THEME ARTICLE

Neuro-Optometric Rehabilitation Accelerates Post-Concussion Syndrome Recovery in a Professional Athlete – A Case Report Presenting a New Paradigm

Steven J. Curtis OD, FCOVD, FNORA
Riverview Eye Associates, OhioHealth Rehabilitation Hospital, Columbus Crew SC

ABSTRACT

Background: Optometrists are becoming increasingly instrumental in the care of brain injured patients. Within the profession of optometry, a segment of optometrists has become highly trained and skilled in rehabilitation of vision dysfunctions and therefore is integral in the interdisciplinary management of a patient's overall recovery from acquired brain injury. No system provides more neurosensory input to the brain than vision. Therefore, optometry has an obligation to and is best prepared to provide this area of care referred to as neuro-optometric rehabilitation.

Case Report: A professional soccer player suffered a head injury during competition. He was diagnosed with a mild traumatic brain injury (concussion) and was unable to obtain complete resolution of symptoms despite current standard return-to-play protocol administered by the team medical staff. Symptoms included intermittent blurred vision during movement, mild photophobia, and feeling somewhat "not present". The team medical staff included a sports medicine physician, head athletic trainer/physical therapist, and a neuropsychologist. Neuro-optometric consultation was requested for the athlete by the team physician to determine if vision dysfunction was contributing to the athlete's persistent symptoms. He was diagnosed with vision dysfunctions presumably associated with the concussion and neuro-optometric rehabilitation was prescribed.

Conclusion: The clinical findings and treatment in a case of post-concussion syndrome involving associated vision dysfunctions are described. Neuro-optometric rehabilitation utilizing a unique paradigm remediated the vision dysfunctions of the athlete and eliminated his post-concussion symptoms. This in turn facilitated his return-to-play process. The paradigm applied began with passive, input-based, bottom-up therapy accompanied by gradual introduction of active, output-based, top-down techniques. In recent years, this author has found this paradigm to be more effective than a top-down approach when non-oculomotor based vision dysfunctions are included in the post-concussion patient clinical findings.

Correspondence regarding this article should be emailed to Steven J. Curtis OD, FCOVD, at curtisten@sbcglobal.net.

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BACKGROUND

Concussion is a mild traumatic brain injury that can occur with or without the presence of impact to the head. It can result in anything from loss of consciousness to impaired cognitive, functional, or physical abilities. Estimated incidence rates for concussion, according to the Centers for Disease Control and Prevention, range from a conservative 300,000 per year to a more liberal and recent estimate of 3.8 million cases in the United States annually.[1]

Post-concussion syndrome (PCS) is a set of symptoms that may continue for weeks, months, a year or more after a concussion.[2,3] The incidence of PCS varies, but most studies report that about 15% of individuals with a history of a single concussion develop persistent symptoms associated with the injury. A history of multiple concussions appears to increase the risk for post-concussion syndrome.[4]

It is likely that many of these symptoms of PCS are, in part, a result of compromised processing of sensory inputs, including visual.[5] Recent research indicates that due to widespread distribution of brain pathways dedicated to vision, vision-based performance testing enhances sideline concussion assessment.[6] This would therefore promote earlier detection and treatment of concussion which in turn decreases the risk for developing PCS. According to Ellis, et al, the findings of vestibular-ocular dysfunction at initial consultation is an independent predictor for the development of PCS in sports related concussions of pediatrics.[7]

A review of the literature reveals that there is not a well-established, broadly-accepted treatment for PCS symptoms. There remains a lack of evidence-based treatment strategies. However, some individuals benefit from several interventions depending on the particular presenting signs and symptoms. The most common treatment options that are effective consist of medications, physical therapy, early education,[8,9] cognitive behavioral therapy,[10] and aerobic exercise therapy.[11] Research has shown that optometric vision therapy should be included in the overall treatment as it provides improvement in post-concussion vision problems.[12] Therefore, a neuro-optometric rehabilitation evaluation can be an instrumental component to the return-to-play process for an athlete.

This paper will propose that optometric rehabilitation providers who treat PCS patients should identify whether the patient would be best served utilizing a "top-down" or a "bottom-up" therapeutic approach. To help make this decision, a differentiation between oculomotor-based vision dysfunctions and non-oculomotor-based vision dysfunctions is presented which will help direct the provider toward the appropriate approach in each case.

Neuro-optometric rehabilitation is a therapy service provided by specially trained optometrists which utilizes therapeutic prisms, lenses, filters, occlusion, and vision therapy to help stimulate visual pathways of the brain which are not functioning properly due to brain injury. Return-to-play refers to criteria that an athlete must satisfy before returning to play. The three conditions required are 1) asymptomatic status at rest, 2) asymptomatic status with physical and cognitive exertion, and 3) intact neurocognitive function (either compared to baseline or normative data). Once the athlete is symptom free under these conditions, he or she may return to full-contact training, then to competition. If symptoms return during full participation, the athlete should return to a previous stage of the return-to-play process.[13]

CASE REPORT

A 22-year-old white male professional soccer athlete was referred by his team physician for a neuro-optometric evaluation 33 days post-concussion. The athlete had a history of one concussion three years prior from which his symptoms resolved completely in five days. Persistent symptoms from his

Table 1. Summary of clinical test results before and after treatment.

