A prospective study of the EYEPORT Vision Training System

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KEYWORDS
Eye exercises;
Accommodation;
Vergence;
Chromatic aberration;
Color

Abstract

BACKGROUND: The purpose of this study was to determine if vision training with the EYEPORT™ system affects vision and reading performance. (Subsequent to this study, the "E.Y.E." has been renamed "*EYEPORT™*")

METHODS: College students with normal vision (n = 31) participated in a blind, crossover study to assess within-subject and between-group effects of EYEPORT training. Half the subjects initially underwent training (10 minutes per day, 6 days a week for 3 weeks), and then crossed over to the no-train control condition (3 weeks); the other half underwent the reverse sequence. Vision and reading performance were assessed at baseline, 3 weeks, and 6 weeks.

RESULTS: Multivariate analyses (Hotelling's T^2) found small improvements in vergence and accommodative facility, reading performance, and stereopsis response time after EYEPORT training ($P < 0.025$). Enhancements in reading performance and vergence facility were still present 3 weeks after cessation of training ($P < 0.001$).

CONCLUSIONS: The EYEPORT training system shows potential to enhance visual performance and reading ability. Studies are underway to assess its efficacy in symptomatic populations.

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There is considerable and compelling support for the concept that visual skills, comfort, and efficiency can be enhanced via vision therapy.[1-7] The efficacy of vision therapy has been shown in the past with children as well as adults.[8] Not only do patients with reduced visual efficiency respond well, but vision therapy is deemed by some to be the treatment of first choice.[9] Vision therapy programs are commonly individually prescribed to the patient and monitored by the optometrist. Vision therapy treatment almost always involves differing exercises and combinations of training tools such as lenses, prisms, computer programs, and vision training instruments (i.e., stereoscopes, cheiroscopes).[10] It is uncommon to find a vision therapy study limited to a single training method or device. What follows is a prospective intervention trial utilizing a single vision training device used in isolation.

Whereas the ability to discriminate the various hues that surround us approaches wavelength accuracy, the human eye, like all optical instruments, manifests chromatic aberration; each wavelength is focused at a unique position relative to the retina. Longitudinal chromatic aberration causes short wavelength (deep blue) light to be focused anterior to the retina, whereas long wavelength (deep red) light is focused posterior to the retina. Thus, a blue target may serve as a stimulus to relax accommodation, whereas a red target may stimulate increased accommodation.[11] Although there is contrary evidence[12] based on recent research, Stark et al.[13] affirmed that longitudinal chromatic aberration "almost certainly provides a direct stimulus to

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Figure 1 The EYEPORT™ system. See text for further details.

accommodation." This suggests that, in addition to changes in viewing distance, systematic changes in the chromatic content of the stimulus may serve as an effective stimulus to accommodation and vergence, with potential application for vision training and therapeutics.

The purpose of this study was to conduct a prospective assessment of a new device, which combines systematic changes in chromaticity, direction, and viewing distance as a stimulus to accommodation and vergence. This new device, known as *Exercise Your Eyes* or the *E.Y.E.* system (renamed *EYEPORT*™ subsequent to this study), is similar to 2 earlier electronic vision training devices. The Gruss Electro-Wand introduced by Mast/Keystone in the mid 1970s, consisted of a 27-inch bar with 7 red fixation lights spaced at 4-inch intervals. One end of the Electro-Wand was held near the nose in a line-of-sight orientation while the patient was instructed to sequentially fixate and "clear" the illuminated lights and to use the white line (on top of the bar connecting the lights) as feedback for fine vergence alignment. The Electro-Wand was equipped with a speed control and 4 automated programs that illuminated the fixation lights in different patterns. This device was designed to serve as an electronic Brock String function to train convergence, fixation, and suppression. The Electro-Wand was followed by a similar but more advanced device, the Liberman Vis-Flex (Vision Flexibility Trainer; Wayne Engineering, Skokie, Illinois) system. The Vis-Flex also incorporated only red fixation lights, but was more fully programmable than the Electro-Wand, and is still available after nearly 20 years of use as a visual therapeutic device. The recently introduced EYEPORT system consists of a 36-inch rod with an array of 12 alternating fully programmable red and blue light emitting diodes (LEDs) (*see* Figure 1). Each unit includes reversible red and blue anaglyphic spectacles, which allows training of each eye independent of the other. Liberman's recommended EYEPORT training protocol incorporates the reversible red–blue glasses to alternately train each eye individually while both eyes are being used. When these red–blue glasses are used in combination with alternating red and blue LEDs, color cancellation occurs in which the eye behind the red lens only sees an illuminated red LED, whereas the eye behind the blue lens only sees an illuminated blue LED. This allows the user to alternately train each eye to become the lead eye at any given moment while both eyes are open. A stated goal is to have the eyes continuously exercise their individual ability to accurately and efficiently aim, focus, and track a target, while simultaneously reinforcing their ability to work together as equal partners. Liberman's recommended protocol also specifies daily training without the red–blue glasses, in which the device is placed in a line-of-sight orientation relative to the user. The user is not only encouraged to focus and fuse each sequentially illuminated light, but also to maintain physiologic diplopia awareness of the white line (on top of the rod connecting the LEDs) so the perceived "Brock string lines" precisely cross at each light when illuminated. Thus, this technique provides the user with feedback about vergence alignment while the alternating red and blue LEDs generate an approximately 1.5-diopter "rocking" stimulus to accommodation (based on peak spectral wavelengths of the LEDs and research conducted by Wald and Griffin, 1947 and Bedford and Wyszecki, 1954).

