Article • Efficacy of Neuro-Optometric Rehabilitation Therapy on the Visual Consequences of Acquired Brain Injury

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ABSTRACT

Neuro-optometric rehabilitation is a recognised intervention for treating visual dysfunctions resulting from acquired brain injury and is practised by a small but enthusiastic group within the profession of optometry. The use of evidence-based medicine has become increasingly important to support the integrity and acceptance of treatment and management of patients within this population. Although this discipline has made great strides in recent times and is becoming increasingly included in multi-disciplinary management, the volume of literature initially has been relatively light and dominated by a small number of researchers. This paper considers some of the most recent research supporting the use of neuro-optometry in the management of patients with visual conditions related to acquired brain injury. As optometrists are seeing increasing numbers of patients with traumatic brain injury/concussion, significant emphasis has been placed on these areas.

Keywords: acquired brain injury, concussion, evidence-based medicine, neuro-optometry, vision therapy

Introduction

The role of optometry in the management of patients with acquired/traumatic brain injury (ABI/TBI) has increased in recent decades.[1] This comes at a time when health professionals have been expected to provide proof that they use techniques and treatment protocols that have solid evidence-based backing. In many ways, medicine forged the path in this regard with other healthcare professions becoming involved to continue this new trend in healthcare. Evidence-based medicine (EBM) is not without its controversies, and this has been highlighted recently with the departure of senior members of Cochrane, the global collaboration of senior health professionals aimed at supporting best practice. Accusations of cherry-picking evidence have been made by some[2] as the pressure for profit by scientific companies plays a role in what evidence reaches the public domain. Indeed, it is now a major issue that many are voicing their concern over 'evidence distortion' in the journals specifically produced to back the practice of EBM.[3]

As we explore this practice as it applies to optometric intervention, it is important to consider the definition of TBI and ABI. It appears to be increasingly accepted that ABI refers to any brain injury that occurs after birth but is not connected to any congenital defect or degenerative disease.[4] ABI includes conditions such as stroke and meningitis, whereas TBI can be considered to be a sub-set of this group.[4] It is often assumed that a concussion can be classified as a mild TBI (mTBI),[5] although this is by no means universally accepted. The 2012 Zurich Consensus Statement on Concussion in Sport[6] proposed that concussion and mild TBI be seen as two separate entities, whereas the American Academy of Neurology in 2013 did not classify the two conditions as being different.[7]

Highlighting the crucial role that optometry can play in helping those with an ABI is not always easy. This is particularly relevant in my own backyard, New Zealand, with the Accident Compensation Corporation (ACC) refusing to fund optometry in the management of ABI patients with visually related symptoms. They cite a lack of evidence-based medicine to back the efficacy of such intervention. Their stance is weakened somewhat by the fact that they stated that optometry was claiming that vision therapy had an effect on cognitive performance following TBI.[8] Unfortunately, misunderstandings can be quick to develop. In reality, optometry simply claims to have an effect on visual performance related to TBI. It is with this in mind that we need to consider more precisely exactly how optometry can play a role when addressing this particular population.

One of the earliest references to optometry's role in the management of this population was by Stark et al. in 1977.[9] As interest gathered pace in the early 1990s, the Neuro-Optometric Rehabilitation Association (NORA) was formed. Since then, a small but increasing group of optometrists and other allied health professionals has furthered the study of this discipline; the amount of literature produced to back their practices has increased exponentially. For example, a recent search of the Auckland University database in May 2020 scored 547 hits for the combined terms 'concussion' and 'optometry.' To set the foundation for understanding and for further studies, a classification of characteristics and symptoms of those who have suffered a TBI was suggested by Padula.[10] He reported that the most common findings were of convergence and accommodation dysfunctions, poor blink rate and associated dry eye, eye movement issues, and unstable ambient vision.[10] We should consider the prevalence of these issues, but we first need to consider just how 'big' is the problem of ABI/TBI.