Test	Pre-treatment	Post-treatment	Population Norms
Uncorrected Visual Acuity at Distance	OD: 20/20- OS: 20/25 (PH: 20/20)	OD: 20/20- OS: 20/25 (PH: 20/20)	Not applicable
Presenting Spectacle Rx	None	None	Not applicable
Refraction	OD: +.25 -1.00 x 096 OS: +.75 -1.25 x 024	OD: +.25 -1.00 x 096 OS: +.75 -1.25 x 024	Not applicable
Cover Test	Distance: Ortho Near: 3 esophoria	Distance: Ortho Near: 2 esophoria	Distance: 1 exophoria Near: 3 exophoria
Bar Vergences at Distance	Base Out: x/12/10 Base In: x/6/4	Base Out: x/18/16 Base In: x/6/4	Base Out: 9/19/10 Base In:x/7/4
Bar Vergences at Near	Base Out: x/25/20 Base In: 12 to blur	Base Out: x/25/20 Base In: x/12/10	Base Out: 17/21/11 Base In: 13/21/13
Vergence Facility at Distance	4 BI/Plano: 0 cyc/30" 8 BO/Plano: 3 cyc/30"	4 BI/Plano: 2 cyc/30" 8 BO/Plano: 6 cyc/30"	Not available
Vergence Facility at Near	8 BI/Plano: 3 cyc/30" 15 BO/Plano: 4 cyc/30"	8 BI/Plano: 6 cyc/30" 15 BO/Plano: 6.5 cyc/30"	Not available
Near Point of Convergence	7 cm	6 cm	</= 7cm
Near Point of Convergence (red/green)	14.5 cm	8 cm	Less than 10cm
Stereo Fly at Near	80 seconds	60 seconds	40"
Maddox Rod Vertical	Ortho	Not tested	ortho
Accomodative Amplitude	OD: 6 D OS: 5D	OD: 11 D OS 10 D	Age expected: 10.5 D
Accomodative Facility +/-1.50	6 cyc/30" OU	6 cyc/30" OU	Not available
Groffman Line Tracing	0 points, age 7	37 points, age 12 (test maximum)	Expected: age 12 (max for test)
Visagraph	Reading Rate: 100#'s/min Fixations: R 200/100 #'s L 198/100 #'s	Reading Rate: 158 #'s/min Fixations: R 122/100 #'s L 122/100 #'s	Not available for # card
Visual Midline Shift	Sitting: 0-5 degrees left Standing: 10 degrees left	Sitting: 0-5 degrees left Standing: 0-5 degrees left	Sitting: 0-5 degrees Standing: 0-5 degrees
Vestibular-Ocular Reflex using Dynamic Visual Acuity	20/25 OU, Slight blur; no HA or nausea	20/20 OU, no blur; no HA or nausea	No blur beyond static acuity level nor symptoms
Functional Visual Fields Blue	OD: 17 degrees OS: 19.3 degrees	OD: 19.5 degrees OS: 20 degrees	>/=20 degrees
Test of Information Processing Skills	Visual Modality: 21st percentile Delayed Recall: 63rd percentile	Visual Modality: 50th percentile Delayed Recall: 99 th percentile	Not applicable
VEP amplitudes 32 x 32 monocular p100 pattern reversal; Hc=85% Lc=15%	OD Hc 5.2uV Lc 4.2uV OS Hc 4.2uV Lc 2.5uV	OD Hc 6.1uV Lc 3.5uV OS Hc 5.4uV Lc 2.8uV	Hc >/=6uV Lc not available

recent concussion included intermittent blurred vision during movement and mild photophobia. He further described feeling somewhat "not present." He denied difficulties with reading, concentration, headaches, imbalance, dizziness, memory, hyperacusis, and diplopia.

Interventions for the athlete prior to optometric involvement included physical therapy, aerobic exercise therapy, and chiropractic treatment. Although these interventions provided some benefits, his symptoms persisted. Medical and neuropsychological testing was essentially negative for pertinent factors.

DIAGNOSES AND PLAN

Diagnoses from the neuro-optometric evaluation (see Table 1 for supportive test data)

Table 2. Summary of therapy techniques and order of use throughout the athlete's vision rehabilitation program.

