ARTICLE

Optometric Management of Sports-related Post-concussion Visual Symptoms in Teenagers with Vision Therapy: A Case Series

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ABSTRACT

Background: Sports-related concussions are among the most common causes of mild traumatic brain injury (mTBI) in children and young adults. Post-concussion visual problems include: changes in refractive status, binocularity, accommodation, ocular motility, visual processing, and vestibular-visual interaction. Modifications to the traditional optometric exam, use of prisms, lenses, binasal occlusion, tints, filters, and a sequence of in-office vision therapy (VT) can successfully rehabilitate the visual symptoms and improve the quality of life (QoL) for this very unique patient population.

Case Reports:

1) A 14 year old male presented with a history of a concussion from soccer. His symptoms included headaches, decreased concentration, difficulty copying form the board and difficulty transitioning from near to far activities. Clinical testing revealed an accommodative and oculomotor dysfunction (OMD). He was prescribed BU yoked prism glasses and vision therapy.
2) A 16 year old female presented with a history of two sports-related concussions from cheerleading. Her symptoms included headaches, blurry vision at near and difficulty keeping her place when reading. Clinical observation revealed OMD and accommodative insufficiency. She was prescribed reading glasses to relieve visual stress when reading while she completed vision therapy.
3) A 19 year old female presented with a history of multiple sports concussions while playing collegiate soccer, which resulted in headaches that became worse when reading, decreased reading stamina and difficulty keeping her place when reading. Clinical observation revealed accommodative insufficiency, binocular dysfunction and OMD. She was prescribed reading glasses and vision therapy.

Conclusion: This case series outlines the exam procedures and therapy techniques used to manage three teenagers with post-concussive visual disorders. Symptoms such as blurred vision, headaches and difficulty reading can profoundly affect activities of daily living (ADLs). Optometric examinations

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and management through the use of prisms, tints, reading glasses, and in-office vision therapy can successfully resolve these visual complaints. Each patient described completed 10-12 sessions of in-office vision therapy [over a span of four to eight months], with home re-enforcement, and graduated with marked improvement of their visual signs and symptoms.

INTRODUCTION

As of 2010, the Centers for Disease Control (CDC) reported approximately 2.5 million cases of traumatic brain injury reported to emergency departments per year.[1] Over 75% of traumatic brain injury cases are considered mild traumatic brain injury (mTBI).[2] The CDC also reports that 65% of brain injuries occur in children ages 5-18, with the majority being males ages 10-18.[2] According to the Centers for Disease Control, a concussion, which is a mild form of mTBI, is "a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces."[2] A mild TBI includes one or more of the following: 1) loss of consciousness lasting 0-30 minutes; 2) post-traumatic amnesia (not required); 3) transient confusion, disorientation, or impaired consciousness; and 4) symptoms such as headache, dizziness, or fatigue.[2] Brain injuries can result in diffuse axonal injury (DAI) as a result of biomechanical forces and/or changes in cytotoxic processes following injury. Damage to the axons can cause alterations in neurotransmitter production and delivery. Damage from the injury can lead to atrophy or white matter changes. Functional magnetic resonance imaging (fMRI) can be used to detect metabolic changes in more severe forms of TBI. Diffusion tensor imaging (DTI) can detect changes in the white matter by looking at alternations in three dimensional water displacement caused by damage to the axons. Diffusion tensor imaging has been shown to detect changes in less severe forms of TBI, and may be a more useful tool when looking at mTBI cases.[4]

The number of sports-related concussions presenting to emergency departments as of 2011 was 248,418, a 62% increase from 2009.[3] Unfortunately, these numbers are likely a gross underestimate as there are approximately 1.6-3.8 million sports-related concussions where no immediate attention post-injury is sought.[3] The sports with the highest rates of concussion were football, basketball and soccer.[3] Due to the large number of children affected by concussions, the CDC and other public health organizations are working on strategies to reduce the risks of brain injury as well as the number of injuries that occur each year. As a part of brain injury awareness, sports teams are urged to implement sideline concussion screenings and return to play strategies. The CDC recommends that athletes with concussions or suspected concussions are screened on the sidelines, removed from play and evaluated by a healthcare professional before returning to play. Return to play decisions are often based on resolution of post-concussion signs and symptoms. Proper post-concussion rest time and strict return to play guidelines help reduce the risk of delayed healing, long-term sequelae and the risk of second impact syndrome. Second impact syndrome is a serious and possibly life threatening condition that occurs when a person suffers from a second concussion while still healing from the first.[3]

Many patients who have suffered a concussion or mTBI have lasting symptoms, known as post-concussion syndrome. Symptoms include headache, dizziness, visual disturbances, cognitive impairments such as attention, memory and executive dysfunction, and emotional and behavioral problems. A majority of patients will recover in the first year but approximately 1-20% of patients can have lasting symptoms that extend beyond the one year mark.[4] Prognosis is dependent upon the number of concussive events, a history of TBI, previous

visual or vestibular dysfunction, past medical history and period of cognitive rest prior to returning to school or work. Immediately following a concussion, patients are often removed from play and prescribed cognitive rest to give their brain a chance to heal. Once this rest period is over, remaining residual symptoms can affect a patients activities of daily living (ADL) and quality of life (QoL). Patients with lasting post-concussion symptoms often undergo several different types of therapy including occupational, physical, speech, cognitive, vestibular and visual.[5]

Post-concussion syndrome often includes visual sequelae such as: binocular dysfunction, accommodative dysfunction, oculomotor deficits, photosensitivity, changes in refractive status, abnormal egocentric localization, visual-vestibular changes and visual processing deficits.[6] An optometric evaluation of patients following a concussion can help to identify deficits in the areas listed above. Visual dysfunctions secondary to concussions can be rehabilitated through the use of vertical and/or horizontal prisms, lenses, binasal occlusion, tints, filters and in-office vision therapy to help rebuild visual skills and reduce visual symptoms.