What feedback does the user get about potential visual improvement? Reportedly, the user should notice the LEDs becoming clear more quickly, a faster and more precise vergence response, plus better and more natural synchronization of all of the aggregate visual subskills with the visual and auditory EYEPORT stimuli. In general, even with increasingly more challenging EYEPORT programs, completion of the activities should become progressively less effortful, easier, and more comfortable (Liberman J, personal communication, Kula, Hawaii 2004).

For the purpose of this study, we chose to follow the training protocol recommended by Liberman, whereby the device was used only for a 3-week training period comprised of progressively more challenging illumination patterns, program speeds, and differing levels of auditory

Table 1 Testing conducted before and after EYEPORT training

Visual performance parameter	Method
Monocular and binocular visual acuity	Distance and near log MAR charts
Monocular and binocular contrast sensitivity	Pelli-Robson Chart Distance and near small letter contrast chart
Refractive error and max plus to 20/20	Objective and subjective refraction
Relative accommodation	PRA and NRA
Vergence ranges and phorias	Phoropter-assisted prism testing
Accommodative facility	+2/−2D lens flipper testing at 40 cm[14]
Vergence facility	8 base-in/8 base-out prism flipper testing at 40 cm[14]
Combined accommodation and vergence facility	Distance Rock test[15]
Timed and threshold stereopsis	Super Stereo Test (SST) near[16] and BVAT distance stereo test
Reading speed and performance	Visagraph II test[17-19]
Reading comprehension	Visagraph II Taylor paragraphs test[17-19]
Quality-of-life profile	Quality-of-life questionnaire

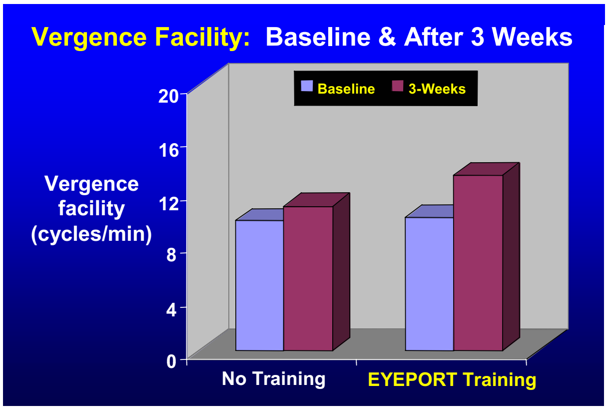

Figure 2 Mean vergence facility at baseline and after either 3 weeks of EYEPORT training (n = 14), or a no-train control period (n = 17).

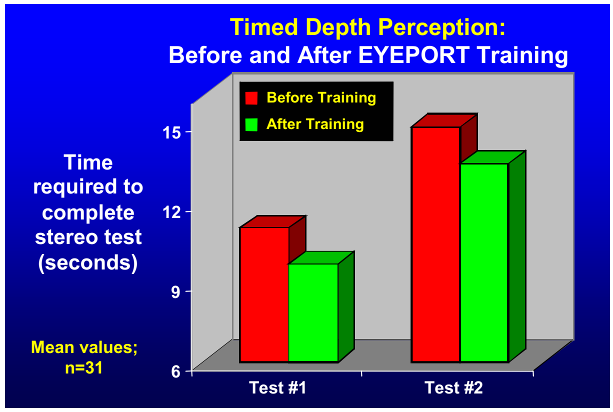

Figure 4 Timed stereopsis before and after EYEPORT training.

feedback (*see* Appendix). This study included visually normal participants in a blind, crossover design to assess within-subject and between-group changes in visual performance and reading ability after EYEPORT training.