Day	Bottom-up Passive Therapy (in-office)	Top-down Active Thearpy (in-office)
1	Optometric phototherapy (OP) using one color, lateral canal vestibular stimulation, auditory training	monocular and binocular horizontal pursuits
2	OP using three colors, posterior and anterior canal vestibular stimulation, auditory training	monocular and binocular vertical pursuits
3	OP using three colors, lateral canal vestibular stimulation, auditory training	monocular and binocular horizontal pursuits
4	OP using three colors, posterior and anterior canal vestibular stimulation, auditory training	monocular and binocular vertical pursuits monocular 4-corner wall saccades, clock dial saccades, Percon mazes level 1
5	OP using four colors, lateral canal vestibular stimulation, auditory training	monocular and binocular horizontal pursuits monocular arrow wall saccades, clock dial saccades, Percon mazes level 1
6	OP using four colors, posterior and anterior canal vestibular stimulation, auditory training	monocular and binocular vertical pursuits, monocular 4-corner wall saccades, clock dial saccades, Percon mazes level 1
7	OP using six colors, lateral canal vestibular stimulation, auditory training	binocular horizontal pursuits binocular arrow wall saccades, clock dial saccades and peripheral awareness, Percon mazes level 1
8	OP using six colors, posterior and anterior canal vestibular stimulation, auditory training	binocular vertical pursuits binocular 4-corner wall saccades, clock dial saccades and peripheral awareness, Percon mazes level 2 +/-.25 lens flipper at near 2 BO and BI loose prism fusion at 15 ft
9	OP using six colors, lateral canal vestibular stimulation, auditory training	binocular horizontal pursuits binocular arrow wall saccades with tandem stance, clock dial saccades and peripheral awareness, Percon mazes level 2 +/-.50 lens flipper at near 4 BO and 2 BI loose prism fusion at 15 ft
10	OP using six colors, posterior and anterior canal vestibular stimulation, auditory training	binocular vertical pursuits binocular 4-corner wall saccades with tandem stance, clock dial saccades and peripheral awareness, Percon mazes level 2 +/-.50 lens flipper 6 BO and 2 BI loose prism fusion at 15 ft
11	OP using six colors, lateral canal vestibular stimulation, auditory training	binocular horizontal pursuits binocular arrow wall saccades balancing on one foot, clock dial saccades and peripheral awareness, Percon mazes level 2 +/-1.00 lens flipper 8 BO and 4 BI loose prism fusion
12	OP using six colors, posterior and anterior canal vestibular stimulation, auditory training	binocular vertical pursuits binocular 4-corner wall saccades balancing on one foot, clock dial saccades and peripheral awareness, Percon mazes level 2 +/-1.00 lens flipper 8 BO and 4 BI loose prism fusion
	HOME THERAPY ONLY BEGINS	
13-30	home OP twice daily using one color; NO further vestibular or auditory training	head rotation pursuits and 4-corner saccades at training facility while team trainer guided return-to-play exercise and gradual training advancement

included convergence and accommodative dysfunctions which likely provided the symptom of intermittent blurred vision;[14,15] pursuit eye movement dysfunction, saccadic eye movement dysfunction, visual midline shift, and vestibular-ocular reflex (VOR) dysfunction contributed to the symptoms of intermittent blurred vision and "not feeling present";[16,17,18] and constricted functional visual fields (green, red, blue) which contributed to both the "not feeling present" symptom and photophobia.[19] Neuro-optometric rehabilitation was ordered with the intent of the athlete regaining visual efficiency and sensorimotor skills for functional performance improvement applicable to his safety during soccer and daily life activities. Goals included age-normed binocular vergence ranges, accommodative efficiency and flexibility, age-appropriate oculomotor skills, midline shift to 5 degrees or less while standing, and non-constricted functional visual field each eye. All members of the team medical staff (head physician, neuropsychologist, and athletic trainer/physical therapist) and this author would then convene at the training facility to re-establish a plan of care appropriate for the athlete's return-to-play process. The athletic trainer would execute this return-to-play workout protocol while in collaboration with his continued vision rehabilitation program.

TREATMENT AND OUTCOMES

The athlete's vision rehabilitation took place daily for 34 days and was comprised of saccade and pursuit oculomotor activities, vergence therapy, optometric phototherapy (syntonics), vestibular stimulation, and multisensory integration training. It consisted of 12 days of in-office therapy followed by 22 days of home therapy. Initial emphasis of therapy was passive utilizing optometric phototherapy, auditory training, and vestibular stimulation. Active therapy was minimal initially consisting of 5-10 minutes of monocular saccadic and pursuit oculomotor activities. Convergence therapy was gradually introduced as tolerated without aggravating symptoms. The saccadic, pursuit, and vergence activities increased in difficulty during the in-office phase of treatment, see Table 2. Balance activities were gradually added to further rehabilitate integration of sensorimotor pathways.