Table 1: Visual Symptoms Intake Questionnaire

Symptoms	Case 1	Case 2	Case 3
Blurred vision for distance viewing	x		
Blurred vision for near viewing	x		
Slow shift of focus from near to far to near	x	x	
Difficulty copying from the board	x	x	x
Pulling or tugging sensation around the eyes	x	x	
Discomfort when reading	x	x	x
Unable to sustain near work or reading for periods of time	x	x	x
General fatigue while work/reading	x	x	x
Loss of place while reading	x	x	x
Easily distracted when reading	x	x	
Eyes get tired when reading	x	x	x
Headaches when reading	x	x	x
Decreased attention span	x	x	
Reduced concentration ability	x	x	x
Difficulty remembering what has been read	x	x	x
Loss of balance	x		
Bothered by movement in the environment	x	x	x
Bothered by crowded environments	x	x	x
Light sensitivity	x	x	x
Dizziness		x	x
Sensation of the room spinning			x
Sensation of not feeling grounded			x

CASE REPORTS

Case 1

A 14 year old male presented for an eye exam after sustaining a sports-related concussion one month prior to his visit, while playing soccer. After his concussion, an MRI was performed; the results were negative. With his pediatrician's prescription for cognitive rest, he had taken a leave of absence from school for one month. He returned to school one week prior to his visit. Since the concussion, our patient noted: blurry vision when looking at distance after reading, difficulty copying from the board, decreased concentration, difficulty sleeping, and fatigue. He had been having headaches usually concentrated to the top of his head but sometimes spreading to the eyes. The headaches occurred several times per week and would range from a 3/10 to 10/10 on the severity scale. He noted that since returning to school his symptoms had increased. On his intake questionnaire he marked the following symptoms shown in Table 1.

His ocular history, systemic history and family history were all unremarkable other than the concussion. He was enrolled in eighth grade and doing well in school prior to the injury, but struggling since his return from the injury.

The patient had a comprehensive exam including a binocular workup, functional vision

Table 2: Case 1: Visual findings pre-and-post vision therapy (10 sessions)

Test	Pre-Vision Therapy	Post Vision Therapy
Distance visual acuity(sc)	OD 20/30 OD 20/30 OD 20/30	OD 20/20 OS 20/20 OU 20/20
Near visual acuity(sc)	OS 20/30 OD 20/30 OD 20/30	OD 20/20 OS 20/20 OU 20/20
Pupils	PERRLA-APD	PERRLA-APD
EOMs	Full range of motion	Full range of motion
Confrontation fields	Full to finger counting	Full to finger counting
Stereopsis	Global: 60" (Preschool stereo) Local:	Not assessed
Color vision (HRR#4)	Mild unclassified defect	Not assessed
Binocular Posture Cover test	Distance(sc): ortho Near(sc): 4 esophoria	Not assessed
NSUCO	Saccades Ability: 5 Accuracy: 3 Head & body movement: 4 Pursuits Ability: 3 Accuracy: 3 Head & body movement: 4	Saccades Ability: 5 Accuracy: 4 Head & body movement: 5 Pursuits Ability: 5 Accuracy: 5 Head & body movement: 5
DEM	Vertical: 34 sec, 30% Horizontal: 42.2 sec, 15% Error: 0 Ratio: 1.24, 17%	Vertical: 29 sec, 80% Horizontal: 35 sec, 60% Error: 0 Ratio: 1.20, 20%
Retinoscopy	OD: +0.25-1.00x180 OS: Plano-0.75x180 (fluctuating reflex)	Not assessed
Refraction	OD: Plano-0.25x180 20/20 OS: -0.25 SPH 20/20	Not assessed
Monocular accommodative facility (MAF)	+2.00/-2.00 OD: 0 cpm OS: 0 cpm unable to clear minus OD,OS	+2.50/-6.00 OD: 8cpm OS: 10cpm
Binocular accommodative facility (BAF)	+/-2.00 OU: 0 cpm Unable to clear minus	+/-2.50 OU: 11cpm (-)suppression
Monocular estimation method	Fluctuating between +1.00 to -1.00 OD,OS	Not assessed
Vergence	NPC: TTN Near: NFV: 4/12/8 PFV: 8/25/18	Not assessed
VO Star	60mm separation with central suppression	Not assessed
Anterior segment	Within normal limits OD,OS	Not assessed
Posterior segment	0.35 C/D OU	Not assessed
Visual field (30-2 Sita-Standard)	Within normal limits OD,OS	Not assessed

assessment and ocular health evaluation (Table 2). The patient had a previous history of concussion as per his pediatrician and was diagnosed with: oculomotor dysfunction (OMD) and a deficit in visual-verbal automaticity based on the DEM, deficiencies of pursuit eye movements based on the NSUCO Oculomotor Test and accommodative spasm. The patient and his mother were educated that these visual findings may occur following a brain injury and could be rehabilitated with vision therapy.

The patient decided to pursue vision therapy with the following goals: improve his eye movements to help with reading and decrease the frequency of losing his place, improve his blurry vision and improve concentration. During his first therapy session, our patient indicated that he felt as if the walls were slanted and he felt slightly off balance. He also noted light sensitivity, especially when reading. Small amounts of vertical yoked prisms were trialed to help with spatial orientation and balance. The patient tried one, two, three and four prism diopters of base up (BU) and base down (BD) prism OU and noted that with three prism diopters BU OU, he felt more grounded and didn't notice the walls slanting as much. Colored filters were also trialed to help with light sensitivity when reading. The patient tried blue, grey, purple, pink, yellow, green and brown filters and subjectively reported that yellow helped the most with reading. The patient was given a yellow filter to place over his reading material or computer for comfort, as well as a prescription for vertical yoked prism

Table 3: Case 1: Vision Therapy Activities

Category	Activity	Initial Performance	Final Performance
Fixation	Dive bombs	Level 1: 60% accuracy	Level 4: 90% accuracy
	Stick-in-straw	50% accuracy in primary gaze OD,OS	80% accuracy in primary gaze OD,OS
	Stationary pegboard	4-8 attempts per target OD,OS	<2 attempts per target OD,OS
Saccades	Hart chart	6 strips reading out to in	Full chart diagonally on walking rail
	Hart chart decoding	Number rows and columns	No numbers on rows or columns
	Wayne Saccadic Fixator	Setting 9.1 OD: 29, OS: 27	Setting 9.1 OD: 33, OS: 34, OU 40
	XO tracing	Level 1	Level 5
	VTS3 saccades	Medium arrows: OD: 95.26%, 0.82 RT* OS: 97.86%, 0.73 RT	Small arrows: OD: 96.1%, 0.99 RT OS: 96.43%, 0.89 RT
	CPT visual scan	1:30 sec/4 letters	0:19 sec/6 letters
Pursuits	Rotating pegboard	70% accuracy OD,OS	85% accuracy OD,OS
	Sherman Rotator		
	Connect the dots	Homework only	
	Mazes	Homework only	
Accommodation	Near/Far Hart chart	Near chart 12 inches OD, OS	Near chart 2 inches OD, OS
	Monocular accommodative rock	+0.50/-0.50 Unable to clear minus	+2.50/-6.00 OD: 8 cpm, OS: 10 cpm
	Binocular accommodative rock	+/-1.00 OU: 8 cpm	+/-2.50 OU: 11 cpm