Methods

This study included 31 participants drawn from the student body of the Pacific University College of Optometry (mean age, 25.8 years; range, 20 to 41). All participants had normal vision corrected to at least 20/20 with no history of strabismus, amblyopia, or ocular disease. All subjects gave their informed consent to participate after protocol approval by our institutional review board. A crossover design was utilized in which each subject underwent testing before and after training with the EYEPORT system. The study was conducted over a period of 6 weeks, with approximately half (n = 14) of the subjects undergoing training during the first 3 weeks, and the other half serving as a control group (n = 17). Each group then "crossed over"; the untrained subjects underwent training during the second 3-week period, whereas the trained subjects did not train during the second 3 weeks. This design allowed for within-subject assessment of EYEPORT training in all subjects (n = 31); comparison between trained and untrained groups during the first 3 weeks; and, in the group that trained first, assessment of the persistence of training effects during the final 3 weeks.

A series of tests to evaluate oculo-motor function and visual performance as they relate to visual reaction time, endurance, and skills was administered to each subject at baseline, 3 weeks, and at 6 weeks (*see* Table 1). Each testing session was conducted in a fully equipped eye lane and clinical laboratory and required approximately 60 minutes. The licensed optometric clinicians performing the tests were "blind" to the status of each subject (control vs. training assessment).

Training was conducted at the College of Optometry in a large, comfortable room equipped with 6 secluded stations with controlled room illumination, where subjects trained on a daily basis. Each daily session consisted of a 10-minute vision exercise program using the EYEPORT system. The 10-minute program consisted of 5 exercises, each 90 seconds in duration separated by a 30-second rest period. The first 4 exercises consisted of visual tracking in the horizontal, vertical, and 2 oblique directions within the fronto-parallel plane at a distance of 60 cm from the observer. The

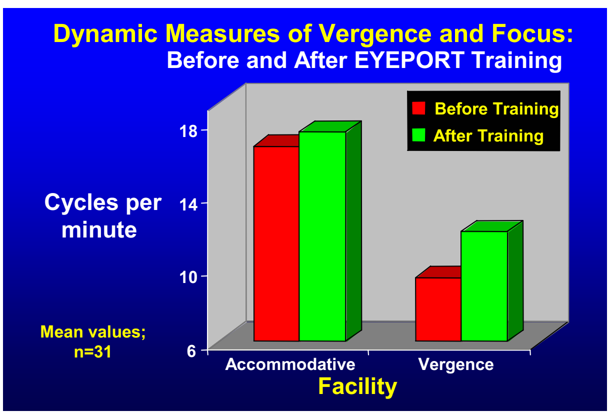

Figure 3 Accommodative and vergence facility before and after training.

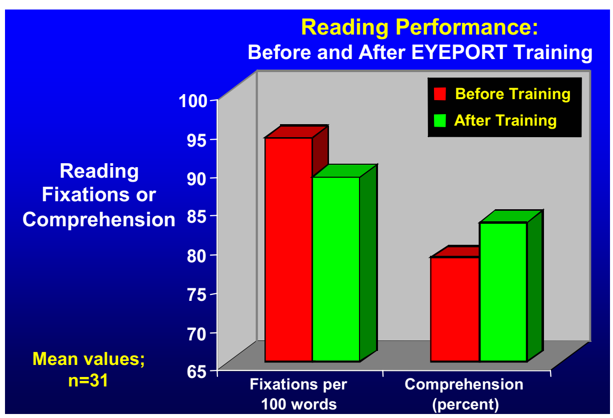

Figure 5 Reading performance before and after EYEPORT training.

fifth exercise, an electronic Brock string technique, consisted of tracking a series of LEDs moving closer and further along a line-of-sight orientation relative to the user. In accordance with the recommended Liberman training protocol, subjects were encouraged to perform their individual EYEPORT training while not wearing habitual lens correction, except for cases in which the lenses were necessary to see the LEDs clearly. Some sessions were performed while wearing red–blue glasses (to alternately train each eye while both eyes were being used), whereas other training was completed without red–blue anaglyphic filters. (*See* Appendix for information about the specific training protocol for each session.) Statistical comparisons within and between subjects were conducted to assess effects of EYEPORT training on visual performance.