Epidemiology

On average, when considering emergency department visits, approximately 140 people are killed in the USA every day due to injury, and TBI accounts for 30% of these.[11] Although most TBIs are classified as mild,[12] there were nevertheless approximately 2.5 million emergency department visits on account of TBIs in the USA in 2013.[13] Indeed, between 2001 and 2009, there was a 57% increase in TBI-related emergency department visits in the 19 years or younger age group related to sport or recreational activities.[14] Some explanation for increases in these figures can be put down to increased public awareness. Professional understanding of these issues has also improved, and it is now widely accepted that sport-related concussions may not be solely prevalent in contact sports, as concussion-type symptoms have also been noted in non-contact sports and activities involving sudden movements (e.g., cheerleading).

ABI may be linked to external causative factors (e.g., a blow to the head from assault, fall, sports injury), or it may be due to internal factors (stroke, tumour, aneurysm, etc.).[4] An open head injury is more likely to cause a focal defect, whereas a closed head injury is more likely to be diffuse.[4] A recent New Zealand study compares the difference in incidence of TBI and ABI, and in particular the ABI sub-set of stroke. While general differences in incidence were found, it was also interesting to note that significant differences were found in gender and ethnicity.[15]

Either way, the effects on the visual system can be debilitating. Ciuffreda et al.[16] found a significant number of visual symptoms in a retrospective analysis of 160 patients suffering from TBI between 2000 and 2003. Accommodative issues were present in 41% of patients, and vergence issues, of which convergence insufficiency was the most prevalent, were present in 56% of patients. Treatment of these patients with vision therapy showed statistically significant improvements, with resolution of all symptoms in most cases.[16] With a smaller sample size of 25, Goodrich et al.[17] also found high levels of accommodative (22%) and vergence deficits (30%) when comparing blast-related and non-blast-related head trauma. The same group later looked at a larger sample size of inpatients (108 patients) and outpatients (125 patients) in 2009.[18] They found that the outpatient group, unsurprisingly, had milder symptoms, with the level of convergence insufficiency at 48% and accommodation issues at 47%. The inpatient group tended to have a more troublesome array of symptoms, including strabismus and/or diplopia, when compared with the outpatient group. Although these studies show that convergence insufficiency is a common finding in mTBI, it is important not to underestimate the prevalence of esophoria and convergence excess.[19] These have been estimated at approximately 30% and 23%, respectively. Leslie[20] summarised a group of studies that cited the prevalence of accommodation deficits in acquired brain injury, finding significant accommodation dysfunction when patients were compared with age norms. Although Ventura[21] suggested caution in relying on figures that quote such high amounts of ocular involvement, citing referral bias, it is certainly reasonable to conclude that, regardless of this factor, ocular involvement is still highly significant. Heinmiller[22] also makes this point when compiling a review of the most recent literature relating to diagnosis and management (Figure 1).

In this day and age of increased awareness of sports-related concussion, it has been demonstrated that the younger population is very much at risk,[23] but more consideration is being given to comparing the male and female populations. A surprising and