On day number seven, the athlete was seen for a progress evaluation. Although he reported that he had been experiencing symptoms of

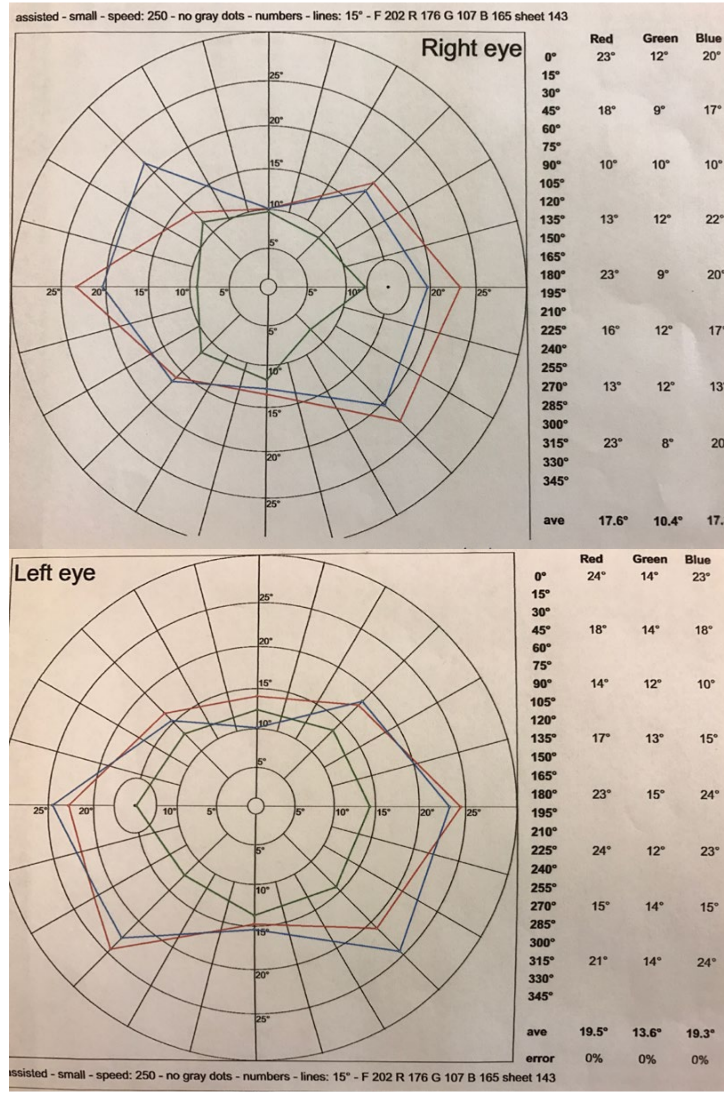

Figure 1: Functional color field results (blue, red, green) one day prior to initiation of therapy.

headache and fatigue during the first three days, now he was tolerating the therapy well. Clinically, he demonstrated improved vergence amplitudes at distance (BO x/15/12, and BI x/6/4), vergence facility at distance (8 BO/pl: 3 cyc/30"), near point of convergence (red/green: 10.5cm), and amplitude of accommodation (OD 9D, OS 8D). Additionally, his functional (color) visual fields expanded (see Figures 1 and 2). General consensus amongst optometric phototherapy providers is that when a small target is used (e.g. 1-2mm diameter), the expected color field sizes are a minimum of 20, 15 and 10 degrees for blue, red and green, respectively.[20] However, these should only be considered general guidelines by vision rehabilitation clinicians. There are several variables that impact performance on color