Results

Training versus control group

All subjects initially underwent a baseline assessment of visual performance and reading ability followed by a 3-week period of EYEPORT training (n = 14) or no training (controls, n = 17). Each group was re-evaluated at the end of this 3-week period to look for changes in performance. Multivariate analysis (Hotelling's Paired Sample T^2; NCSS 2004 Statistical Software; NCSS, Kaysville, Utah) indicated improved accommodative and vergence facility as well as reading ability in the treatment group (T^2 = 383.38, $P < 0.0001$), whereas the no-train control group showed no significant change in performance (T^2 = 35.50, $P = 0.11$). Paired *t* testing with the significance level adjusted for multiple comparisons ($P = 0.0083$; Bonferroni correction[20]) confirmed a significant improvement in vergence facility in the treatment group ($P <$ 0.0002), as well as improvement trends in accommodative facility ($P < 0.035$), reading fixations ($P < 0.015$), and reading comprehension ($P < 0.025$), but only vergence facility achieved statistical significance.

Results for vergence facility are shown in Figure 2. The mean number of vergence cycles per minute, in response to alternating base-out and base-in 8-prism diopter demands, is shown for control (no-train) and EYEPORT training groups before and after the initial 3-week period. Although both groups showed improvement, the enhancement observed in the training group (3.2 cycles per minute) was 3 times greater than in the control group (0.9 cycles per minute), with the change in the control group not significantly different from zero ($P = 0.15$).

Performance after EYEPORT training: all subjects

The initial control group (no EYEPORT training during first 3 weeks) "crossed over" to undergo training during the second 3 weeks. Similar trends were observed in this group after training, including improved vergence facility and reading ability. To increase statistical power for detecting change, data from all subjects (n = 31) were pooled to compare performance before and after training. Improvement trends were observed for vergence and accommodative facility, reading ability, and timed stereo tasks (Hotelling's Paired Sample T^2 = 91.09, $P < 0.001$).

Figure 3 shows mean accommodative and vergence facility for all subjects before and after EYEPORT training. As in the initial treatment group (*see* Figure 2), vergence facility increased after training (mean increase, 2.5 cycles per minute), whereas accommodative facility increased slightly.

Figure 4 shows the mean time in seconds to complete the SST stereo-depth tasks before and after training. Mean response time decreased 1.5 seconds after training, but by less than 0.5 seconds in the no-train control group.

Figure 5 shows mean reading performance for all subjects before and after training. The number of fixations decreased (from 94 to 89) and reading comprehension increased (5%) after training. In contrast to this result, the no-train control group showed no change in fixations (mean, 92 before and after the control period), and a lesser increase in comprehension (1.3%).

Maintenance of training effects over time

The initial treatment group underwent a 3-week no-train control period after EYEPORT training, making it possible to assess persistence of effects over that time. Figure 6 shows mean reading performance and vergence facility before, immediately after EYEPORT training, and 3 weeks after cessation of training. Multivariate analysis found changes after training (T^2 = 14.09, $P < 0.001$) but no difference between performance immediately after training and 3 weeks later (T^2 = 1.70, $P = 0.72$). Although longer-term effects are yet to be assessed, this finding suggests the potential to sustain positive effects of EYEPORT training.

Z-score comparison

Figure 7 shows the change in reading fixations, comprehension, timed stereo, and vergence facility for all subjects after EYEPORT training. To facilitate comparison across different performance measures with distinct units, all data are expressed as Z-scores—the number of standard deviations (SDs) from baseline performance. (Control group data were used to calculate the within-subject standard deviation for each measure.) In this analysis, *increased performance (positive SD)* indicates an *increase* in comprehension or vergence facility compared with baseline, but a *decrease* in reading fixations or stereo response time relative to baseline. It is clear that relatively few subjects showed improvement exceeding 2 SDs, often cited as a significant change. Nevertheless, many subjects showed some degree of improvement, suggesting the potential of EYEPORT training to enhance reading and vision performance.