Table 4: Case 2: Visual findings pre-and-post vision therapy (12 sessions)

Test	Pre-Vision Therapy	Post Vision Therapy
Distance visual acuity (sc)	OD $20/25^{+2}$ OS $20/25^{+3}$ OU $20/20^{-2}$	OD 20/20 OS 20/20 OU 20/20
Near visual acuity (sc)	OD 20/20 OS 20/20 OU 20/15	OD 20/15 OS 20/15 OU 20/15
Pupils	PERRLA-APD	PERRLA-APD
EOMs	Full range of motion	Full range of motion
Confrontation fields	Full to finger counting	Full to finger counting
Stereopsis	Global: 63″ Local: 20″ Random Dot Lea	Global: 63″ Local: 20″ Random Dot Lea
Color vision (HRR#4)	Normal	Not assessed
Binocular Posture: **Cover test** **Von Graefe**	Cover Test: Distance(sc): ortho Near(sc): 2 exophoria Von Graefe: Distance: 2 exophoria Near: 3 exophoria	Cover Test: Distance(sc): ortho Near(sc): 3 exophoria Von Graefe: Not assessed
NSUCO	Saccades Ability: 5 Accuracy: 4 Head & body movement: 4 Pursuits Ability: 5 Accuracy: 5 Head & body movement: 4 *discomfort	Saccades Ability: 5 Accuracy: 5 Head & body movement: 5 Pursuits Ability: 5 Accuracy: 5 Head & body movement: 5
DEM	Vertical: 29 sec, 75% Horizontal: 32sec, 75% Error: 0 Ratio: 1.10, 50-60%	Vertical: 26.89 sec, 90% Horizontal: 26.95 sec, >99 % Error: 0 Ratio: 1.00, 95-99%
Retinoscopy	OD: +0.50 Sph OS: +1.00-0.50x180	OD: +0.50 Sph OS: +0.50 Sph
Refraction	OD: +0.50 Sph 20/20 OS: +0.50 Sph 20/20 Near Vision Only	OD: plano 20/20 OS: plano 20/20
Amplitude of accommodation	Minus lens to blur OD: 4.50D OS: 5.25D Pushup OD: 5.50D OS: 7.00D	Minus lens to blur OD: 9.00D OS: 9.50D
Monocular accommodative facility (MAF)	+2.00/-2.00 OD: 0 cpm Unable to clear plus or minus OS: 2.5 cpm Difficulty with plus	+2.50/-6.00 OD: 16 cpm OS: 20 cpm
Binocular accommodative facility (BAF)	+/-2.00 OU: 0 cpm OD suppression	+/-2.50 OU: 8 cpm

Continued from page 37

Table 4: Case 2: Visual findings pre-and-post vision therapy (12 sessions)

Test	Pre-Vision Therapy	Post Vision Therapy
Monocular estimation method	OD: +0.50 Sph OS: +0.75 Sph	OD: +0.50 Sph OS: +0.50 Sph
Vergence	NPC: TTN Distance: NFV: x/11/6 PFV: x/10/8 Near: NFV: 5/19/16 PFV: x/29/12 Clown Vectogram: BO: x/13/9 BI: x/L/E Appreciated SILO and float	NPC: TTN Distance: NFV: x/6/2 PFV: x/12/10 Near: NFV: x/18/14 PFV: x/>45/30
VO Star	40mm separation	67mm separation
Anterior segment	Within normal limits OD,OS 2 flat iris nevi at 6:00 OD	Not assessed
Posterior segment	0.15 C/D OU Chorioretinal scar nasal OD Vitreoretinal tuft superior temporal OS	Not assessed
Visual field (30-2 Sita-Standard)	Within normal limits OD,OS	Not assessed

*Response time

glasses based on his subjective improvement in orientation and balance: Plano SPH 3 BU OD, Plano SPH 3 BU OS.

The patient completed ten sessions of vision therapy with complete resolution of his initial symptoms and those indicated on the intake form. His activities and performance in vision therapy for the ten sessions are detailed in Table 3. After session eight, our patient noted that he no longer felt off balance or that the walls were slanted. Therefore, he discontinued using his glasses. He said he felt "back to normal" and his eyes only grew tired if he studied for long periods of time without breaks. At his re-evaluation, five months after the initial visit, the patient showed marked improvement in all of his visual findings and no longer had accommodative or oculomotor difficulties (Table 2). He noted that before therapy "my grades had been affected as well. They dropped significantly. I struggled to get C's and D's when I used to be an A student … After therapy, my grades went back up to the 90's and higher. I have the doctors to thank for that." (See Appendix 1 for full testimonial)

Case 2

A 16 year old female presented for an eye exam with a history of two sports-related concussions while cheerleading in the previous year. Her most recent concussion occurred 2 months prior to her visit. She had been a cheerleader for seven years but her neurologist strongly recommended she quit. Her chief complaint was asthenopia and blurry vision while reading and doing computer work. She also noted difficulty changing focus from distance to near, losing her place when reading, using her finger to read, and light sensitivity. She was experiencing daily band-like headaches that would increase with near work to a severity of 10/10. Pain medication would not alleviate the headaches. The patient was recently prescribed Celebrex for her headaches by her neurologist. Following her concussion(s), an MRI was performed;

Table 5: Case 2: Vision Therapy Activities

Category	Activity	Initial Performance	Final Performance
Fixation	Dive bombs	Level 1	Level 4
	Stick-in-straw	80% accuracy in primary gaze OD,OS	100% accuracy in primary gaze OD,OS
	Stationary pegboard	2-3 attempts per target OD, 6-7 attempts OS	<2 attempts per target OD,OS
Saccades	Thumb Saccades	Headache	Completed with ease
	Hart chart	8 strips reading out to in (+)Dizziness	Full chart diagonals on walking rail
	Hart chart decoding	Homework only	
	Michigan Tracking	Level 1	Level 5
	Black/White Number Chart	Read number, tap foot, half turn, read number on new chart	
Pursuits	Thumb Pursuits	Headache	Completed with ease
	Rotating pegboard	70% accuracy OD,OS	90% accuracy OD,OS
	Sherman Rotator		
Accommodation	Lens Sorting	Sorted +/- 0.50, 1.50, 2.50, (+)SILO	Sorted 0.50D steps (+)SILO
	Near/Far Hart chart	Near chart 6 inches OD, OS	Near chart 2 inches OD, OS
	Monocular accommodative rock	+0.50/Plano	+2.50/-6.00 OD: 16.5 cpm, OS: 20 cpm
	Binocular accommodative rock	+/-1.50 OU: 7 cpm	+/-2.50 OU: 8 cpm
Vergence	Quoit Vectogram	Not assessed at beginning	BI: I/K, BO: 29/28
	Clown Vectogram		BI: I/G, BO: >40
	Spirangle Vectogram		Walking BI: K/G, BO: 27/10

the results were unremarkable. On her intake questionnaire she reported the following symptoms seen in Table 1.

