

# Optometric vision therapy in rehabilitation of cognitive dysfunctions caused by traumatic brain injury

---

## Evidence-based review

<b>Business Group</b>	Clinical Services Directorate
<b>Date requested</b>	1 March 2015
<b>Date completed</b>	2 November 2015
<b>Authors</b>	Tanya Skaler, MBBS, MPH, MBHL Patricia Niland, MA (Health Psych), PhD (Social & Health Psych), MISCHP, MSASP

**Important note**

- The main purpose of this report is to review research evidence on the effectiveness of optometric vision therapy in rehabilitation of cognitive dysfunctions following traumatic brain injury.
- The systematic literature search for primary studies was undertaken for the period from January 2007 to May 2015.
- A reasonable attempt has been made to find and review all papers relevant to this topic; however, the search does not claim to be exhaustive.
- The report has been prepared by the Knowledge Management Team, Clinical Services Directorate.

## Abbreviations used in this report

ADL – activities of daily living

CI – convergence insufficiency

mTBI – mild traumatic brain injury

OMT – oculomotor therapy

OVT – optometric vision therapy

RCT – randomised controlled trial

SIGN – Scottish Intercollegiate Guidelines Network

TBI – traumatic brain injury

## Glossary of terminology (adapted from (Suter & Harvey, 2011))

Accommodation	The act of focusing the eyes to provide a clear image.
Active Optometric Vision Therapy	Treatment of visual problems with a range of equipment and techniques, such as penlights and mirrors and electronic optical instruments etc. Involves eye movement tasks designed to improve visual dysfunctions.
Attention	The cognitive process of allocation of processing resources, or selectively concentrating on one aspect of the environment.
Binocular	The organised simultaneous perception of information from the right eye and the left eye.
Convergence	See Vergence.
Oculomotor	Pertaining to eye movements, such as pursuits or saccades, or the muscle system controlling the eyes.
Optometric Vision Therapy	An umbrella term used to refer to a broad range of non-surgical treatments of a range of vision dysfunctions.
Passive Optometric Vision Therapy	Treatment of visual problems with eye patches, miotics, prisms, lenses etc
Pursuit	Ocular movement that holds the image of a target on the fovea, when either self, the target, or both are moving, to keep the dynamic image from blurring.
Saccade	A relatively rapid jump movement of the eyes from one place in space to another to bring images of objects of interest onto the fovea.
Vergence	Eye movements involving both eyes in which each eye moves in opposite directions. Vergence movements help to attain and

	maintain fusion at various distances. Convergence is the turning inward of the lines of sight to attain or maintain single vision while viewing objects or print at nearpoint.
Version	The movement of both eyes in a coordinated and conjunctive manner.
Saccadic latency	Time from stimulus change to saccadic onset.

## Contents

1	EXECUTIVE SUMMARY .....	6
	Background .....	6
	Methodology .....	6
	Results .....	6
	Conclusion.....	7
	Recommendation .....	7
2	BACKGROUND .....	8
	The business need .....	9
	ACC's current position on optometric vision therapy .....	9
	The purpose of this report .....	9
	Structure of the report .....	10
3	REVIEW OF PRIMARY STUDIES 2007-15.....	10
	Methodology.....	10
	Main findings .....	11
	Primary studies.....	11
	Retrospective cohort study .....	11
	Studies using same cohort of participants .....	12
	characteristics of the participants included in these studies .....	12
	Limitations of these studies .....	15
	Horizon Scanning .....	15
4	DISCUSSION .....	16
5	CONCLUSIONS AND RECOMMENDATION .....	17
	References .....	18
	APPENDIX A – Critical Appraisal.....	20
	APPENDIX B – Methodology .....	25
	Literature search strategy.....	25
	Scope .....	25
	Search criteria.....	25
	Databases searched.....	26
	Search keywords .....	26
	Search time-frame .....	26
	Evidence grading system.....	27

Table 1: Demographics of study participants - Thiagarajan & Ciuffreda (2014b) 13

Table 2: Critical appraisal of primary studies on effectiveness of optometric vision therapy in rehabilitation of TBI patients.....20

# 1 EXECUTIVE SUMMARY

## **Background**

ACC receives requests to fund optometric vision therapy for clients with cognitive and visual dysfunctions following traumatic brain injury (TBI).