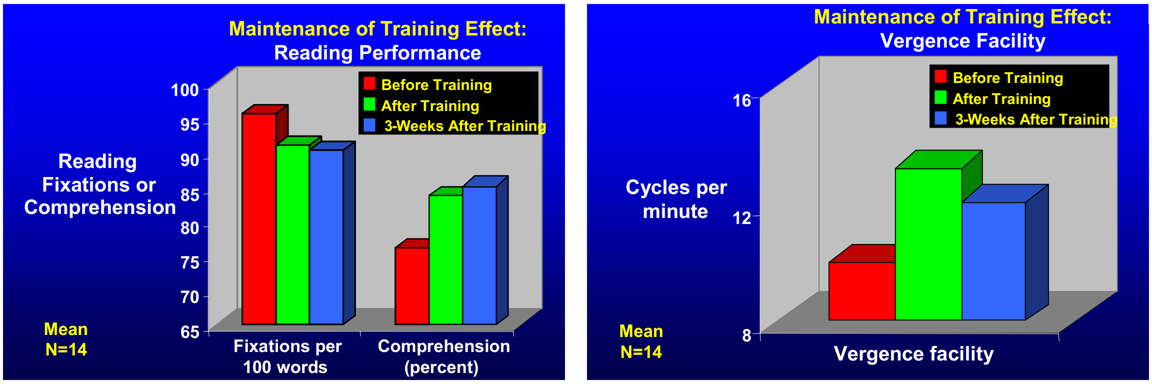

Figure 6 Persistence of EYEPORT training effects.

Discussion

This study shows the potential for improved visual performance after EYEPORT training. Enhancements were observed in vergence facility, reading performance, and timed depth perception. Improvements were observed without the use of lenses or prisms (often necessary in conventional vision training), and with minimal investment of time (10 minutes per day for 3 weeks; 3 hours total training time). The improved vergence facility and reading performance persisted up to 3 weeks after termination of training.

It is possible that the enhancements were caused by learning effects or motivational factors related to the training experience. However, control subjects showed no comparable changes in performance, and several tests used objective measures (e.g., number of fixations during reading) or forced-choice methods less affected by subjective factors. Nevertheless, learning effects and motivational factors cannot be excluded as contributory in this study.

The subjects in this study lacked significant visual and asthenopic symptoms. Hence, the clinical significance of the trends reported herein awaits further application and analysis in symptomatic populations. Additional studies are underway to further explore the efficacy and utility of EYEPORT training.[21]

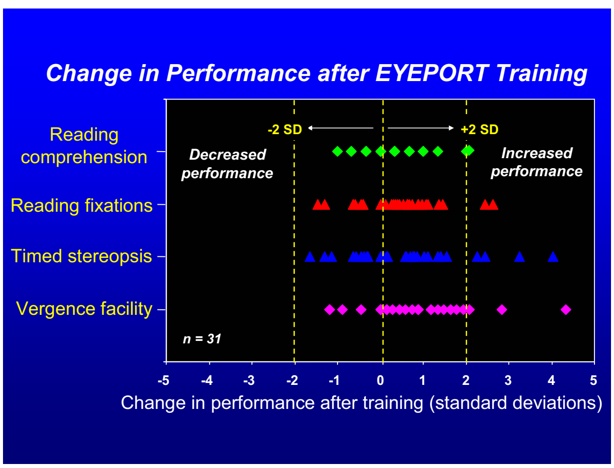

Figure 7 The change in performance after EYEPORT training expressed as SDs from baseline. See text for further details.

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References

1. Hung GK, Ciuffreda KJ, Semmlow JL. Static vergence and accommodation: population norms and orthoptic effects. *Doc Ophthalmol* 1986;62:165-79.
2. North R, Henson DB. The effect of orthoptic treatment upon the ability of patients to adapt to prism-induced heterophoria. *Am J Optom Physiol Opt* 1982;59:983-6.
3. North R, Henson DB. The effect of orthoptic treatment upon the vergence adaptation mechanism. *Optom Vis Sci* 1992;69:294-9.
4. Cooper J, Selenow A. Ciuffreda KJ, et al. Reduction of asthenopia in patients with convergence insufficiency after fusional vergence training. *Am J Optom Physiol Opt* 1983;60:982-9.
5. Grisham JD. Visual therapy results for convergence insufficiency: a literature review. *Am J Optom Physiol Optics* 1988;65:448-4.
6. Grisham JD, Bowman MC, Owyang LA, et al. Vergence orthoptics: validity and persistence of the training effect. *Optom Vis Sci* 1991;68:441-51.
7. Daum KM. The course and effect of visual training on the vergence system. *Am J Optom Physiol Opt* 1982;59:223-7.
8. Cohen AH, Soden R. Effectiveness of visual therapy for convergence insufficiencies for an adult population. *J Am Optom Assoc* 1984;55(7):491-4.
9. Wick BC. Horizontal deviations. In: Amos JF, ed. *Diagnosis and management in vision care*. Boston: Butterworth-Heinemann, 1987:502-3.
10. Vision therapy: Information for Health Care and Other Allied Professionals. Joint policy statement by the American Academy of Optometry and the American Optometric Association. *Optometry* 1999;76(11)739-40.