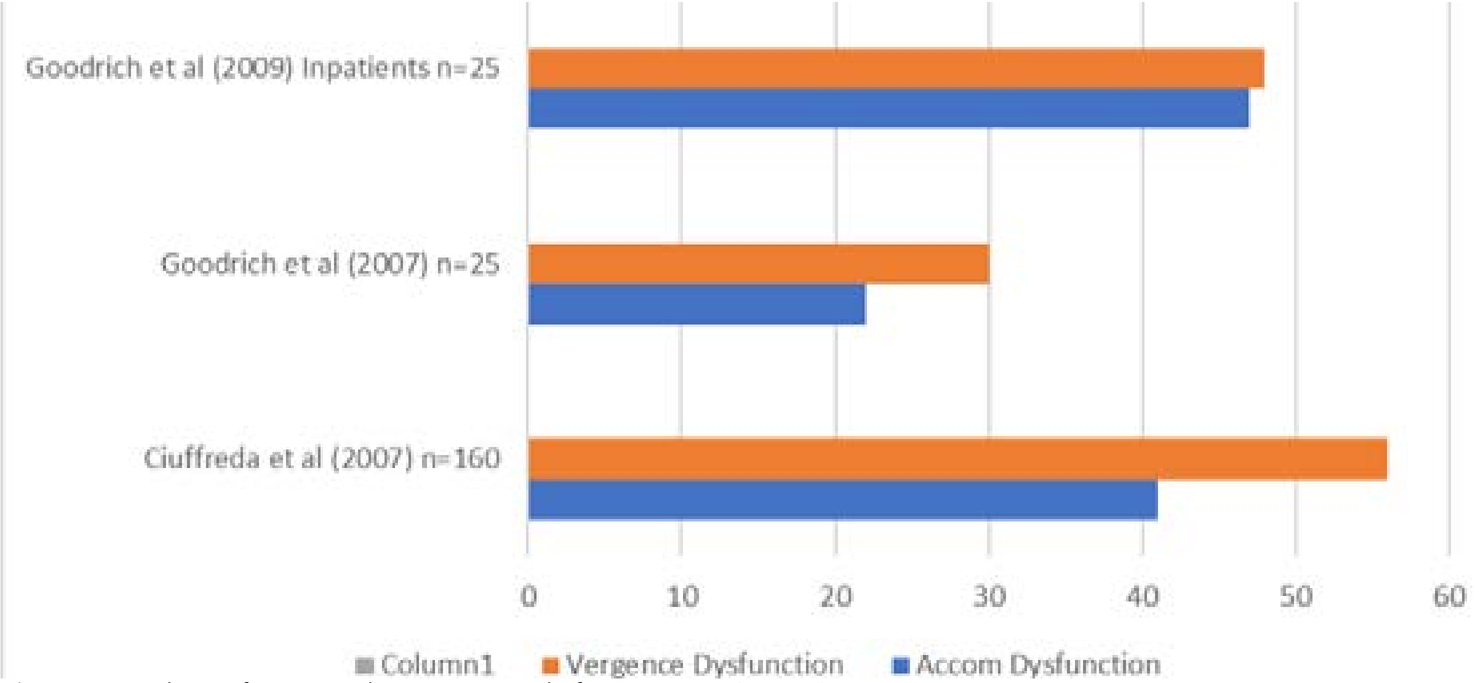

Figure 1. *Prevalence of accommodation/vergence dysfunction in ABI (percent)*

alarming study by Lincoln et al.[24] showed that girls' soccer was second on the list for rate of concussion-related issues when compared with six different sports for each gender. In fact, this study went further to demonstrate that overall, girls showed twice the rate of concussion than did boys. Since girls are 5 times more likely to return to playing soccer on the same day after concussion,[25] education and awareness in this group are of paramount importance. This is gaining much attention in the current literature, to the extent that a rigid return-to-play criterion has been suggested. The extent to which this is being adhered is currently being investigated.[26] Recently, the eye skills of girls have been implicated as being a major factor related to these disturbing findings.[27] It has previously been suggested that causes behind the increased rate of concussion in the young female soccer-playing population may be multi-factorial, including differences in spinal musculature and skull thickness.[28] Now we have a study which hypothesises that sports vision therapy in this group may be hugely beneficial, especially when we consider that soccer has an estimated 250 million active players worldwide[29] amongst the entire population. The Clarke study[27] assessed a similar number of players from each gender (176 male high school students vs. 170 female students). The authors searched the terms 'high school female soccer header' and 'high school male soccer header' on Google in June 2015 and found a statistically significant increase in female players who had their eyes closed when heading the ball compared to male players. It was also suggested that by keeping their eyes open, male players had better field awareness, and the importance of peripheral awareness was noted as a possible method of avoiding concussion injury. Certainly, the phrase 'keep your eye on the ball' couldn't be more apt. Consequences of concussion and the differences between genders have also been assessed. Again in the high school population, depression and gait differences between the two groups have been measured, with little difference found in depression rates[30] between the two groups but a definite difference in 'dual-task' gait.[31] Dual-task gait can be effectively thought of as multi-tasking whilst walking with an added cognitive load. On a similar theme, Brooks et al. observed that although those with prior concussion reported more symptoms, there was no statistical difference between the two gender groups when assessing cognitive performance.[32]

