Oculomotor Training Improves Vision & Symptoms

Oculomotor Training for Poor Pursuits Improves Functional Vision Scores and Neurobehavioral Symptoms

Melissa Hunfalvay, RightEye LLC, 7979 Old Georgetown Rd, Suite 801, Bethesda, MD 20814, U.S.A. (301) 979 7970 melissa@righteye.com

Nicholas P. Murray, Professor, East Carolina University, Department of Kinesiology, Minges Coliseum166, Greensville, NC 27858, U.S.A. (252) 737 2977 murrayni@ecu.edu

Ankur Tyagi, RightEye LLC, 7979 Old Georgetown Rd, Suite 801, Bethesda, MD 20814, U.S.A. (301) 979 7970 ankur@righteye.com

Jason Whittaker, DC, DACNB, FABCDD, 38 Proulx Place, Winnipeg, MB R3X 0C5, CANADA. (204) 230 5743; drjasonwhittaker@gmail.com

Cedric Noel, DC, DACNB, FABCDD, 45 W Crossville Rd, Suite 503, Roswell, GA 30075. drnoeldc@gmail.com

*Please direct all correspondence to Dr. Melissa Hunfalvay
Oculomotor Training for Poor Pursuits Improves Functional Vision Scores and Neurobehavioral Symptoms
Abstract

Smooth pursuit eye movements (SPEMs) are critical to human’s ability to see and interact with the world. However, limitations exist in the oculomotor training designed to improve SPEMs. The purpose of this study is to determine if participants with predetermined poor SPEMs improved via a standardized oculomotor training program. A secondary objective is to accurately quantify change in SPEM using eye tracking. A third objective is to examine a patients’ neurobehavioral symptoms before and after oculomotor training using the Neurobehavioral Symptom Inventory (NSI; Cicerone, 1995). Participants were randomly assigned to the control or intervention group. The intervention group engaged in 10 minutes of oculomotor training daily. Results revealed significant interactions between control and intervention groups. SPEM metrics showed improved tracking abilities (on-target, predictive and latent) for the intervention group. The NSI showed significant reduction in all neurobehavioral factors and of a total summation of symptoms. Future research should consider examination of eye movement metrics for saccades and gaze stability using this oculomotor training program.

Keywords: Functional vision, oculomotor training, smooth pursuit eye movements
Introduction

Smooth pursuit eye movements (SPEM) are critical to our ability to see, process and respond to our environment. The purpose of SPEM’s is to stabilize the image of a moving object on the fovea. The fovea is used to see the image in detail and with high acuity, therefore where objects are moving, such as watching a ball in flight or a car in motion, smooth pursuit eye movements are used to see the ball and car in detail.

By trying to stabilize the target on the fovea, SPEMs are continually translating signals and converting deviations from the ideal trajectory into compensatory eye movements (Thier & Llg, 2005). Hence SPEMs are deeply integrated in the eye-brain connection. Eye movements, such as SPEMs, have brain related anatomical circuits that make distinct contributions to the eye movement and ultimately to action.

SPEMs are mediated by a cerebro-ponto-cerebellar pathway (Thier & Llg, 2005). Cerebral cortex contains several frontal and parietooccipital areas that have distinct roles in generating SPEMs. Visual area middle temporal (MT) is a visual motion processor that contributes to smooth pursuit by extracting retinal motion of the target. Lesions in this area has resulted in an inability to track targets within the confines of the motion scotoma (Dursteler & Wurtz, 1988).

SPEMs are also foreseen by the middle superior temporal (MST) area that represent an object in motion in world-centered coordinates (Llg, Schumann & Thier, 2004). A lesion in the MST causes and directional error; lowered speed toward the side of the lesion (Wong 2008).

The cerebellum uses at least two areas for processing signals relevant to smooth pursuit: the flocculus–paraflocculus complex; and the posterior vermis. Lesions in the cerebellum show mild deficits in horizontal and vertical pursuits in both directions and Vestibular Ocular Reflex
Oculomotor Training Improves Vision & Symptoms

(VOR) cancellation if the lesion is unilateral in the VPF. Bilateral lesions of the flocculus and VPF result in severe deficit in horizontal and vertical pursuits in both directions and VOR cancellation. Lesions in the vermis region of the cerebellum result in ipsiversive horizontal smooth pursuits. Lesions in the fastigial nucleus result in deficits in the contraversive horizontal pursuit (Wong, 2008). Lesions starting from the medial vestibular nucleus also affect the VOR because the pursuit and the VOR share similar pathways from this point forward. Hence resulting symptoms tend to overlap.