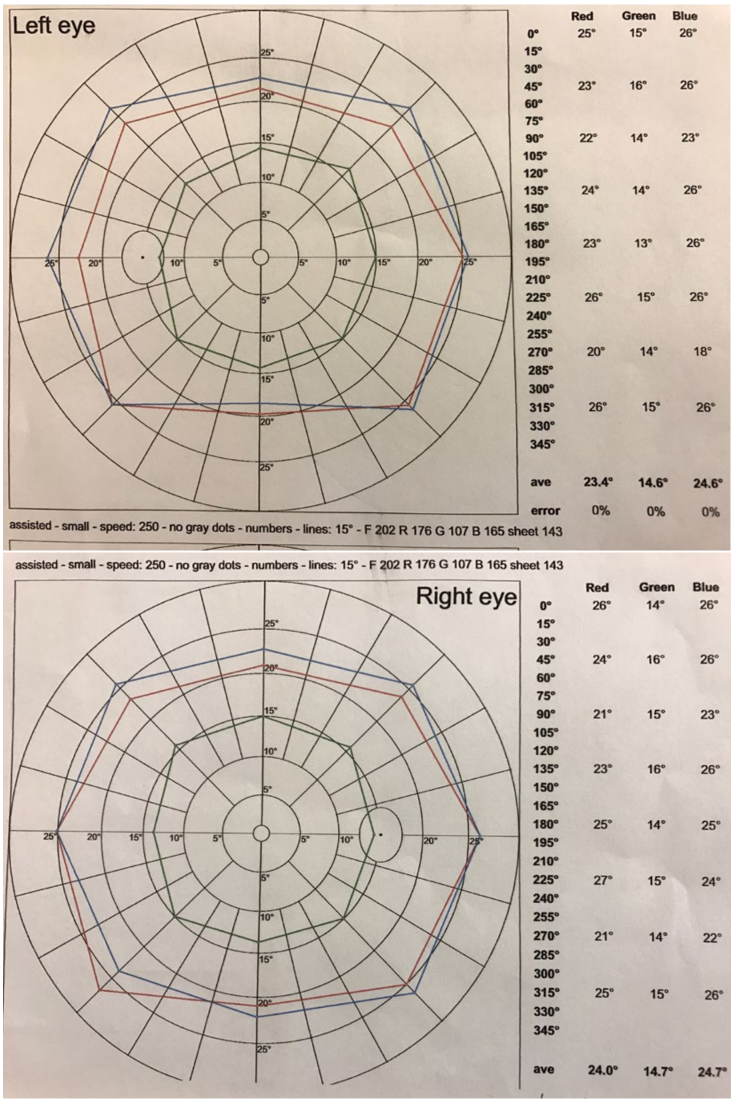

Figure 2: Functional color field results (blue, red, green) on day number 13 of therapy.

field testing, such as, patient fatigue, sensitivity, time of day, test environment, stimulus size and speed of presentation, and more.[21] This is likely the reason that the literature lacks establishment of definitive norms for functional visual fields. Moreover, therapy goals should include an expansion of color fields relative to pre-therapy. This provides the clinician a tool to monitor the effectiveness of the prescribed light and to make modifications if indicated. As shown in Figures 1 and 2, the athlete's blue color fields (average of eight meridians) improved 42% in right eye and 28% left eye indicating the current light sequence was appropriate to this point.

Home therapy activities were added and he continued coming for daily in-office sessions. Home therapy consisted of BI and BO prism fusion at 15 ft. progressing from 2BI/2BO to 4BI/8BO over several days. Additional home therapy included +/- .25 and then +/-.50 lens flippers at a 20/30 near point target.

On day number 13, the athlete was seen again for a brief progress evaluation. He stated that his blurred vision had completely resolved. He was very pleased with improved perception of his location in space and retrospectively realized this was what caused him problems when trying to play during initial return-to-play protocol prior to being referred for neuro-optometric management. Clinically, he had been gradually advancing in performance of therapeutic vergence and accommodation activities without increased symptoms. Treatment was transitioned from in-office to home-based optometric phototherapy combined with oculomotor activities at the team training facility assisted by the athletic trainer, under this author's direction. All providers of the team medical staff, including this author, convened the day after this appointment to collaboratively determine his continued plan of care. Communication continued by phone or text nearly every day over the next three weeks regarding his progress. During this period, minor adjustments were made to his home vision rehabilitation activities to gradually increase therapy complexity.

Thirty-four days after initiation of therapy, the athlete was seen for an extensive vision rehabilitation progress evaluation. He stated his "vision is fantastic" and he felt "fully present". His photophobia had resolved. All clinical testing revealed findings either at or near goals as shown in the post-treatment column of Table 1. These findings were shared by phone consultation with the team physician and resulted in a decision that the athlete would resume return-to-play protocol. Goals included partial game participation in 11 days and full game participation in 18 days if symptoms remained absent. The athlete's vision rehabilitation was discontinued and he was advised to return for monitoring in four weeks. At that evaluation he remained symptom-free and clinical testing confirmed he had maintained clinical measures similar to his prior visit. He was able to continue full playing time in his team's remaining 19 games of the season and was selected for and participated on the league all-star team two months after completion of vision rehabilitation.

DISCUSSION

This case introduces a paradigm of optometric vision rehabilitation to consider when a PCS patient presents with non-oculomotor based vision problems. Non-oculomotor based vision symptoms include motion sensitivity, mental clarity issues, photophobia, dizziness, nausea, and visual information processing deficits.[22] In this author's experience, PCS patients who present with non-oculomotor based vision symptoms recover more efficiently and holistically when a bottom-up to top-down therapeutic approach is employed. In this context, bottom-up refers to therapy that is subconscious-based and targeted at brainstem function, whereas top-down therapy expects the patient to provide cognitive receptiveness to instruction of activities and provide an output response (e.g. motor action). A conventional top-down model is reserved for concussed patients who present with strictly oculomotor based vision problems (vergence, accommodative, saccadic, and pursuit dysfunctions). A clinical guide by D'Angelo and Tannen describes this traditionally successful model.[23]