The purpose of this report is to review research evidence on the effectiveness of optometric vision therapy (OVT) in rehabilitation of cognitive dysfunctions secondary to TBI. The report attempts to answer two research questions:

1. Is OVT effective in cognitive rehabilitation of clients with TBI?
2. Is OVT better than no treatment in cognitive rehabilitation of clients with TBI?

## **Methodology**

This report is based on a systematic review of relevant research published from January 2007 to May 2015. A detailed search strategy is provided in Appendix A.

The research on the effectiveness of OVT is critically appraised. The two authors of this report independently applied SIGN (Scottish Intercollegiate Guidelines Network, 2014) criteria to assess the quality of the primary studies identified through the literature search.

## **Results**

The systematic search found five published papers relevant to the research questions. Overall these studies provide some evidence that OVT results in improvements in essential oculomotor functions such as vergence, version and accommodation. However, only one paper reports on a functional rehabilitation outcome, such as reading, from this type of therapy.

Furthermore, the following research limitations have to be noted:

- Four out of the five papers are based on one PhD research project with a sample size of 12 participants.

- The total length of treatment varies considerably, from 6 to 26 weeks, and the results suggest that in many cases this duration wasn't sufficient to bring about positive changes.
- The different treatment durations don't specify a treatment effect that could be achieved. Hence it is unclear what length of treatment is needed to achieve successful outcome(s).
- No follow-up beyond 3 months was reported; therefore it is not known whether the improvements in oculomotor function(s) are sustainable over a longer duration of time.
- Only one paper reported on cognitive functional outcomes (ie reading and attention).
- None of the studies measured how improvements in the oculomotor functions led to improved rehabilitation outcomes, such as return to work and activities of daily living.
- Placebo effect cannot be discounted. It has been highlighted that, while eye exercises appear to be effective in improving oculomotor functions, the motivation and encouragement effects of this therapy cannot be dismissed (Horwood, Toor, & Riddell, 2014).
- Individuals over 40 years of age were excluded from the trial, so it is unclear whether the findings of the studies can be generalised to older populations.
- Studies are done mostly on patients with mTBI and it has not been determined whether the results are applicable to individuals with the sequelae of moderate to severe TBI.

### **Conclusion**

While some quality research has been done over the last decade, there is insufficient evidence that OVT has significant positive effects on the rehabilitation of patients with TBI.

### **Recommendation**

The current available evidence is insufficient to support the use of OVT in post-TBI cognitive rehabilitation.

Based on this evidence the recommendation for OVT is: Do not purchase.

## 2 BACKGROUND

Visual pathways are vulnerable to insult in brain injuries, and traumatic brain injury (TBI) often results in compromising the integrity of the visual system. Hence visual complaints and problems are routinely observed following TBI, and the adverse effects of TBI on vision have been well described (Barnett & Singman, 2015; Greenwald, Kapoor, & Singh, 2012; Ventura, Balcer, & Galetta, 2014).

A review of 18 studies from the late 1990s to 2009 identifies common visual complaints and deficits in the first year after TBI. Common self-reported vision-related symptoms included blurred vision, reading difficulties, diplopia, eye strain, dizziness, visual field defects, colour blindness and light sensitivity. These symptoms were linked to damage of the visual and brain pathways and structures (Greenwald et al., 2012).

The common post-TBI clinical presentations include oculomotor dysfunctions, binocular dysfunctions, visual field deficits and/or reduced visual acuity (Alvarez et al., 2012; Ciuffreda et al., 2007). The common oculomotor dysfunctions are problems with vergence, version and accommodation (Ciuffreda et al., 2007; Ciuffreda & Ludlam, 2011; Suter & Harvey, 2011).