Her past ocular and systemic history were otherwise unremarkable. Her family history was positive for a grandmother with cataracts and high blood pressure. She was taking a birth control pill. She reported no other medications and no allergies. She had been attending physical therapy since her second concussion and was scheduled to start occupational therapy and cognitive therapy. She was enrolled in eleventh grade but was struggling in school since her concussions.

The patient had a comprehensive exam including assessment of her binocular and accommodative status (Table 4). The patient was diagnosed with Accommodative Insufficiency, and difficulty tracking as per patient report. The DEM did not reveal an ocular motor dysfunction. The visagraph is another option to assess ocular motility. The patient and her mother were educated that these visual findings may occur following a brain injury and could be rehabilitated with vision therapy.

The patient was given reading glasses to wear while working through her accommodative

and visual symptoms in vision therapy. Due to her complaints of light sensitivity and asthenopia while reading, colored filters were trialed. The patient felt that the yellow filter was more comfortable when reading and her subjective reading rate improved. A yellow filter was given to her to use over her reading material and computer screen. She was also prescribed plano yellow tinted lenses (85%) to use outdoors and for driving. The vision therapy activities and performance details are shown below in Table 5.

After twelve sessions of vision therapy, the patient reported that she no longer depended on her near vision glasses to read comfortably. The patient reported that she could now read for long periods of time without triggering her initial symptoms, however, she was advised that the near glasses could be employed with prolonged reading to help minimize near point stress. Proper visual hygiene such as taking breaks with prolonged reading and the appropriate near working distance was also discussed. The yellow filter was no longer being used and the patient was able to sit through the entire SAT, something she was unable to achieve prior to vision therapy. Her re-evaluation, 6 months after the initial visit, revealed that all of her visual findings had improved (Table 4).

Case 3

A 19 year old female presented to for an eye exam with a history of four sports-related concussions while playing collegiate soccer. At the time of presentation, it had been 8 months since her fourth and most recent concussion. She had a history of three previous concussions, which occurred 2 years, 1 year and 3 weeks prior to the most recent concussion. Six months prior to her visit, her symptoms reached a point where she had to take a medical leave from school. Her neurologist strongly recommended that she stop playing soccer, as another concussion could have life-threatening consequences. Her previous MRI's were unremarkable.

Our patient was currently enrolled in speech, vestibular, and cognitive therapy. Her chief complaint was that she was experiencing headaches which became more severe when reading. Our patient was only able to read for one to two minutes before triggering a headache. If she continued to attempt reading, her headache would escalate to 9/10 on the severity scale. In addition to triggering a headache, our patient would also lose her place, re-read lines, and words would run together. On her intake questionnaire she reported the following symptoms seen in Table 1.

Her past ocular history was unremarkable. Her systemic history was remarkable for exercise induced asthma, a torn ACL with associated repair, four concussions in 2013 and resulting insomnia. She was taking an albuterol inhaler as needed for asthma, amitriptyline for headaches, lamictal for dizziness, and clonazepam and melatonin for the insomnia. She was a freshman in college prior to her fourth concussion but was currently at home, recovering.

The patient had a comprehensive exam including a binocular workup, functional vision assessment and ocular health evaluation (Table 6). The patient had a history of multiple concussions and was diagnosed with: Accommodative Insufficiency, Accommodative Infacility, Ocular-motor Dysfunction, and Binocular Instability. The patient and her father were educated that these visual findings may occur following a brain injury and could be rehabilitated with vision therapy.

The patient was given reading glasses to help alleviate near point stress while working through her accommodative and visual symptoms in vision therapy. Due to her complaints of light sensitivity and asthenopia while reading, colored filters were trialed. The patient felt that the yellow filter was more comfortable when reading and her reading rate improved with use of the yellow filter. Small amounts of vertical yoked prisms were tested to see if they made her feel more

Table 6: Case 3: Visual findings pre-and-post vision therapy (10 sessions)

Test	Pre-Vision Therapy	Post Vision Therapy
Distance visual acuity (sc)	OD $20/20^{-2}$ OS $20/20^{-1}$ OU $20/20^{-1}$	OD 20/20 OS 20/20 OU 20/20
Near visual acuity (sc)	OD 20/20 OS 20/20 OU 20/20	OD 20/20 OS 20/20 OU 20/20
Pupils	PERRLA-APD	PERRLA-APD
EOMs	Full range of motion	Full range of motion
Confrontation fields	Full to finger counting	Full to finger counting
Stereopsis	Global: 63" Local: 12.5" Random Dot Lea	Not assessed
Color vision (HRR#4)	Normal	Not assessed
Binocular Posture: **Cover test** **Von Graefe**	Cover Test: Distance(sc): ortho Near(sc): ortho Von Graefe: Distance: 4 esophoria Near: 3 esophoria	Cover Test: Distance(sc): ortho Near(sc): 2 exophoria Von Graefe: Distance: 3 exophoria Near: 3 exophoria
NSUCO	Saccades Ability: 5 Accuracy: 3 Head & body movement: 5 Pursuits Ability: 5 Accuracy: 5 Head & body movement: 5 *discomfort	Saccades Ability: 5 Accuracy: 5 Head & body movement: 5 Pursuits Ability: 5 Accuracy: 5 Head & body movement: 5
DEM	Vertical: 24 sec, 99% Horizontal: 34 sec, 65% Error: 0 Ratio: 1.4, 1%	Vertical: 21.6 sec, 100% Horizontal: 26.0 sec, >99 % Error: 0 Ratio: 1.20 84-87%
Retinoscopy	OD: +0.25 Sph OS: +0.25 Sph	Not assessed
Refraction	OD: +0.50 Sph 20/20 OS: +0.50 Sph 20/20 Near Vision Only	Not assessed
Amplitude of accommodation	Minus lens to blur OD: 4.25D OS: 4.25D Push Up OD: 6.00D OS: 6.00D	Minus lens to blur OD: 7.75D OS: 8.00D
Monocular accommodative facility (MAF)	+2.00/-2.00 OD: 0 cpm OS: 0 cpm Unable to clear plus	+2.50/-6.00 OD: 4 min OS: 4 min *cycles per minute not measured