However, many PCS patients are too sensitive to tolerate and gain from an approach that begins with active/output-based, high-complex vision therapy. Top-down therapy involves conscious and intentional mental processing at the level of the cerebral cortex.[24] Chang, Cohen, and Kapoor describe top-down visual processing as voluntary and strategic, whereas, bottom-up is reactive and involves the brain's reception of information from sensory inputs.[25] Peachy and Peachy refer to bottom-up and top-down visual pathways as subconscious/subcortical and purposeful/cortical, respectively. They state that initially, vision rehabilitation in traumatic brain injured patients may need to address dysfunctional subcortical collicular and multisensory pathways. Then oculomotor deficits can benefit from therapeutic procedures that require visual direction, followed by perceptual accuracy treatment.[26]

This is exemplified in PCS patients who present with complaints of mental fatigue. They spend so much of their daily energy supply on deliberate compensation for their injury-based brainstem inefficiencies that their executive, output-based processing becomes exhausted likely resulting in foggy-headedness/mental fatigue. This diversion of cortical resources is exhibited in the functioning of the prefrontal cortex (PFC). The PFC, which accounts for about 30% of the frontal lobe, is a large collection of interconnected sub-regions that send and receive direct projections from structures throughout cortical and subcortical regions of the brain. The PFC organizes and executes intentional behavior through top-down processing "in situations when the mapping between sensory inputs, thoughts, and actions are weakly established,"[27] such as when an individual suffers with PCS.

Based on research in neuroplasticity,[28] Chang, Cohen, and Kapoor promote use of top-down processing therapy to increase function and decrease symptoms in TBI patients. However, while this is a valid concept for many PCS patients, they do not exclude use of it on the hypersensitive/ highly symptomatic patients. A top-down therapy approach assumes the patient is ready for motor output demands such as saccades, pursuits, vergences, and accommodation. Too often the patient with PCS "pulls back", contorts their face, breaks into a cold sweat, alters their breathing, or completely resists the sensory-motor activity. The patient needs to first regain sensory tolerance and regulation foundationally in the brainstem before attempting to rehabilitate oculomotor skills.

Therefore, a proposed treatment paradigm for patients presenting with non-oculomotor based symptoms is one that begins with passive, sensory input-based … bottom-up therapy. According to Taylor, et al, bottom-up therapy mechanisms influence central neural processing activities via ascending pathways from the periphery to the brainstem and then the cerebral cortex. Although concussion usually occurs after a blow to the head, it can also be the result of inertial linear and rotational acceleration/deceleration forces without impact to the head. Cortical gray matter is more susceptible to damage from linear forces. Rotational forces are more likely to affect axonal tracts within the brainstem[29] resulting in disruption of the electrophysiological and subcellular activities of the neurons of the reticular activating system. Damage here often occurs from rotational forces exerted during an oblique whiplash.[30] Whiplash is a common traumatic injury in sports activities and estimated to occur in a high percentage of soccer players.[31]

The purpose of starting with a bottom-up emphasis is to help restore brainstem function, particularly autonomic nervous system imbalance and multisensory integration dysfunction. Multisensory integration describes a process by which an intact, well developed brain is able to integrate information from multiple sensory pathways and modulate these inputs for optimal identification of and reactivity to environmental events. All brains engage this strategy at multiple levels of the neuraxis,[32] however, most researchers believe it begins in the thalamus and midbrain regions. For example, the superior colliculus houses the initial processes that are involved in receiving converged multiple sensory inputs before integration even occurs.[33] Dysfunction in these areas needs to be remediated to allow successful cortical processing and subsequent executive function. Further appreciation of this can be construed from the fact that our nervous system has many more sensory fibers and sensory pathways (input) than motor (output) fibers.[34]

In this case, the bottom-up protocol utilized was what this author refers to as optometric phototherapy-based multisensory training (OPMST). This involves simultaneous application of optometric phototherapy, vestibular stimulation, auditory stimulation, and gradually applied oculomotor therapy as tolerated. This multisensory integration training spreads the therapy amongst several sensory systems creating opportunity for the stronger systems to support the weaker systems[35] until all reach the balanced and synergistic status that existed before the brain injury. Patient gains are uniquely quick, relatively consistent, and comprehensive especially on patients who have hit a plateau in their PCS recovery.