Neuro-Optometric Intervention

As has been highlighted, solid evidence-based medicine to back the use of neuro-optometric rehabilitative therapy is vital to the credibility of this discipline. As health professionals, optometrists have a duty of care to our patients. We also have a requirement to practice within safe and established guidelines, and these are very much set by the evidence-based models that have become more common in recent decades. In my part of the world, we have discussed the failure of neuro-optometry to have vision therapy accepted for government funding. The document outlining the government decision used the Scottish Intercollegiate Guidelines Network (SIGN) method of establishing whether or not to fund vision therapy. SIGN is one of a number of networks aimed at standardising and reducing variance in health care by using evidence-based medicine. This is one of a number of established guidelines and organisations aimed at advising health professionals in the area of best clinical practice, with others such as the United States Preventive Services Task Force (USPSTF), Grading of Recommendations, Assessment, Development and Evaluations (GRADE), or the Centre for Evidence-Based Medicine (CEBM). An understanding of how the various guidelines suggest that evidence is assessed and how clinical guideline recommendations are made is crucial if the professional is to appreciate how to make sense of this topic. A full explanation of how systematic reviews are formulated by the SIGN group and how the quality of the evidence is assessed is outside the scope of this paper but can easily be found online.[33] It is strongly recommended that we become familiar with these procedures as eye care professionals. As clinical practice develops and new treatments become available, the aforementioned document explains the need for constant revision of the published papers used in any particular guideline to ensure that the document itself remains current. It uses a traffic light system, with a 'green' given only to papers that have been published within three years or that have been revalidated if published longer than three years ago. With this in mind, and with regard to evidence supporting the optometric management of ABI patients, more data is starting to emerge, and it is very encouraging that there is much recent evidence coming through.

A recent paper[34] has suggested a more advanced range of testing by the neuro-optometrist, including the use of electro-retinography, optical coherence tomography, b-scan ultrasound, visual-evoked potential, dark adaptation, glare sensitivity, intuitive colourimetry, and perceptual testing. They make the comment that, by including even a few of these techniques alongside more established testing protocols,[35] neuro-optometrists are equipping themselves with more effective means of helping their patients. It is encouraging to see that efforts are being made to establish the most efficient, high-yield testing protocol in order to provide the best management for ABI patients.[36] Finding an objective biomarker has been a goal for a number of years due to the prohibitive cost of existing excellent biomarkers such as functional magnetic resonance imaging (fMRI) or diffusion tensor imaging (DTI).[37] The latter techniques are simply impractical on the touchline of a sports event or on a battlefield, where many concussions take place.[38] Ciuffreda et al.[39] have identified peak convergence as such a biomarker and suggest either a portable video-based system or a virtual reality goggle-type piece of equipment as an economic means to bring the detection of mTBI into everyday practice right now, rather than in the distant future. Recent work has been underway to identify blood biomarkers, which may pave the way for a concussion blood test. McCrea et al.[40] identified an increased level of a number of proteins post-concussion in college athletes when compared