Cognitive dysfunctions are a common consequence of TBI. The cognitive sequelae include poor concentration and problems with cognitive processing speed, memory and executive function (Ubukata et al., 2014). The most common neurocognitive effects of TBI relevant in the context of OVT are problems with attention, memory, reading and the ability to concentrate.

OVT is an umbrella term used to refer to a broad range of non-surgical treatments of a range of vision dysfunctions. OVT is also referred to as oculomotor training, behavioural vision therapy, vision or visual training, and orthoptics. Another commonly used term is behavioural optometry, but there does not appear to be an agreed definition of behavioural optometry. This concept may reflect the extension of an optometrist's role beyond the traditional optometry model and include an optometrist's holistic approach to treatment of visual disorders (Barrett, 2009).

The range of vision therapy techniques is diverse. These techniques are categorised into passive and active. Passive methods include treatment of visual problems with eye patches, miotics, prisms, lenses etc. Active vision therapy is therapy that uses a range of equipment and techniques, such as penlights and mirrors, video games, biofeedback,



electronic optical instruments etc. The active approach involves eye movement and eye focusing exercises that are designed to remediate a person's vision dysfunctions and improve their overall visual function and performance.

While there is a range of active OVT equipment and techniques (and our review did not exclude any particular one), the studies that met the inclusion criteria all used a particular form of OVT - oculomotor training (OMT) via electronic computerised optical instruments. This OVT technique involves a person performing eye movement activities in response to visual stimuli presented to them via electronic or computerised optical instruments. For instance, a person is asked to track a light across a screen, or look to where a light flashed on the screen, and their saccadic or pursuit eye movements are recorded. A base-line recording is then compared to a normal range of eye movement responses for these tasks, and it is used to assess any improvement gained from trials of these eye tasks over a number of sessions. Measures for cognitive tasks such as reading are also pre and post assessed alongside the therapy sessions. This form of OVT uses OMT combined with attention training aimed at helping patients with mTBI to improve the function of their visual system and correct visual deficits (Barnett & Singman, 2015).

### **The business need**

ACC receives requests to approve funding for ACC clients for treatment of visual dysfunctions secondary to TBI. Such requests are based on the premise that improvements in visual function support clients' cognitive rehabilitation following TBI and expedite return to work and activities of daily living (ADL).

### **ACC's current position on optometric vision therapy**

ACC has not made formal purchasing recommendations in the past. ACC's current position is based on the brief report published in 2007 (Accident Compensation Corporation, 2007). The report concluded that at that time no studies had been published to assess the effectiveness of OVT in rehabilitation of cognitive dysfunctions secondary to TBI.

### **The purpose of this report**

The main purpose of this report is to review clinical research on the effectiveness of vision therapy in rehabilitation of cognitive dysfunctions caused by TBI.

This paper focuses on the research questions:

1. Is OVT effective in cognitive rehabilitation of clients with TBI?
2. Is OVT better than no treatment in cognitive rehabilitation of clients with TBI?

This evidence review will inform ACC purchasing recommendations.

### **Structure of the report**

This report covers a critical appraisal of primary research on OVT. It includes a brief background, describes the methodology of this review, summarises the key research papers and presents a critical appraisal of primary studies on OVT in rehabilitation of cognitive dysfunctions. The quality of these studies has been graded by the two authors of this report according to SIGN (Scottish Intercollegiate Guidelines Network, 2014) quality criteria. Detailed evidence tables are presented in Appendix A.

## **3 REVIEW OF PRIMARY STUDIES 2007-15**

This section outlines the methodology of this review, presents its key findings and provides a summary of the five research papers selected through the systematic search.

### **Methodology**

Two researchers systematically searched the key medical and psychology databases. The search strategy is explained in detail in Appendix B.