Continued from page 41

Table 6: Case 3: Visual findings pre-and-post vision therapy (10 sessions)

Test	Pre-Vision Therapy	Post Vision Therapy
Binocular accommodative facility (BAF)	+/-2.00 OU: 0 cpm OD suppression	+/-2.50 OU: 14.5 cpm (-)suppression
Monocular estimation method	OD: +0.25 Sph OS: Plano	Not assessed
Vergence	NPC: 6/8, 8/10, 8/10 Distance: NFV: x/6/2 PFV: 5/23/10 Near: NFV: 12/21/8 PFV: 6/26/15 Clown Vectogram: BO: 27>33/16 BI: I/M/B Appreciated SILO and float	NPC: 8/9 Distance: NFV: x/6/2 PFV: x/12/10 Near: NFV: x/18/14 PFV: x/>45/30 Quoit Vectogram: BO: 33/>33/19 BI: J/L/H
VO Star	42mm separation	Not assessed
Keystone	Over convergence	Not assessed
Anterior segment	Within normal limits OD,OS Capped glands OD, OS Low TBUT OD, OS multiple flat iris nevi OD, OS	Not assessed
Posterior segment	0.3 C/D OD, 0.25 C/D OS	Not assessed
Visual field (30-2 Sita-Standard)	Within normal limits OD,OS	Not assessed

grounded or less dizzy, however, she did not experience any subjective improvement with any of the base directions presented. Due to her 3 hour commute to our clinic (one-way), the patient attended in-office VT every other week and reinforced the skills at home in between sessions. The vision therapy activities and performance details are shown below in Table 7.

After ten sessions of vision therapy, the patient reported that she no longer required her near vision glasses to read comfortably, her headaches had improved, and she could now sustain reading for approximately 30 minutes at a time. She also started taking online college classes. She was still attending vestibular therapy, and her residual headaches were attributed to her vestibular dysfunction as per her neurologist and vestibular therapist. Her re-evaluation, 8 months after her initial visit, revealed that all of her visual findings had improved (Table 6). She wrote a testimonial and described her progress after completing therapy: "Now, I can confidently say that my vision is back in the normal ranges and has improved significantly from my first evaluation. I have even started taking my first college course [since last year] and will begin my second course [next month]". (See Appendix 2 for full testimonial)

DISCUSSION

The three teenagers discussed in this paper all had sports-related concussions with visual sequelae consistent with post-concussion syndrome. The severity of their concussions varied, but in all three cases their symptoms affected their quality of life

Table 7: Case 3: Vision Therapy Activities

Category	Activity	Initial Performance	Final Performance
Fixation	Dive bombs	Level 1	Level 4
	Stick-in-straw	90% accuracy in primary gaze OD, 60% OS	100% accuracy in primary gaze OD,OS
	Stationary pegboard	2-3attempts per target OD, 6-7 attempts OS	<2 attempts per target OD,OS
Saccades	Thumb Saccades	Jerky movements, overshooting	Completed with ease/accuracy
	Hart chart	4 strips reading out to in (+)headache	Full chart diagonals on walking rail
	Wayne Saccadic Fixator	Setting 9:1 OD: 33, OS: 33, OU: 36	Setting 9:1 OD: 38, OS: 36, OU: 42
	Hart chart decoding	Homework only	
	Michigan Tracking	Level 1	Level 5
	Word Tracking Limericks	Level 1	Level 3
	Black/White Number Chart	2 charts 90 degrees away, squat for white, turn, calf raise for black, turn	
Pursuits	Thumb Pursuits	Headache	Completed with ease/accuracy
	Rotating pegboard	70% accuracy OD,OS	90% accuracy OD,OS
	Sherman Rotator		
Accommodation	Lens Sorting	Sorted +/- 0.50, 1.50, 2.50, (+)SILO	Sorted 0.50D steps (+)SILO
	Near/Far Hart chart	Near chart 12 in OD, OS (+)headache	Near chart 2 in OD, OS
	Monocular accommodative rock	+0.50/-1.00 OD: 25 cpm OS: 30 cpm	+2.50/-6.00 OD: 4 min reading, OS: 4 min reading
	Binocular accommodative rock	+/-1.50 OU: 7 cpm	+/-2.50 OU: 14.5 cpm
Vergence	Quoit Vectogram	BI: L/K, BO: 5/>33/22	BI: J/L/H, BO: 33/>33/19
	Clown Vectogram	BI: N/L, BO: 29/22	

and ability to complete their school work. They presented with headaches, difficulty with near work, and loss of concentration. Consequently, their academic status was in jeopardy. Concussions are often labeled as mild traumatic brain injury, but the sequelae that follow can be devastating for the patient. Common symptoms of mTBI are listed in Table 8.

In cases 2 and 3, each patient had sustained multiple concussions and presented with more severe signs and symptoms. Prior to the vision consultation, they were enrolled in other forms of rehabilitative therapy, including physical, occupational, cognitive, speech and vestibular therapy. Craig and Kapoor (2008) conducted a retrospective study which showed that in addition to vision therapy, patients with a history

Table 8: Symptoms in TBI[5,7,8]

Visual	Vestibular	Attention
Eyestrain	Loss of balance	Loss of attention
Blur	Dizziness	Loss of concentration
Headaches	Vertigo	Feeling slow
Light sensitivity	Motion sickness	Feeling foggy
Loss of place when reading		
Diplopia		

of severe concussions also undergo physical therapy, cognitive therapy, speech therapy and occupational therapy.[5] This underscores the importance of multidisciplinary care for patients with TBI.