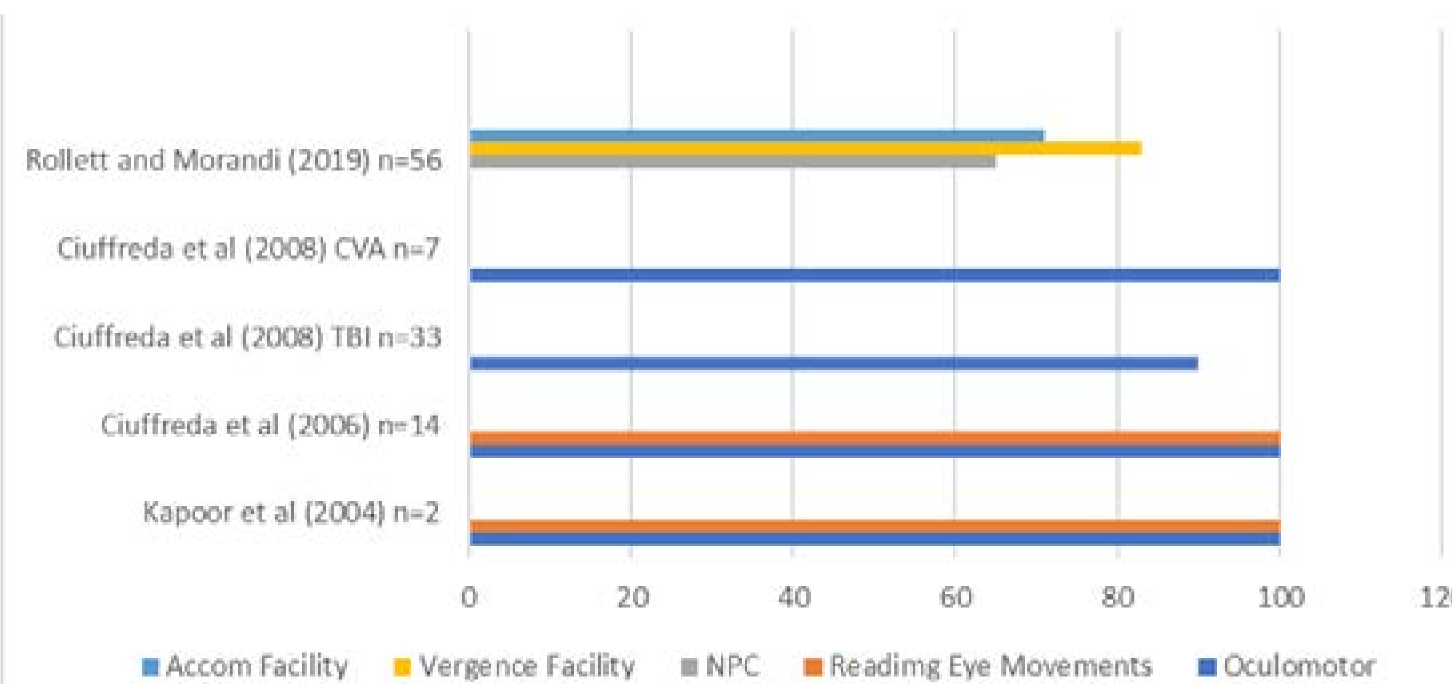

Figure 2. *Improvements in ocular skills in recent research papers (percent)*

with pre-season, pre-concussion baseline readings. Although they acknowledge that more evidence is needed before this technique can be implemented, it is nevertheless a step in the right direction.

Many optometrists use a pre-examination/post-examination questionnaire so that they can demonstrate improvement following treatment. The Brain Injury Vision Symptom Survey (BIVSS) is backed by scientific evidence showing that there is excellent test-retest reliability, and the authors of one study[41] make the point that the profession would benefit from further studies to show improvements in specific subset scores (Appendix A). The initial targeting of patient symptoms has been recommended by Groce et al.,[42] and their text is a useful guide to anyone new to this area (Figure 2).