The search identified 12 primary OVT research papers related to TBI-induced cognitive dysfunctions. Out of these publications five papers were selected using the inclusion and exclusion criteria outlined below. The seven excluded studies were related either to establishing vision therapy measurements only or to non-TBI conditions (ie stroke, convergence insufficiency in children).

Despite further research carried out since 2007, only one study was found that directly answers the main research question: whether vision therapy may improve rehabilitation outcomes for patients with TBI.

#### *Study inclusion criteria*

- study design level 2 and above (cohort studies, interventional design, randomised controlled trials (RCTs))
- studies that included patients with visual sequelae of TBI

- all degrees of TBI severity were included (mild, moderate and severe)
- studies on 'active' vision therapy, eg eye exercises carried out under the direction of a trained optometrist
- publications in English language
- studies published since January 2007.

#### *Study exclusion criteria*

- non-analytical studies (eg case control studies, case series, case studies)
- publications in languages other than English
- studies that included patients with acquired brain injuries (eg stroke) and children with vision dysfunctions unrelated to TBI
- studies on 'passive' vision therapy, eg lenses, prescription glasses
- studies published before January 2007.

### **Main findings**

This appraisal includes five papers: one report on a retrospective study and one cross-over interventional trial. Studies were critically appraised using the SIGN criteria and detailed evidence is presented in Table 2 in Appendix A.

### **Primary studies**

#### *RETROSPECTIVE COHORT STUDY*

In a retrospective study, Ciuffreda et al. (2008) analysed the records of 33 patients with TBI. All patients were referred to and completed a full course of an OMT programme. The patients' oculomotor symptoms and signs were measured at the start and after the completion of the programme. An improvement in at least one of the signs and symptoms on the completion of the programme was deemed a success. Ninety percent of patients had either complete, or significant, reduction in their oculomotor-based symptoms and clinical signs, and these improvements remained when measured at 2 to 3 months after the therapy. The authors concluded that the findings demonstrate the effectiveness of OMT in rehabilitation of oculomotor abnormalities associated with TBI (Ciuffreda et al., 2008).

### *STUDIES USING SAME COHORT OF PARTICIPANTS*

The four studies described below are based on one PhD research project (Thiagarajan, 2012). This research used the same sample of 12 patients, but the papers report on the effects of OMT on three different oculomotor dysfunctions and one functional outcome (ie reading). The first paper reports on the effects of OMT on version (Thiagarajan & Ciuffreda, 2014a), the second paper analyses the effects of OMT on vergence (Thiagarajan & Ciuffreda, 2013), the third study measures the OMT effects on accommodation (Thiagarajan & Ciuffreda, 2014b), and the fourth article presents the reading-related measures (Thiagarajan, Ciuffreda, Capo-Aponte, Ludlam, & Kapoor, 2014).

The study was designed as a cross-over interventional experimental trial where subjects were blinded to the nature of the intervention. During phase 1, odd-numbered participants received OMT and every even-numbered subject received placebo treatment. During phase 2, the groups swapped interventions. Each phase lasted for 6 weeks, with a 1-week interval between the phases. The total duration of the study was 15 weeks, and it included taking baseline measurements 1 week before the start of the programme and the repeat baseline measurements 1 week following phase 2. Each subject received two 60-minute training sessions per week, with total training time of 9 hours.

### *CHARACTERISTICS OF THE PARTICIPANTS INCLUDED IN THESE STUDIES*

The characteristics of the participants included in these studies are shown in Table 1 below. All patients were classed as having mTBI and the table below shows that the aetiology of their TBI was mainly from motor vehicle accidents (MVAs), followed by falls, assaults and hitting head against a metal rod-shaped device. The patients were young, aged between 24 and 33 years, and had variable visual symptoms, although the majority reported they had 'eye strain'. Time lapse after initial TBI was variable.

Also of note, there is nothing about imaging in these patients so their inclusion is done from the aetiological effects of their TBI rather than what is known about their structural damage, so it is not identified what parts of their brain were affected.