When a person can effectively use their eyes to smooth pursuit then follow on cognitive processes are enabled. For example, effective tracking of a car allows the person to determine speed, time-to-interception and ultimately decision making such as when to cross the road. Such activities facilitate the integration of head movements into smooth-pursuit behaviors and the coordination of perception and action (IIg, Schumann & Thier, 2004).

As a person ages, smooth pursuit performance often declines. This decline is commonly tied to the cerebellar disease and drugs that effect the nervous system (Leigh and Zee, 2000).

Optimization and repair of smooth pursuits can be enhanced using oculomotor training. Eye movement training is based on neuroplasticity, which is the foundation of the rehabilitation.

Eye movement training has been used to improve those with clinical conditions who display poor performance, as well as to those trying to achieve elite performance in sport.

Oculomotor training, including pursuit training, has been shown to be successful in improving various clinical conditions including gait functions (Kwon-Young Kang, Kyung-Hoon Yu, 2016); macular degeneration (Janssen, Verghese, 2016); progressive retinitis pigmentosa (Yoshida, Origuchi, Urayama, Takatsuki, Kan, Aso, Shiose, Sawamoto, Miyauchi, Fukuyama, Seiyama; 2014); cognitive function, depression and functional ability (Eksteen & Wyk, 2015),
Oculomotor Training Improves Vision & Symptoms

mitigation of tunnel vision (Iliya V. Ivanov, Manfred Mackeben, Annika Vollmer, Peter Martus, Nhung X. Nguyen and Susanne Trauzettel-Klosinski) and Progressive Supranuclear Palsy (PSP: Zampieri & Di Fabio, 2009). Training specific to pursuit eye movements has been successful in mitigating spatial neglect following a stroke (Hill, Coats, Halstead, Burke, 2015; Kerkhoff, Bucher, Brasse, 2014).

Eye movement training has shown to improve elite level performers as well. Zupan, Arata, Wile and Parker (2006) used eye movement training to improve Airforce fighter pilot’s reaction time, near-far focusing and number of saccades.

The current state of eye movement interventions has been created using clinically relevant principles of neuroscience, neurology, motor learning and rehabilitation. However, limitations exist in the sensitivity and specificity of the eye movement outcome measures from such interventions. Therefore, the purpose of this study is to determine if participants with pre-determined poor pursuits improved via a standardized oculomotor training program. A secondary objective is to accurately quantify change in SPEM using eye tracking. A third objective is to examine a patients’ neurobehavioral symptoms before and after oculomotor training using the Neurobehavioral Symptom Inventory (NSI; Cicerone, 1995).

Methodology

Participants

The total number of participants considered for this study were 92. The Intervention Group (IG) included 46 participants who completed the EyeQ Trainer Exercises and no other oculomotor training. The Control Group (CG) included 46 participants who did no training (EyeQ Trainer or any other oculomotor training).
Oculomotor Training Improves Vision & Symptoms

Participants were between the ages of 12-68 years ($M = 41, SD = 22$). Participants in the IG were between the ages of 12-58 ($M = 35, SD = 23$). There were 13 males (28%) and 33 females (72%) in the IG. In the CG there were 24 males (52%) and 22 females (48%).

**Apparatus**

Testing and training interventions were done on the same apparatus. Stimuli were presented using the RightEye tests on a Tobii I15 vision 15” monitor fitted with a Tobii 90 Hz remote eye tracker and a Logitech (model Y-R0017) wireless keyboard and mouse. The participants were seated in a stationary (non-wheeled) chair that could not be adjusted in height. They sat in front of a desk in a quiet, private room. Participants’ heads were unconstrained. The accuracy of the Tobii eye tracker was $0.4^\circ$ within the desired headbox of 32 cm × 21 cm at 56 cm from the screen. For standardization of testing, participants were asked to sit in front of the eye tracking system at an exact measured distance of 56 cm which is the ideal positioning within the headbox range of the eye tracker.