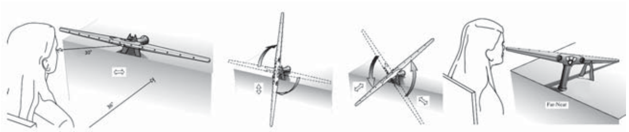
11. Kruger PB, Matthews S, Aggarwala KR, et al. Chromatic aberration and ocular focus: Fincham revisited. *Vision Res* 1993;33:1397-411.
12. Bobier WR, Campbell MC, Hinch M. The influence of chromatic aberration on the static accommodative response. *Vision Res* 1992; 32(5):823-32.
13. Stark LR, Lee RS, Kruger PB, et al. Accommodation to simulations of defocus and chromatic aberration in the presence of chromatic misalignment. *Vision Res* 2002;42(12):1485-98.
14. Birnbaum MH. *Optometric management of nearpoint vision disorders*. Boston: Butterworth-Heinemann, 1993:230-233,253.
15. Haynes HM. The distance rock test-a preliminary report. *J Am Optom Assoc* 1979;50(6):707-13.
16. Super S, Cronje S, Grobler D, et al. Stereoscopic vision testing. *J Behav Optom* 1991;2(4):94-9.
17. Laukkanen H. Eye movements in reading. In: Barber A, ed. *Vision therapy; pursuits and saccades, theories and testing*. Santa Ana, CA: Optometric Extension Program; 1995:41-84.
18. Colby D, Laukkanen H, Yolton R. Use of the Taylor Visagraph System to evaluate eye movements made during reading. *J Am Optom Assoc* 1998;69(1):22-32.
19. Ciuffreda M, Ciuffreda K, Santos D. Visagraph baseline analysis & procedural guidelines. *J Behav Opt* 2003;14(3):60-4.
20. Weisstein EW. Bonferroni Correction. From MathWorld—A Wolfram Web Resource. *http://mathworld.wolfram.com/BonferroniCorrection.html.* Last accessed March 2006.
21. Bland JM, Altman DG. Measuring agreement in method comparison studies. *Stat Meth Med Res* 1999;8:135-60.

Appendix

E.Y.E. weekly training schedule

Program 1: sequential light pattern; Program 2: sequential jump pattern; Program 3: random jump pattern

Auditory 1: feedback; Auditory 0: no feedback; Speed 1: 2.5-second light duration; Speed 9: 0.2-second duration



R/B = red filter over right eye/blue over left; B/R = blue over right eye/red filter over left eye; NONE = no filter

Week 1

Day	Date	Program	Speed	Auditory	⇔	⇕	⤡	⤢	Far-Near
1	/ /	1	2	1	R/B	B/R	R/B	B/R	None
2	/ /	1	3	1	R/B	B/R	R/B	B/R	None
3	/ /	1	4	1	R/B	B/R	R/B	B/R	None
4	/ /	1	5	1	R/B	B/R	R/B	B/R	None
5	/ /	1	6	1	R/B	B/R	R/B	B/R	None
6	/ /	1	7	1	R/B	B/R	R/B	B/R	None

Week 2

Day	Date	Program	Speed	Auditory	⇔	⇕	⤡	⤢	Far-Near
1	/ /	2	1	1	R/B	B/R	R/B	B/R	None
2	/ /	2	2	1	R/B	B/R	R/B	B/R	None
3	/ /	2	3	1	R/B	B/R	R/B	B/R	None
4	/ /	2	4	1	R/B	B/R	R/B	B/R	None
5	/ /	2	5	1	R/B	B/R	R/B	B/R	None
6	/ /	2	6	1	R/B	B/R	R/B	B/R	None

Week 3

Day	Date	Program	Speed	Auditory	⇔	⇕	⤡	⤢	Far-Near
1	/ /	3	0	0	None	None	None	None	None
2	/ /	3	1	0	None	None	None	None	None
3	/ /	3	2	0	None	None	None	None	None
4	/ /	3	3	0	None	None	None	None	None
5	/ /	3	4	0	None	None	None	None	None
6	/ /	3	5	0	None	None	None	None	None

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