To be included in these studies the participants had to have at least one clinical sign reflecting accommodative dysfunction, stable health and no significant cognitive dysfunction.

*Table 1: Demographics of study participants - Thiagarajan & Ciuffreda (2014b)*

Age (yrs)	Age at mTBI (yrs)	Mechanism of mTBI	Visual symptoms/complaints
25	23	Head hit against metal rod	Slow reading, skipping lines
27	22	Head hit with baseball bat	Intermittent diplopia, poor concentration, intermittent blur at near
30	27	Assault	Eye strain, difficulty reading, poor focusing ability
31	25	MVA	Eye strain, headache
25	22	MVA	Difficulty performing computer work, eye strain
24	22	Fall	Difficulty performing ophthalmoscopy, eye strain
29	27	MVA	Intermittent blur, intermittent diplopia, difficulty reading, skipping lines, visual motion sensitivity
28	27	Fall	Headache, near vision blur, intermittent diplopia
33	31	MVA	Blurry vision, intermittent diplopia, difficulty reading, peripheral visual motion sensitivity
29	25	MVA	Headache, intermittent diplopia at near, trouble focusing at near, dry eye, hyperacusis, photosensitivity, eye strain
33	31	Assault	Difficulty shifting focus, blur at near, loss of place while reading, visual fatigue, headache, nausea, loss of balance
31	25	Fall	Intermittent diplopia, imbalance, difficulty reading

### Study 1: Thiagarajan & Ciuffreda (2013)

A single-blinded cross-over interventional study compares the results of OMT to placebo training in a group of 12 patients with mTBI. Each patient received vision training (Treatment A) as well as placebo training (Treatment B). The training was delivered by an optometrist in a college-based laboratory. The study lasted for 15 weeks. During the first phase (first 6 weeks) half of the group received Treatment A, while the other half received Treatment B, both for 9 hours a week. In the second phase, after 6 weeks of training and a 1-week break the groups swapped the interventions. Objective laboratory and subjective clinical measures of vergence were measured before and after vergence-based OMT. The authors reported subjective and objective improvements in nearly all of the measures of vergence, and increased visual attention concurrent with OMT (Thiagarajan & Ciuffreda, 2013).

### Study 2: Thiagarajan & Ciuffreda (2014a)

The second paper in the series describes the effects of the OMT on version. The vision parameters were assessed before the start of the interventions, and 1 week after each phase. The study measured versional eye movements: binocular central fixation, saccadic gain, saccadic latency and saccade ratio.

The results indicated significant and statistically significant improvement in overall oculomotor function following the OMT. The authors suggested that OMT had a positive impact on version; however, the duration of treatment was not long enough to normalise oculomotor control, and treatment protocols needed to be further refined (Thiagarajan & Ciuffreda, 2014a).

### Study 3: Thiagarajan & Ciuffreda (2014b)

The third paper in the series reports on the effects of OMT on accommodative dysfunction. The participants' common symptoms and complaints were difficulties with reading, eye strain, headaches, intermittent diplopia, blurry vision, poor focusing and concentration, and visual fatigue. The study assessed the following parameters: clinical measures using vision-related tests, laboratory measures of accommodative dynamics, subjective visual attention using a validated tool, and a near vision symptom-related scale. The authors concluded that subjectively and objectively nearly all abnormal parameters of accommodation were improved as a result of OMT (Thiagarajan & Ciuffreda, 2014b).

#### Study 4: Thiagarajan et al. (2014)

The fourth paper presented the effects of OMT on reading and attention. The authors made references to the effects of TBI on reading through disruptions in coordination in the oculomotor (vergence, version and accommodation) and non-oculomotor (eg attention, speech, memory) processes. The paper analysed the results of the study in relation to reading. The study used the same pool of 12 participants to record reading eye movements, and to compare a range of reading-related measures, such as reading rate in words per minute, number of progressive and regressive saccades, and comprehension. The study also tested visual attention and self-reported symptoms. The results demonstrated improvements in the vast majority of measured oculomotor parameters. Sham treatment had no significant effect on any of the measured parameters.