**Oculomotor Testing Tasks.** Pre and post-tests were conducted using the same set of oculomotor tasks, collectively called Functional Vision EyeQ. These tasks included three smooth pursuit tests, 2 saccade tests, one fixation test, two reaction time tests.

**Pursuit Tests:** Three types of pursuit tests were run. A Circular Smooth Pursuit (CSP), Horizontal Smooth Pursuit (HSP) and Vertical Smooth Pursuit (VSP). Participants were asked to “follow the dot, on the screen, as accurately as possible with their eyes.” The dot is 0.2 degrees in diameter and moved at a speed of 25 degrees of visual angle per second. The tests were taken with a black background with white dot and lasted 20s. The diameter of movement of the CSP circle was 20 degrees.
Oculomotor Training Improves Vision & Symptoms

*Self-Paced Saccade Tests* (for more details see Hunfalvay, Roberts, Murray, Tyagi, Kelly & Bolte, 2019): In the Horizontal Saccade (HS) test, participants were asked to look at a countdown of three, two, one in the center of the screen before moving their eyes back and forth between two dots. Their goal was to ‘target each dot’ on the left and right of the screen as quickly and accurately as possible. The targets were 10 cm apart and 1 cm in diameter. The tests were taken with a black background with white dots and lasted 10’s. The protocol for the Vertical Saccade (VS) test was the same as that for the HS test. However, the VS test was in a vertical plane.

*Fixation Test:* In the Fixation Test (FS), participants are asked to look at three different optotypes for seven seconds each with a three second break between. Optotype 1 is a cross the size of one-degree of visual angle. Optotype 2 is a circular dot, of one-degree in size. Optotype 3 is a small four-point diamond, that is 3 cm in size on the edge. The tests were taken with a white background with black dots and lasted a total of 30-seconds, including the breaks.

*Reaction Time Tests:* Two reaction time tests were given; a Choice Reaction Time test (CRT) and Discriminate Reaction Time test (DRT; see Lange, Hunfalvay, Murray, Roberts, Bolte, 2018). In brief, the CRT test, the participant viewed three stimuli and was asked to provide one of three responses. In the DRT test, the participant viewed three stimuli and was required to respond to only one stimulus.

**The Functional Vision EyeQ Score (FVEQ):** includes a linear combination of saccade, pursuit, fixation and reaction time oculomotor variables. A total of 58 metrics makes up the model. Weights range from 0.1 to 13% across metrics.

**Oculomotor Training Tasks.** Training exercises took 5 minutes and were conducted twice a day, once in the morning and once in the evening, for a total of five days. The training
Oculomotor Training Improves Vision & Symptoms

Exercises assigned took participants through a series of exercises including: Down-gaze Central No-No, Up-gaze Central No-No, Down Right-Diagonal Saccades followed by Upward Pursuit, and Down Left-Diagonal Saccades followed by Upward Pursuit.

For Down-gaze Central No-No, participants are asked to tilt their head to the top line and then back to center, when they see the target presented on screen. They had to repeat the process, each time the target jumps.

For Up-gaze Central No-No, participants are asked to move their head one time to the bottom line and then back to the center, when they see the target presented on screen. They had to repeat the process, each time the target jumps.

Procedure

Participants were pre-selected via the database if they met the following criteria: 1. they had pursuit eye movements that were in the bottom 25th percentile compared to age-matched controls and 2. if they had less than 30 days since their assessment.

Table 1

Summary of time interval between pre and post assessments, for Intervention Vs Control Group.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control</th>
<th>Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
</tr>
<tr>
<td>Functional Vision EyeQ Score</td>
<td>53 ± 22</td>
<td>53 ± 21</td>
</tr>
<tr>
<td>Days difference between</td>
<td>20 ± 10</td>
<td>15 ± 8</td>
</tr>
<tr>
<td>Pre and Post Assessment</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SD = Standard Deviation

Note. Functional Vision EyeQ Score, and Time interval between pre and post assessment for Intervention and matched Control group.
The nature of the study was explained to the participants, and all participants were provided a written University Approved informed consent to participate. The study was conducted in accordance with the tenets of the Declaration of Helsinki. The study protocols were approved by the Institutional Review Board of East Carolina University. Following informed consent, participants were asked to complete a pre-screening.