Optometric Phototherapy, also known as Syntonic Optometry, is the application of light through the pupil to the retinal blood supply and to retinal photoreceptors. It is a method of neuromodulation using photo-transduction – photons of light activating a graded change in membrane potential and a corresponding change in the rate of transmitter release onto postsynaptic neurons.[36] It is a noninvasive use of prescribed light frequencies to treat injury and diseases of the nervous system including visual dysfunction, brain injury and imbalanced autonomic nervous systems.[37,38] As the photonic energy of the light stimulates the biochemistry of the brain, it can re-energize many neural pathways including visual, vestibular, auditory, brainstem nuclei, and glands including the hypothalamus, the pineal, the pituitary, and more. The colored light filter sequence ulitized in this case was magenta, ruby, red, yellow-green, blue-green, violet, and magenta once again. This order of light frequencies was determined based on integration of principals taught by the College of Syntonic Optometry, the Sensory Learning Institute, and readings

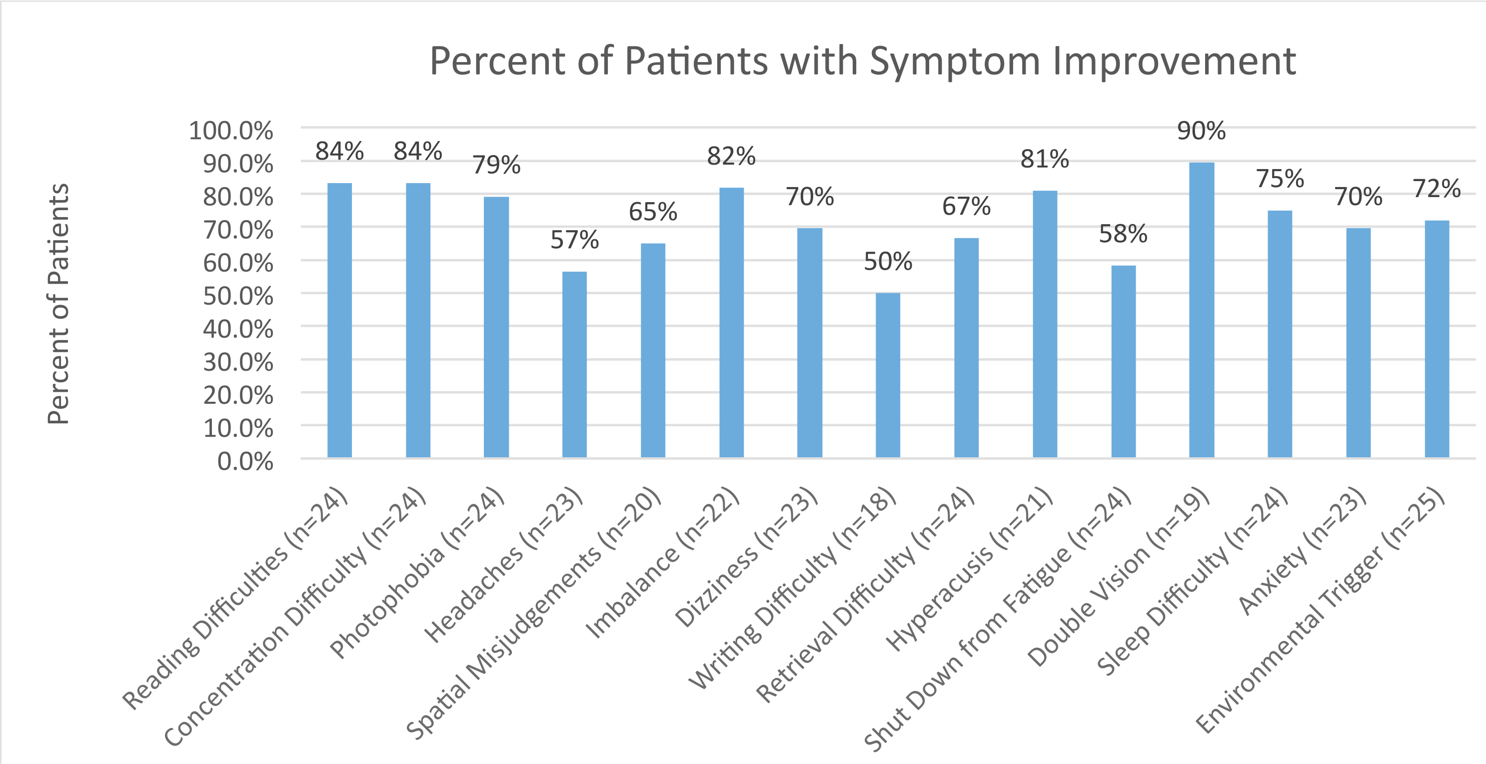

Figure 3: Percentage of patients reporting improvement for each symptom.

from the works of Dr. Edwin Babbit and Dr. Dinshah Ghadiali, 19th and 20th century pioneers in the use of light therapeutically.[39]

The vestibular stimulation is achieved by slow and gentle 7″ circular rotation of the patient in supine position on a trochoidal motion table. The patient's horizontal position is alternated daily so that stimulation of both the anterior/posterior and the lateral semi-circular canals is achieved.

The auditory stimulation is comprised of tracks of unfamiliar music that is randomly attenuated and has pre-determined frequencies filtered out. The specific program utilized is The Sensory Learning Acoustic Training Program created by Mary Bolles based on the work of French physicians Alfred Tomatis and Guy Berard.