All three patients were diagnosed with oculomotor dysfunction and accommodative dysfunction which occurs in 29% and 20-51% of TBI patients respectively.[5,7-13] The most common visual findings in TBI are listed below in Table 9 (the percentages are an average for each condition based on 8 different studies).[5,8-14]

Table 9: Visual Findings in TBI[5,8-14]

Oculomotor Dysfunctions	60-90%
Visual-Vestibular	56-58%
Vergence Convergence Insufficiency	56% 40-49%
Versions	51-55%
Accommodative Dysfunction	20-51%
Light Sensitivity	49%
OMD	29%
Strabismus	25%
CN Palsy	10-33%
Binocular Instability	10%

Vision therapy was recommended for all three patients to rehabilitate their oculomotor, binocular and accommodative dysfunctions. Two patients were prescribed reading glasses in addition to vision therapy. While the accommodative systems were within normal limits after vision therapy for both patients, the glasses could be worn on an "as needed basis", especially with prolonged near work. In addition to the reading glasses, the importance of visual hygiene: taking breaks and Harmon's working distance, were also discussed.

Common treatment elements in each case were trialing filters/tints and yoked prisms. In order to help reduce light sensitivity, glare, and improve reading comfort, the patients were presented with different colored filters. All three patients independently selected the yellow filter to place over their reading materials and/or computer screens. They each reported decreased glare, a subjective improvement in reading and an objective increase in reading rate. Yellow filters can help reduce photosensitivity, increase contrast sensitivity and increase reading rate. An alternative option is the use of tinted lenses. Such lenses are typically prescribed as 30-40% tint for indoor use and 85-90% tint for outdoor use.[15] Yellow and blue tints are thought to improve reading rate because the magnocellular cells in the reading pathway are most sensitive to short wavelengths: blue and yellow. The magnocellular cells are part of the dorsal pathway which processes high temporal frequencies. The dorsal pathway identifies where things are in space and helps guide movement. This pathway also communicates with the frontal eye fields for saccadic eye movement control and visual-spatial localization.[6]

Yoked prisms were presented to address each patient's symptoms related to visual-vestibular dysfunction. All three patients tried small amounts of horizontal and/or vertical yoked prisms. Yoked prism can alter vergence, accommodation, spatial localization, perception, posture and balance. Yoked prism induces a change in the direction light is bent, which translates into a change in perception of space. Altering the expansion and contraction of space at different distances can counteract visual distortion and imbalance.[16] Binasal occlusion is another option to address visual-vestibular symptoms and alter visual space. Although

Table 10: Vision Therapy Flow[6,7,10,11,13-22]

	Phase 1	Phase 2	Phase 3	Phase 4
Visual Skills	- Gross monocular fixation, saccades and pursuits - Gross accommodation - Gross vergence	- Improve monocular fixation - Improve large saccades - Improve small pursuits	- Improve fine monocular fixation - Improve small saccades - Improve large pursuits	- Decrease latency of saccades and pursuits - Integrate with accommodation and vergence
Accommodation		- Lens sorting (SILO, float, parallax) - Monocular accommodative rock - N/F Hart Chart Level 1*	- Bi-ocular rock - N/F Hart Chart Level 2** - Bulls Eye Hart Chart	- Binocular accommodative rock - Vectograms with +/- flippers - Integrate with skills and vergence
Vergence		- Physiological diplopia - Brock string - Projected Vectograms (SILO, float, parallax) - Vectograms (smooth BO) - Computer Randot Stereo (BO) -Barrel Cards	- Bug on a String - Vectograms (Smooth BO & BI, Step BO & BI) - Computer Randot Stereo (BO & BI) - Free Fusion (See 3 Coins/Overlapping Pictures) - Lifesaver cards and/or Eccentric Circles	- Vectogram Jump Ductions - Computer Randot Stereo Jump Ductions - Aperture Rule - Integrate with skills and accommodation
Vestibular (Incorporate into each Phase)	Examples: - Saccadic charts and/or accommodative charts with walking rail - Yoked prism on walking rail (to identify changes in space, posture and balance) - Charts on balance board - Saccadic charts and/or accommodative charts on balance board - Vectograms while walking - Charts on different walls to engage head movement - Infinity walk to engage eye and head movement			

* Near chart at first sustained blur; focus on feeling of relaxing and stimulating accommodative system when switching between charts

** Trombone near chart to 2-3 inches (or expected amplitude) while reading near letters; goal = 10cpm (reading one line at near and then one line at far)

binasal occlusion was not trialed in these cases, it has been shown to alter the way signals travel through the brain to decrease the suppression of visual information.[23] The 14 year old patient had the most severe spatial distortion complaints and chose base up (BU) yoked prisms. He noted that the BU prism helped him feel more grounded and made the walls appear less distorted. His description of the improvement with BU prism is consistent with the literature which states that: 1) BU prism can help a patient sustain and attend to central space better, 2) bring the world in, by shifting gaze downward (making the patient feel more grounded),and 3) decreasing size and distance by convergence.[16]

Some form of oculomotility problem is found in 60-90% of TBI patients with 29% of them being diagnosed specifically with OMD.[5,8-14] Ciuffreda and Kapoor have done several studies on rehabilitating oculomotor skills in TBI. The most common visual symptoms are blurred vision (46%), diplopia (30-54%), headaches (13-44%), losing place when reading (81%) and eyestrain (54%).[5,7,8] In one retrospective study, 33 patients with oculomotor problems underwent 10-30 sessions of vision therapy with a 90% success rate. The success rate was based on normalization or marked improvement of one or more sign or symptom.[7] Another study was done to assess subjective and objective

improvement in reading using computer oculomotor training. In this study, 9 patients underwent 9.6 hours of computer fixation, saccade, pursuit and reading training to see if symptoms and reading improved. The results showed that the patients had an improvement in symptoms and a 3% increase in reading rate.[17] These studies illustrate support for OMD therapy to help improve signs and symptoms in patients with mTBI.

Accommodative dysfunction is present in 20-51% of TBI patients versus only 10% of the normal population.[5,8-14] Accommodative problems can cause intermittent blurry vision at near and distance; a particular hallmark is a slow shift in focus from near to distance. Near vision glasses, in addition to vision therapy, can also be used to help relieve near point visual stress related to accommodative dysfunctions. Several case studies have shown that accommodative therapy is effective in the TBI population.[18,19,20] Green et al conducted a prospective pilot study in 2010 with 12 TBI patients and 10 control patients and found a 90% success rate with vision therapy.[20]

The vision therapy protocol was based on traditional vision therapy techniques as well as well as recent literature on TBI therapy.[7,10,11,13-22] The general therapy flow for these patients is shown below in Table 10. Vestibular feedback was integrated at each stage by adding movement or rotation. Procedures were performed on the walking rail and/or balance board. Each patient's vision therapy plan was tailored for their specific needs and rate of progress. During each 45 minute session, the patients were given breaks between activities and allowed to rest in a dark room if necessary.