The last decade in particular has seen a plethora of published papers that show improvements in the most common of visual signs and symptoms following ABI. Kapoor et al.[43] compared two patients' eye movement recordings pre- and post-treatment and found significant improvements in eye movement performance. They found similar results in a further study[44] involving 9 patients with TBI and 5 with stroke. Ciuffreda et al. showed a complete or partial reduction of symptoms in 90% of 33 patients who had suffered TBI and who completed a full course of vision therapy.[45] In a series of studies for a PhD thesis, Thiagarajan et al. found vastly improved findings in various oculomotor functions in a small number of TBI patients with TBI.[46-49] Rollett and Morandi[50] studied 56 patients retrospectively and found clinically significant improvements in oculomotor findings following concussion. Interestingly, they also agreed with the gold standard CITT trial[51] in that they showed that increasing the number of sessions of vision therapy had better and less-variable outcomes compared with patients who received just 5-10 sessions. More recently, Galloway et al.[52] have shown successful or improved outcomes in the vast majority of patients with post-vision concussion disorders. This relatively large study retrospectively studied 218 patient records with a diagnosis of concussion over an 18-month period.

Phan et al.[53] suggest a protocol for visual and visual-vestibular rehabilitation. They describe a multi-phase approach to rehabilitation starting with emphasis in the initial phase being placed on stabilising the visual input system in preparation for future therapy. Phase two involves the improvement of binocular function and the ability to sustain this control. The final phase works on improving visual processing performance using a top-down approach. Baxstrom[54] also takes a similar approach and suggests a 7-step process for enhancing the TBI patient's performance depending on individual circumstances. He states that cervical input is important to consider in this process, as it serves as the foundation for the rehabilitation of these patients. More recently, Blanc[55] addressed this in full with a discussion considering the effects of a whiplash injury on various aspects of the visual system.

Visual midline shift syndrome (VMSS) is a term coined in the early 1990s by Padula,[56] although it has been argued that the term abnormal egocentric localisation (AEL) is more correct.[57] Padula's text was invaluable in suggesting that AEL occurs due to a mismatch in the relationship between the focal and ambient visual systems. AEL is particularly common in patients with ABI/TBI,[58] and the use of yoked prism to help patients who suffer such a mismatch has been investigated.[58] Unfortunately, there doesn't seem to be any accepted standard of measuring AEL. The original method using a Wolff wand and asking the patient to respond has issues depending on variables such as room clutter, patient delay, and examiner's position. In fact, a different response can be obtained from a patient depending on which side of the body the examiner is situated. Nevertheless, once AEL is established, the use of yoked prism in many patients proves very effective, in particular with patients with a homonymous quadranopsia, with one study finding a 58.3% indication for prescribing yoked prism with this condition.[59] This particular study was retrospective and had a reasonably large sample of 60 patients. It also found that other indications for prescribing yoked prism were unilateral spatial inattention (USI), the lack of attention to the side opposite the lesion (indicated in 40.0% of patients), and AEL (in 11.7% of patients).[59] The study found that two-thirds of the patients responded favourably to the prism. It is encouraging that studies from outside the optometric profession are aware that yoked prism can impact gait and posture,[60] although the authors acknowledge a lack of awareness of long-term effects of the prism. This study used an electronic mat with good test-retest reliability and compared gait with and without the use of yoked prism goggles.

Not all patients are in a position to benefit from vision therapy, and often an optometrist may need to use other means in their toolbox to help their TBI patients. As mentioned earlier, this is particularly relevant in my area, New Zealand. As vision therapy isn't funded by the relevant government authority (ACC), often we make the best of the situation by using these other tools. Doble et al.[61] found that just by using prisms in a group of patients with vertical diplopia symptoms, they were able to demonstrate a sustainable reduction in symptoms of more than 70%. Hillier,[62] in a case series, showed the importance of using optometric means with ABI patients. In one of the three cases, the use of yoked prism, non-yoked prism, and tinted lenses provided instant relief. Although the other two cases used vision therapy, the initial application of lenses and prisms made a significant initial impact.