Participants were excluded from the study if they reported past head injury, any neurological condition, or static visual acuity of greater than 20/400. Participants were also excluded if they were unable to pass a 9-point calibration sequence.

Following pre-screening, participants completed the Neurobehavioral Symptom Inventory (NSI) and then took the Functional Vision EyeQ series of tests. Once testing was complete, they were randomly assigned to the oculomotor training (IG) or to the CG.

Participants were randomly assigned to the groups. The IG did the RightEye EyeQ Trainer exercises and no other interventions. The CG did not do the RightEye EyeQ Trainer exercises nor any no other intervention.

After training was complete the participant returned for a post-test Functional Vision EyeQ and completed the NSI and debriefing of the study.

**Data Analysis**

Separate 2 (Group) x 2 (Time) repeated measures ANOVAs were used to determine differences in RightEye Test Metrics: Functional Vision EyeQ Score (#), latent, predictive and on-target smooth pursuit percentages between the two Groups (Control and Intervention) and over Time (Pre and Post Assessments). We analyzed the NSI similarly (2 (Group x 2 (Time) ANOVA) using the dependent variables of Q23, which asked participants to “rate your overall symptoms.” Total Score and the 4-Factor scoring approach (Vestibular, Somatosensory,
Cognitive, and Affective; Dretsch, et al. 2016). The 4-Factors included vestibular (n = 3), somatosensory (n = 7), cognitive (n = 4) and affective (n = 6). As well as a summated total score of 22 factors. We used simple effects post hoc test for significant main effects and interactions.

Results

Functional Vision EyeQ Score

The ANOVA results for Functional Vision EyeQ Score demonstrated a non-significant main effect for Group (Intervention, Control) (p = .344); however there was a significant main effect for Time (Pre, Post), $F(1, 90) = 4.00, p = .048, \eta^2_p = .01$ and more importantly a significant interaction (Group x Time), $F(1, 90) = 4.65, p = .034, \eta^2_p = .01$. Simple effects revealed a slight decrease in the Functional Vision EyeQ Score for control from pre (53.15) to post (52.87); however, the intervention group’s Score increased from pre (53.20) to post (60.80) (See Table 2).

Table 2

Metric values for pre and post assessments in Intervention group and Control group.
Oculomotor Training Improves Vision & Symptoms

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control</th>
<th>Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td></td>
<td>(Mean ± SD)</td>
<td>(Mean ± SD)</td>
</tr>
<tr>
<td>Functional Vision EyeQ Score</td>
<td>53.15 ± 21.76</td>
<td>52.87 ± 20.27</td>
</tr>
<tr>
<td>(#)</td>
<td>21.76</td>
<td></td>
</tr>
</tbody>
</table>

SD: Standard Deviation, Pre: Pre-Assessment metric value, Post: Post-Assessment metric value

On-Target Smooth Pursuit (%)

On-Target Smooth Pursuit demonstrated a non-significant main effect for Group (Intervention, Control) (p = .776) and non-significant main effect for Time (Pre, Post), (p = 0.253); however there was a significant interaction (Group x Time), $F(1, 90) = 4.29$, $p = .041$, $\eta^2_g = .01$. Simple effects revealed a decrease in On-Target Smooth Pursuit for control from pre (63.89) to post (59.12); however, the intervention group’s metric value increased from pre (59.81) to post (61.17).
The ANOVA results for CSP: Latent Smooth Pursuit (%) demonstrated a non-significant main effect for Group (Intervention, Control) \( (p = .604) \) and non-significant main effect for Time (Pre, Post), \( (p = .564) \); however there was a significant main effect for Interaction (Group x Time), \( F(1, 26) = 4.87, p = .036, \eta^2_g = .05 \). Simple effects revealed an increase in the Latent Smooth Pursuit (%) for control from pre (28.25) to post (31.46); however, the intervention group’s metric value decreased from pre (30.84) to post (25.32).