At the conclusion of vision therapy, all three patients showed improvement in their visual skills. Near work was no longer a trigger for headaches, and each reported significant improvement in academic performance. All three patients worked on oculomotor, accommodative, and vergence skills in therapy for 10-12 sessions. While the number of sessions appears to be on the lower end of the spectrum, they were spread across four to eight months with home re-enforcement. There were periods of time when the patients would attend vision therapy every other week due to transportation barriers or other therapies. The improvements made in therapy were still seen at follow-up visits post-therapy. A study by Thiagarajan and Ciuffreda shows the benefits of therapy and the persistence of improvements made even after a short period of therapy. The study found that after only nine hours of oculomotor therapy, patients showed retention and improvement in their skills three and six months post-therapy.[24]

After only 9 hours of oculomotor therapy, more than 90% of the abnormal baseline data improved at the three month and six month follow-up with no maintenance therapy. This study suggests neural plasticity of the human brain and continued improvement of the visual system post-therapy.[24]

CONCLUSION

Sports-related concussions in children are becoming a public health concern. Public health organizations are increasing awareness about the devastating effects of sports-related concussions. The risks of returning to play too soon include increased risk of re-injury and delayed healing as well as long term cognitive, visual, vestibular, memory, emotional, attentional and behavioral changes.

These three cases illustrate the visual sequelae of sports-related concussions and how it negatively impacted their schoolwork, concentration, and emotional and social well-being. Case 1 discussed a 14 year old male whose grades went from A's to C's and D's; case 2 was a 16 year old female unable to complete her SATS; and case 3 was a 19 year old female who had to take medical leave from College. In each scenario, the visual problems resulting from the traumatic brain injury were beginning to hinder advancement in their scholastic activities. A comprehensive

optometric evaluation including assessment of the binocular and accommodative status, ocular motility, photosensitivity, abnormal egocentric localization, and integrity of the visual field should be mandatory for those with a history of traumatic brain injury. As optometrists specializing in neuro-rehabilitation, we can offer our patients relief from their visual symptoms through the use of prisms (fusional or yoked), glasses for near work, bi-nasal occlusion, filters/tints, and in-office vision therapy.

CONCLUSION

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Appendix 1: Patient 1 Testimonial

"After my concussion I felt I was different, that I could never be the same again. I had trouble in every subject especially math, reading and computer work. Everything felt harder than it had to be. It was very frustrating and irritating. I kept mixing words together and just was always hurting. I just wanted it to stop. With this this problem, my grades had been affected as well. They dropped significantly. I struggled to get C's and D's when I used to be an A student.

After therapy I feel that I am new and can do so many things. I am happy to say I don't have to do vision therapy homework anymore, even though it was sometimes fun. After completing therapy, I feel unstoppable and thankful to the doctors that helped me so I can play sports again, of course with some caution. After therapy, my grades went back up to the 90's and higher. I have the doctors to thank for that."

Appendix 2: Patient 2 Testimonial

"[11 months ago], I suffered from my third concussion. Then, three weeks later, before I had finished healing from the third, I sustained my fourth. At this time I had just started playing soccer at College, we were only five games into the season and I was only a few weeks into school when my symptoms became so bad I had to stop going to class. I literally just laid in my dorm room all day because any sort of stimulation would set me over the edge. I had close teammates and friends who thought I was faking it all and had a coach and trainer who could've cared less about my health situation. When I would read I would get these awful headaches that would lead to mental fogginess, fatigue and migraines. Once this happened my body would just start shutting down. I persisted through fall as best as I could, recuperated over Christmas break, tried attending again in the spring but the same process ensued. The more classes began to pick up, the more I had trouble keeping up. I finally made the decision to come home and focus on my health and medically withdrew in [four months after my fourth concussion]. From there I began seeing Dr. X, a concussion specialist. He referred me to begin vestibular therapy. Not long after, I began Speech and Vision Therapy as well.

When I had my first evaluation for Vision Therapy, [eight months after my fourth concussion], it was an awful, horrible mess. I could barely read for two minutes without having headaches or mental fogginess. I couldn't watch TV for more than a few minutes, I couldn't drive, I was on a hiatus from all social media, and basically anything that caused my eyes to

focus for more than a few minutes caused the onset of my symptoms. I went from being a high level athlete, honor roll student to lying in bed all day because I couldn't function without headaches or migraines. I would drive 2hr 30min/3hrs for an appointment that lasted about 30 minutes at the most but as time passed, I began seeing little improvements. In time, my reading increased and although it may have only been by a few minutes, it still counted. I continued on with therapy and ended up doing a good portion of the exercises at home due to living in the Keys. There were days where I just wanted to quit and give up but deep down, I knew that wouldn't get me anywhere.

With a ton of patience, determination and the help of some amazing doctors/therapists I can finally say that I'm done with vision therapy. It's been a long and difficult 9 months, but it was well worth it in the end. Now, I can confidently say that my vision is back in the normal ranges and has improved significantly from my first evaluation. I have even started taking my first college course [since last year] and will begin my second course [next month]. Although I have improved a ton, I still have my limitations. Every 20-30 min of continuous work I have to get up and take a break all so I don't get headaches/migraines, but even so, it's 10x better than where I started and I know that with time, it will get even better.

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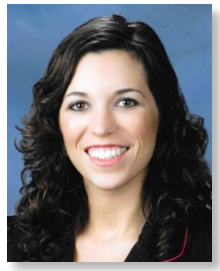

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Appendix: Vision Therapy Activity Descriptions