Binasal occlusion has long been included in the specialty optometry practice's toolbox and, indeed, the first use of binasal occlusion can be traced back to approximately 600 AD.[63] Indications include the treatment of esotropia and brain injury. Although its use in more recent times has been discussed for nearly 50 years,[64] there have been a number of papers over the last few years that have attempted to explain how this treatment may be beneficial. Binasal occlusion is not only limited to patients with esotropia or the more obvious ocular sequalae of ABI such as effects on the ambient visual process; it has recently been successfully used in the treatment of a patient with vestibular hypofunction following an mTBI.[65]

The manner in which binasal occlusion helps patients in the TBI population has multiple explanations. Gallop[66] suggests that an increase in peripheral awareness may play a role, as well as the obscuring of the nasal field of each eye to reduce the challenging workload. The mismatch in visual space and between central and peripheral integration results in a hypersensitivity to the environment. Ciuffreda[67] further discussed the role of binasal occlusion, in particular with its management of visual motion sensitivity, by using visual evoked potential (VEP) probes. A significant amount of literature from Padula has been published on this topic.[68] An early study used VEP on a control group and a group who had experienced TBI.[68] They had earlier theorised that the ambient visual process played a significant role in stabilising binocular vision, so that disturbance of the ambient visual process would affect the amplitude of the VEP. They found that binasal occlusion, together with base-in prism, helped to increase the amplitude of the VEP in the brain injury group but had a negative effect on the control group. Yadav[69] went one step further and tried to assess the relative contribution of binasal occlusion and base-in prism on the VEP response. They found that only the binasal occlusion group showed a significant increase in VEP amplitude when compared with the base-in prism and visually normal groups. Proctor[70] has recently added to the literature on binasal occlusion. As well as providing a case report, she gives a succinct discussion on the possible mechanisms involved. Of note is the almost instantaneous improvement in the patient following application of the binasal occluders.[70] This is an experience with which many of us in this field are familiar. Posvar et al.[71] have perhaps pushed the standard bar higher in their case series of three patients with vision motion sensitivity who were treated with binasal occlusion. Uniquely, this paper used gait analysis as a clinical diagnostic measure and suggested that all clinicians should consider this when using binasal occlusion in those patients with visual motion sensitivity.

Those dealing with the TBI population on a regular basis will be well aware that photophobia is a common complaint within this group. People with the specific condition 'pattern glare' are particularly photophobic, and those with TBI, as well as other groups, are more likely to experience these effects.[72] It should also be noted that we need to be careful to distinguish between glare and photophobia, as the two terms are not interchangeable.[73] We must also make certain of our diagnosis due to the photophobic symptoms. For example, photophobia due to dry eye will have a different treatment than photophobia due to other reasons. Relief of photophobia symptoms with specific coloured filters has received much attention. It has been accepted for a while that specific coloured filters can have a positive impact on magnocellular function and oculomotor function in general.[74] Clark et al.[75] used a simple method of determining the benefits of filters by using off-the-shelf tinted glasses together with a penlight to see what impact they made. They found particular improvement of symptoms with blue, green, red, and purple tints. Although the study was basic in its approach, and we need to be aware of a positive effect simply by using a dark lens, it is encouraging to see non-eyecare professionals acknowledging the visual side effects associated with mTBI. Fimreite et al.[76] considered the objective improvement reported by TBI patients and concluded that the use of coloured filters is very advantageous, although they advised that adjunctive vision therapy should be considered in many cases. Truong[77] performed a retrospective analysis on a group of patients from the State University of New York (SUNY) College of Optometry clinics with mTBI and photosensitivity. They considered what effect the use of a coloured tint had on helping these individuals and found that lesser magnitudes were better in promoting adaptation to photosensitivity. Indeed, as it was found that in some situations tinted lenses inhibited the reduction of photosensitivity, there is the definite implication that careful titration of the required tint is crucial if we are to give optimum relief to our ABI/TBI patients.

An interesting question is posed by Connolly and Lyon[78] in their case report on a patient with visual symptoms caused by post-concussion syndrome who was treated with vision therapy. They comment that many optometrists and vision therapists treat patients with similar findings, but then they ask whether we really know that vision therapy is beneficial versus whether the critical factor in patients' healing is simply time. Perhaps Moore et al.[79] go part way in answering this question. They report on a case of a 17-year-old female who had presented 12 months after a concussion and whose symptoms had plateaued. After 21 sessions of vision therapy, her visual findings had normalised, and her score on the College of Optometrists in Vision Development (COVD) Quality of Life Questionnaire had improved accordingly.