Predictive Smooth Pursuit (%)

Predictive Smooth Pursuit demonstrated a non-significant main effect for Group (Intervention, Control) \( (p = .865) \); however there was a significant main effect for Time (Pre, Post), \( F(1, 94) = 5.65, p = .019, \eta^2_g = .01 \) and a significant interaction (Group x Time), \( F(1, 94) = 7.30, p = .008, \eta^2_g = .02 \). Simple effects revealed an increase in the Predictive Smooth Pursuit for control from pre (8.65) to post (8.87); however, the intervention group’s metric value reduced from pre (10.29) to post (6.80) (See Table 2).
Neurobehavioral Symptom Inventory (NSI)

For the NSI, the findings were similar across all the total score and the 4-factor scoring approach (See Table 3 and 4). Specifically, the total score analysis indicated a main effect for Time, $F(1, 94) = 1595.28$, $p < .001$, $\eta^2_p = .944$, for Group, $F(1, 94) = 17.22$, $p < .001$, $\eta^2_p = .943$, but more interesting was a significant effect for the interaction of Time x Group, $F(1, 94) = 2433.82$, $p < .001$, $\eta^2_p = .963$. Similarly, the Vestibular $[F(1, 94) = 221.96$, $p < .001$, $\eta^2_p = .702]$, Somatosensory $[F(1,94) = 351.632$, $p < .001$, $\eta^2_p = .905]$, Cognitive $[F (1,94) = 1208.77$, $p < .001$, $\eta^2_p = .230]$, and Affective factors $[(1,94) = 106.318$, $p < .001$, $\eta^2_p = .149]$, and Affective factors $[(1,94) = 103.83$, $p < .001$, $\eta^2_p = .576; F(1,94) = 137.49$, $p < .001$, $\eta^2_p = .682]$ demonstrated significant main effect for Time and Group Comparisons, respectively. In addition there was a significant interaction of Time x Group for all factors: Vestibular $(p<.001, \eta^2_p = .789)$, Somatosensory $(p<.001, \eta^2_p = .912)$, Cognitive test $(p < .001, \eta^2_p = .730)$; Affective $(p < .001, \eta^2_p = .682)$. Lastly, results for overall symptom change (Q23), before and after analysis showed a main effect for Time, $(1,94) = 52.39,$
Oculomotor Training Improves Vision & Symptoms

p < .001, $\eta_p^2 = .650$ and for Group, (1,94) = 20.68, p < .001, $\eta_p^2 = .548$; however, more importantly a significant Time x Group interaction, F(1,94) = 34.27, p < .001, $\eta_p^2 = .548$

Table 3: NSI itemized scores for each Group (Intervention/Control) and by Time (Pre/Post)