This author hypothesizes that the success of OPMST is based on the optometric phototherapy energizing neural transmission throughout the integrative pathways in the midbrain at the same time that oculomotor and vestibular inputs arrive. Additionally, optometric phototherapy likely improves the flow of neural energy through the magnocellular pathway and dorsal stream enhancing parietal lobe function. This, in turn, provides the patient with improved spatial awareness of and anchoring in their environment creating improved cortical visual processing available for integration and eventual top-down therapy. This allows development of more accurate and efficient production of motor output including posture, balance, and eye movements thereby reducing related PCS symptoms, both oculomotor-based and non-oculomotor-based. The end result will be re-establishment of a synchronized relationship between top-down and bottom-up processing.

In a retrospective study using OPMST on PCS patients, 84% of patients reported substantial improvement in a majority of their symptoms (including oculomotor based and non-oculomotor based symptoms) within 38 days[40] (see Figure 3). These broad spectrum gains represent the unique rehabilitative opportunity optometry can provide via stimulation to the widely distributed and integrated visual pathways of the brain.

Table 3. SCAT3 symptom survey results at 38 days post initiation of treatment. N=54 consecutive patients.

Symptom	Number of patients reporting symptom pre-treatment	Percentage of patients reporting improvement in symptom at 38-day followup	Average amount of change for the group reported at 38-day follow up (in percentage)
1. Headache	45	65	30
2. Pressure in the head	41	74	38
3. Neck Pain	43	67	30
4. Nausea or Vomiting	27	78	63
5. Dizziness	42	74	51
6. Blurred Vision	40	75	47
7. Balance Problems	43	70	44
8. Sensitivity to the Light	49	78	46
9. Sensitivity to Noise	45	78	42
10. Feeling slowed down	50	80	53
11. Feeling in a Fog	43	81	58
12. Don't feel Right	51	76	52
13. Difficulty concentrating	49	88	47
14. Difficulty remembering	48	65	21
15. Fatigued or low energy	49	80	45
16. Confusion	43	88	42
17. Drowsiness	42	86	51
18. Trouble falling asleep	40	78	46
19. More emotional	39	72	31
20. Irritability	42	83	44
21. Sadness	35	71	53
22. Nervous or Anxious	46	67	28

This author also considers filters, bi-nasal occlusion, yoked prism therapy and lens therapy as bottom-up techniques and finds them to be effective alone or as adjuncts to OPMST. However, vision rehabilitation of the PCS patient has been significantly more efficacious when OPMST is utilized as the initial modality.

Moreover, this case provided this author with an appreciation of a widely used concussion symptom survey, the Sports Concussion Assessment Tool, third edition (SCAT3).[41] It measures a global range of self-reporting symptoms and was employed by the athlete's team physician to assist with monitoring the player's concussion recovery. Since this case, this author has included the SCAT3 symptom survey for all PCS cases treated in his clinic. Results exhibited in Table 3 further support that this bottom-up treatment approach is comprehensive and that the SCAT3 can be a useful tool for neuro-optometrists treating concussion patients.

CONCLUSION

This case report exemplifies optometry's continued growth in recognition as a credible intervention for brain injury. The medical personnel of a professional soccer team requested neuro-optometric services for this athlete due to prior successful cases. It also presents an alternative paradigm for neuro-optometric rehabilitation when non-oculomotor vision dysfunctions are involved. If subcortical/brainstem damage is suspected or known, as with many of the non-oculomotor vision dysfunctions, the initial phase of therapy should be heavily weighted with passive sensory input-based techniques. This is then followed by a gradual addition of active output based techniques as tolerated such as oculomotor, accommodative, and vergence activities. In other words, a sensory input emphasis initially will better prepare the patient for optimal engagement in motor output.

Further study on this treatment paradigm is needed to provide evidence-based support that this bottom-up to top-down order of vision rehabilitation therapy facilitates the post-concussion patient's recovery when non-oculomotor vision dysfunctions are present. As this case report demonstrates, this paradigm potentially provides PCS patients broad resolution of symptoms in a relatively short period of time. Therefore, the patients return to work (and play) sooner.

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CORRESPONDING AUTHOR BIOGRAPHY:
Steven J. Curtis OD, FCOVD, FNORA

Dr. Steven J. Curtis is president of Riverview Eye Associates in Columbus, Ohio where he provides general, developmental, and neuro-optometric services. He is on the medical staff of the OhioHealth Rehabilitation Hospital and the professional soccer team, Columbus Crew. Dr. Curtis is a Fellow of COVD and NORA. He lectures to area physicians and therapists on neuro-optometric involvement in rehabilitation. Dr. Curtis works extensively with patients who suffer persistent vision disturbances after concussion including athletes from professional teams of the MLS and NHL.