Category	Activity	Description of Activity
Fixation		**Purpose: To develop accurate fixation**
	Dive bombs	Monocular then Binocular (can also be done bi-ocular) Patient holds a writing utensil in their dominant hand. The writing utensil should be held behind the ear. The patient should fixate on a target and then in one smooth movement bring the pen to the paper to place a mark inside the target.
	Stick-in-straw	Monocular then Binocular Patient holds a fixation stick behind their ear and Doctor or Therapist holds a straw. The patient should fixate on the center of the straw and then bring the fixation stick from behind their ear into the straw in one smooth movement. This can be done in primary gaze as well as in all other fields of gaze.
	Stationary pegboard	Monocular then Binocular Patient holds peg behind their ear and fixates on a hole in the pegboard. The patient then should bring the peg to the hole.
Saccades		**Purpose: To develop accurate eye movements independent of head movement. Monocular then binocular.**
	Thumb Saccades	Patient holds both thumbs up in front of them at approximately 40cm (distance can be modified) and looks from one thumb to the other (the thumbs provide proprioceptive feedback). The goal is to be able to accurately move their eyes from one thumb to the other without moving their head and without symptoms. Once they are able to do this, two objects can be used instead of thumbs.
	Hart chart	Column Jumping: The patient should stand about 10 ft from the Distance Hart Chart (closer if needed). The patient should read the first letter in the first column then move their eyes across the row to the last letter of that column. And continue from the first to the last letter of each column moving down the chart. Once the first and last columns are completed with ease, the patient can continue their way inward by reading columns 2-9, 3-8, 4-7, 5, 6. Modifications: *Less difficult: cut the chart into stripes; increase spacing between letters; enlarge font size *More difficult: X pattern; decrease font size.
	Wayne Saccadic Fixator	Monocular then Binocular Tracking: The timer is set for either 30 seconds, one minute or two minutes. The patient locates the first light with their eyes and then presses the lighted button with their finger. When they accurately press the button, the next button will light up. At the end they will get a score of how many lights they pressed in the time given. This can be done using the dominant hand or using the right hand for the right side of the board and the left hand for the left side of the board. Central/Peripheral Training: The patient is asked to keep looking only at the center of the board and they have to use their peripheral vision to find the light and accurately press it.
	Michigan Tracking	Start with Level 1 Patient has to find the letters of the alphabet in order in the jumbled nonsensical paragraph. This activity is timed to see how long it takes to find all 26 letters. The goal is to find them in less than one minute. After the goal is met the patient moves on to the next level. With each level, the letters get smaller.
	XO tracing	This is a version of Michigan tracking using symbols (X, O)
	Word Tracking Limericks	This is a version of Michigan tracking where the targets are words in a limerick
	VTS3 saccades	This program is on the Vision Therapy System The patient uses their eyes to find each arrow presented on the screen and then presses the appropriate direction key. This can also be done with letters.
	CPT visual scan	This program is on the Computer Perceptual Therapy System Numbers (or letters) are arranged in an array on the computer screen and the patient has to click the letters (or numbers) that are hidden in the array.
	Black/White Number Chart	This chart is set up similar to the Hart Chart, but it has numbers in rows across the page. Some numbers are black and enclosed in a white circle and some numbers are white and enclosed in a black circle. This can be used in many ways. In this case series one chart was placed on a wall and another identical chart was placed on a wall 90 degrees away. The patient had to read the first number on the first chart and perform a movement corresponding to the color and then turn to the other chart and read the next number and perform the movement corresponding to that color. The movements and turning from one chart to the next incorporated the vestibular system. E.g. of movement: bouncing or tossing a ball

Continued from page 52

Category	Activity	Description of Activity
Pursuits		**Purpose: To develop accurate eye movements to follow an object or text independent of head movement.**
	Thumb Pursuits	The patient holds their thumb ~40cm in front of them and uses their eyes to follow their thumb in different directions. Once the patient is able to do this without moving their head and symptom free, the patient can use an object.
	Rotating pegboard	The patient holds a peg behind their ear and follows a specific hole with their eyes and then brings the peg from behind their ear into the hole.
	Sherman Rotator	The Sherman Rotator has the numbers 1-8 spread out around in a circle. Next to each number is a grouping of small letters and capitalized letters. The patient has to find the number and then record the small letters that are next to that number and then the capitalized letters.
	Connect the dots	Any connect the dots game can be used. In order to make the activity more challenging, make the targets smaller or add more targets.
	Mazes	Any maze can be used. In order to make the activity more challenging use mazes with smaller spacing or more paths.
Accommodation		**Purpose: To develop the ability to feel when the eyes are relaxing and when they are focusing; to appreciate the changes that lenses make to objects; to develop the flexibility between stimulating and relaxing the accommodative system.**
	Lens Sorting	Monocular This activity is used to teach the patient SILO and the feeling of relaxing and focusing. The patient is given (+) and (-) lenses to sort in order of power. The patient should note if the lens make the image bigger or smaller and closer or farther. Start with a large just noticeable difference (JND) and progress to a smaller JND.
	Near/Far Hart chart	Monocular then binocular The patient holds the near chart as close as they can while maintaining clarity and stands ~10ft from the distance chart. They alternate reading letters on the near chart then letters on the far chart. The near chart can be brought closer to maximize accommodative amplitude.
	Monocular accommodative rock	Lenses: 1:2 ratio as plus:minus lenses. Powers can be modified for each patient. The patient holds a lens in front of their eye and reads one word,on a Rock Card or in a book, then flips the lens. The number of cycles of words (one word with + and one with -) read in one minute is recorded as cycles per minute (cpm).
	Bi-ocular accommodative rock (e.g. Red-Red Rock)	Lenses: 1:2 ratio as plus:minus lenses. Powers can be modified for each patient. This activity is done with Red/Green glasses and a (+) lens over one eye and a (-) lens over the other eye with both eyes open. On one side of the board is red acetate with black words on it and on the other side are white tiles with red letters. Match tiles to words on the red acetate.
	Binocular accommodative rock	Lenses: +/-0.50, +/-1.00, +/-1.50, +/-2.00, +/-2.50 with suppression check. The patient reads one word, on a Rock Card or in a book, with the first lens and then flips the lens. The number of cycles per minute is recorded (cpm).
Vergence		**Purpose: To develop the ability of the eyes to cross and uncross accurately as well as for the patient to appreciate feedback cues of SILO, float, parallax, localization.**
	Brock String	Physiological Diplopia: When looking at a bead the patient should appreciate one bead and two strings coming into the bead and two strings leaving the bead. NPC Work: While the patient focuses on the near bead work on bringing the bead in towards the nose while maintaining a single bead. Smooth Vergence: Have a patient focus on a bead and move the bead closer and further while the patient maintains one bead and two strings in and out. Jump Vergence: Have the patient jump accurately between the beads as the bead stays single and the strings cross at the bead. Voluntary Vergence-Have the patient imagine there is a bug crawling up and down the string. Be able to voluntarily move their eyes in and out accurately and smoothly without the cue of the bead.
	Vectograms	The patient should first learn to identify SILO, float, parallax and localization. Sometimes these are easier to identify when the vectogram is projected. Smooth, step, and jump vergence. Suggested order: Quoits, Clown, Mother Goose, Spirangle, Chicago Skyline.