As far as the future goes, we need to strive to validate the approaches that we use in the treatment of these populations. Many very respected and highly experienced neuro-optometrists practice syntonic phototherapy[80] as a treatment for ABI/TBI. Although the solid evidence as to the efficacy of such treatment still needs development, it is nevertheless encouraging to see other professions acknowledging the use of light in the treatment of the mTBI patient.[81] A randomised, double-blind, placebo-controlled trial used 32 patients to demonstrate superior findings in sleep patterns and cognitive performance when using blue light compared to amber light.[81]

Conclusion

Optometrists must look for guidance from randomised clinical trials when making treatment decisions when such guidance is available. We have seen a surge in evidence in recent years to back the discipline of neuro-optometry in the treatment of visual conditions with ABI/TBI patients. Certainly, more randomised clinical trials will be published to help us further develop the science behind such treatments.

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Appendix A

BIVSS CHECKLIST (Brain Injury Vision Symptom Survey)

Patient Name: ____ Today's date: _______

My brain injury was: ____ years ago My age is: ____ years today's date: _______________

☐ I have had a medical diagnosis of brain injury (check box if true) Cause of injury: ______________________

☐ I sustained a brain injury without medical diagnosis (check box if true) ______________________

☐ I have NOT ever sustained a brain injury (check box if true)

Please check the most appropriate box, or circle the item number that best matches your observations. All information will be held in confidence. Thank you for your help!

SYMPTOM CHECKLIST ***Circle a number below:***

Please rate each behavior. **How often does each behavior occur?** (circle a number)	Never	Seldom	Occasionally	Frequently	Always
EYESIGHT CLARITY					
Distance vision blurred and not clear -- even with lenses	0	1	2	3	4
Near vision blurred and not clear -- even with lenses	0	1	2	3	4
Clarity of vision changes or fluctuates during the day	0	1	2	3	4
Poor night vision / can't see well to drive at night	0	1	2	3	4
VISUAL COMFORT					
Eye discomfort / sore eyes / eyestrain	0	1	2	3	4
Headaches or dizziness after using eyes	0	1	2	3	4
Eye fatigue / very tired after using eyes all day	0	1	2	3	4
Feel "pulling" around the eyes	0	1	2	3	4
DOUBLING					
Double vision -- especially when tired	0	1	2	3	4
Have to close or cover one eye to see clearly	0	1	2	3	4
Print moves in and out of focus when reading	0	1	2	3	4
LIGHT SENSITIVITY					
Normal indoor lighting is uncomfortable – too much glare	0	1	2	3	4
Outdoor light too bright – have to use sunglasses	0	1	2	3	4
Indoors fluorescent lighting is bothersome or annoying	0	1	2	3	4
DRY EYES					
Eyes feel "dry" and sting	0	1	2	3	4
"Stare" into space without blinking	0	1	2	3	4
Have to rub the eyes a lot	0	1	2	3	4
DEPTH PERCEPTION					
Clumsiness / misjudge where objects really are	0	1	2	3	4
Lack of confidence walking / missing steps / stumbling	0	1	2	3	4
Poor handwriting (spacing, size, legibility)	0	1	2	3	4
PERIPHERAL VISION					
Side vision distorted / objects move or change position	0	1	2	3	4
What looks straight ahead--isn't always straight ahead	0	1	2	3	4
Avoid crowds / can't tolerate "visually-busy" places	0	1	2	3	4
READING					
Short attention span / easily distracted when reading	0	1	2	3	4
Difficulty / slowness with reading and writing	0	1	2	3	4
Poor reading comprehension / can't remember what was read	0	1	2	3	4
Confusion of words / skip words during reading	0	1	2	3	4
Lose place / have to use finger not to lose place when reading	0	1	2	3	4

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