficulty.

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