<table>
<thead>
<tr>
<th></th>
<th>Intervention</th>
<th></th>
<th>Control</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>Dizzy</td>
<td>2.78 (0.89)</td>
<td>1.60 (0.68)</td>
<td>2.56 (1.013)</td>
<td>2.56 (1.19)</td>
</tr>
<tr>
<td>Balance</td>
<td>2.36 (1.21)</td>
<td>0.71 (0.77)</td>
<td>2.76 (0.74)</td>
<td>3.16 (0.76)</td>
</tr>
<tr>
<td>Poor Coordination</td>
<td>3.17 (0.60)</td>
<td>0.76 (0.67)</td>
<td>2.2 (0.75)</td>
<td>2.4 (0.80)</td>
</tr>
<tr>
<td>Headaches</td>
<td>3.36 (0.57)</td>
<td>1.00 (0.63)</td>
<td>1.4 (1.21)</td>
<td>1.58 (1.48)</td>
</tr>
<tr>
<td>Nausea</td>
<td>2.63 (0.60)</td>
<td>1.36 (0.48)</td>
<td>1.6 (1.37)</td>
<td>1.6 (1.37)</td>
</tr>
<tr>
<td>Vision Problems</td>
<td>3.39 (0.49)</td>
<td>1.04 (0.59)</td>
<td>2.42 (1.23)</td>
<td>2.24 (0.79)</td>
</tr>
<tr>
<td>Sensitivity to light</td>
<td>2.08 (0.91)</td>
<td>3.5 (0.50)</td>
<td>1.4 (1.37)</td>
<td>1.2 (1.17)</td>
</tr>
<tr>
<td>Hearing Difficulties</td>
<td>1.71 (0.58)</td>
<td>1.06 (0.85)</td>
<td>0.64 (0.82)</td>
<td>0.84 (1.18)</td>
</tr>
<tr>
<td>Sensitivity to Noise</td>
<td>1.84 (0.69)</td>
<td>1.19 (0.54)</td>
<td>0.8 (0.75)</td>
<td>0.8 (0.80)</td>
</tr>
<tr>
<td>Numbness</td>
<td>1.89 (0.60)</td>
<td>1.19 (0.61)</td>
<td>0.62 (0.53)</td>
<td>0.62 (0.53)</td>
</tr>
<tr>
<td>Change in taste or smell</td>
<td>1.76 (0.87)</td>
<td>1.28 (0.75)</td>
<td>0.62 (0.53)</td>
<td>0.62 (0.53)</td>
</tr>
<tr>
<td>Loss of Appetite</td>
<td>2.36 (0.48)</td>
<td>1.23 (0.67)</td>
<td>0.64 (0.52)</td>
<td>0.84 (0.76)</td>
</tr>
<tr>
<td>Poor Concentration</td>
<td>2.26 (0.90)</td>
<td>0.63 (0.48)</td>
<td>1.6 (0.49)</td>
<td>1.8 (0.40)</td>
</tr>
<tr>
<td>Forgetfulness</td>
<td>2.19 (1.02)</td>
<td>2 (0.89)</td>
<td>1.4 (0.49)</td>
<td>1.4 (0.49)</td>
</tr>
<tr>
<td>Difficulty Making Decisions</td>
<td>2.56 (0.62)</td>
<td>1.80 (0.65)</td>
<td>1.42 (0.83)</td>
<td>1.42 (0.83)</td>
</tr>
<tr>
<td>Slowed Thinking</td>
<td>2.30 (0.66)</td>
<td>1.47 (0.98)</td>
<td>1.42 (0.53)</td>
<td>1.8 (0.75)</td>
</tr>
<tr>
<td>Fatigue</td>
<td>2.15 (0.63)</td>
<td>1.58 (0.49)</td>
<td>1.78 (.73)</td>
<td>1.78 (.73)</td>
</tr>
</tbody>
</table>
Table 4: NSI Q23, Total, and 4-Factor Mean (SD) scores for each Group (Intervention/Control) and by Time (Pre/Post)

<table>
<thead>
<tr>
<th></th>
<th>Intervention</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>Q23 Symptom</td>
<td>2.60 (0.61)</td>
<td>0.71 (0.80)</td>
</tr>
<tr>
<td>Total Score</td>
<td>53.23 (5.27)</td>
<td>28.71 (5.54)</td>
</tr>
<tr>
<td>Vestibular</td>
<td>8.32 (1.31)</td>
<td>3.08 (1.29)</td>
</tr>
<tr>
<td>Somatosensory</td>
<td>18.39 (1.43)</td>
<td>9.17 (1.88)</td>
</tr>
<tr>
<td>Cognitive</td>
<td>9.32 (1.57)</td>
<td>5.91 (1.91)</td>
</tr>
<tr>
<td>Affective</td>
<td>13.10 (3.38)</td>
<td>8.23 (2.56)</td>
</tr>
</tbody>
</table>

Discussion

The primary purpose of this study was to determine if a series of oculomotor exercises improved participants who had poor SPEMs. Results revealed that the FVEQ score significantly improved. This score includes three types of eye movements – SPEMs, saccades and fixations. Each is weighted in accordance to a linear combination of oculomotor variables. A significant positive change in this score reveals an overall improvement in oculomotor behavior.
Improvement in the FVEQ score is further supported by a significant reduction in overall symptoms as shown on the NSI. The total score revealed statistically significant differences for main effects (group, time) and more importantly for the interaction of group and time. The results reveal that participants who engaged in the eye movement training had an overall reduction in symptoms using the 4-Factor analysis. Furthermore, when specifically asked to rate their overall symptoms pre and post, the results were consistent with the NSI total score. Adding further validation to the belief that participants “felt better” after engaging in oculomotor training.

The FVEQ score, total NSI score and Overall Symptoms question (Q23), collectively reveal a broad improvement not only in the oculomotor variables, but also in self-reported symptoms. This is a critical link in intervention research. In other words, it is important to show oculomotor change, however, from a participants’ perspective it is perhaps more important that the changes in oculomotor behavior have ‘real life” impact to their quality of life and activities of daily living.

A secondary objective of this study was to accurately and specifically quantify change in SPEMs using eye tracking. The eye tracking technology employed in this study allowed for specific location recording of SPEM in relation to the target. Results revealed a significant interaction between the groups in all three SPEM metrics (on-target, latent and predictive). Although no main effects were found for the IG all metrics were trending in the right direction. Results showed a reduction in latent and predictive SPEM and an increase in on-target SPEMs. In contrast, the CG, without any intervention, showed increases in poor SPEM behavior. This was seen by increases in latent and predictive SPEMs and decrease (4.77%) in on-target SPEMs. This finding was important in two respects. First, if no oculomotor training is engaged in when a
Oculomotor Training Improves Vision & Symptoms

person has poor SPEMs they continue to decline. Second, if oculomotor training is engaged in this stops the decline and moves the SPEM behavior is a desirable, improved, direction.

A third objective of this study was to examine a patients’ neurobehavioral symptoms before and after oculomotor training using the Neurobehavioral Symptom Inventory (NSI; Cicerone, 1995). In addition to the total NSI score and Overall Symptoms question (Q23), the analysis revealed significant differences in all 4-factors.

The first factor, classified as Vestibular consisted of questions relating to dizziness, poor balance and coordination. VOR, fixations and pursuits are all in the functional class of eye movements that stabilize gaze and keep images steady on the retina (Leigh and Zee, 2015). Therefore, lesions in brain areas associated with these eye movements will result is neurobehavioral symptoms for factor 1: Vestibular.

Vestibular symptoms are affected by poor pursuits if there is a brain lesion is starting from the level of the medial vestibular nucleus because vestibular and pursuit pathways are shared from this point forward (Wong, 2008). VOR and gaze stability (fixations) also affect vestibular related neurobehavioral symptoms. Therefore, future research should look to specifically examine eye movement metrics related vestibular symptoms when engaged in this eye movement training protocol.

The second factor, classified as Somatosensory consisted of questions relating to headaches, nausea, vision, sensitivity to light and noise, numbness, changes in taste. Results for Somatosensory factors were also highly significant. The third factor classified as Cognitive consisted of questions relating to poor concentration, forgetfulness, difficulty making decision and slowed thinking. Results obtained from the NSI revealed significant main effects and interactions for the Cognitive factor. Hence, future research should look to examine metrics
related to saccades when engaged in this eye movement training protocol. Saccades are associated with a variety of Cognitive and Somatosensory neurobehavioral symptoms.

The fourth factor classified as Affective consisted of questions relating to fatigue, difficulty falling asleep, feeling anxious, feeling depressed, irritability, poor frustration. Results obtained from the NSI revealed significant main effects and interactions for the Affective factor.

Emotional lability, including increased frustration, impulsiveness and a quickness to anger have been linked to frontal lobe areas of the brain that are also associated with saccadic eye movements. Yoshida, et al., (2012) observed that eye movement training that consistent of various eye movements (e.g. fixations, pursuits and binocular training) showed remarkable decreases in other eye movements (e.g. saccades). Hence the neurological pathways for some eye movements overlap. The resulting neurobehavioral symptoms may also overlap, especially if that symptom is of a broad nature, such as a brain “fog”.

In conclusion, this study examined the pre and post score of SPEMs in relation to an eye movement training protocol. Results showed improvements in SPEMs as well as decline in the CG who did not engage in oculomotor training. Furthermore, the NSI confirmed that the eye movement training reduced neurobehavioral symptoms significantly. Future research should examine other eye movements in relation to this oculomotor training regime.
Oculomotor Training Improves Vision & Symptoms

References


Dretsch, Bleiberg, Williams, Caban, Kelly, Grammer, & DeGraba. (2016). Three scoring approaches to the Neurobehavioral Symptom Inventory for measuring clinical change in service members receiving intensive treatment for combat-related mTBI. *J Head Trauma Rehabil,* 31(1), 23–29. https://doi.org/10.1097/HTR.0000000000000109


Oculomotor Training Improves Vision & Symptoms


Oculomotor Training Improves Vision & Symptoms