However, many of the measures didn't normalise, and the authors hypothesised that increasing the time for oculomotor rehabilitation could lead to more positive results (Thiagarajan et al., 2014).

#### **Limitations of these studies**

The authors listed the following limitations of this research:

- Only patients with mTBI were included; hence any positive or negative effects found with OMT for less or more severe TBI are limited.
- The duration of training was limited to 9 hours. Future studies need to determine whether longer durations may be more effective.
- A longer-term follow-up is required at regular intervals up to 4 years after the initial treatment (Thiagarajan et al., 2014).

In addition, the cross-over intervention's experimental design is a limitation as it doesn't allow control for carry-over effect. Furthermore, the fact that the studies come from the same group of researchers introduces a risk of researcher bias, as these results have not been replicated yet by any other research groups.

The SIGN ratings given to these studies by the two authors of this report (see Table 1 in Appendix A) suggest that research in this area is of an acceptable quality.

#### *HORIZON SCANNING*

This appears to be an emerging area of research. The authors of these papers indicated that further follow-up will be carried out on the participants three and six months after the

intervention. It may be warranted to revise this review in the future when new research relevant to the research questions is published.

## 4 DISCUSSION

The key research question this report attempted to answer was whether OVT is an effective treatment modality and provides tangible and sufficient benefits to people recovering from TBI.

The systematic search found five papers directly relevant to the research questions, and these studies were critically appraised using the SIGN criteria.

Overall, the studies provide some evidence that OVT results in improvements in some specific oculomotor functions (such as vergence, version and accommodation). One of these studies reports how the improvements in oculomotor function translate into improved cognitive outcomes (ie improvement in reading).

However, the following research limitations have to be noted:

- four out of the five papers are based on one PhD research project, with a sample size of 12 participants
- the total length of treatment varies considerably, from 6 to 26 weeks, and the results suggest that in many cases this duration wasn't sufficient to bring about positive changes
- the different treatment durations do not specify a treatment effect that could be achieved. Hence it is unclear what length of treatment is needed to achieve successful outcome(s)
- no follow-up beyond 3 months was reported; therefore it is not known whether the improvements in oculomotor function(s) are sustainable over a longer duration of time
- only one paper reported on cognitive functional outcomes (ie reading and attention)
- none of the studies measured how improvements in oculomotor functions led to improved rehabilitation outcomes, such as return to work and activities of daily living
- placebo effect cannot be discounted. Horwood et al. (2014) highlighted that, while eye exercises appear to be effective in improving oculomotor functions, the



motivation and encouragement effects of this therapy cannot be dismissed (Horwood et al., 2014)

- individuals over 40 years of age were excluded from the trial, so it is unclear whether the findings of the studies can be generalised to older populations
- studies are done mostly on patients with mTBI and it has not been determined whether the results are applicable to individuals with the sequelae of moderate to severe TBI.

## 5 CONCLUSIONS AND RECOMMENDATION

While some research has been done over the last decade, no studies have been found to demonstrate that OVT has a significant positive effect on cognitive rehabilitation following TBI. It should be noted, however, that this is an emerging area of research.

There is evidence of some benefits in using this treatment modality for improving oculomotor functions, such as vergence, version and accommodation. However, this research does not translate the positive effects into functional gains, and it does not answer the key research question of whether OVT expedites or enhances post-TBI recovery of cognitive function.

Overall, the current published evidence is insufficient to determine that OVT is more effective than no treatment in rehabilitation of clients with TBI-related cognitive dysfunction.

Based on this evidence, the recommendation for optometric vision therapy is: Do not purchase.

## References

- Accident Compensation Corporation. (2007). *Optometric vision therapy in rehabilitation of cognitive deficit secondary to traumatic brain injury. Brief report*. ACC.
- Alvarez, T., Kim, E., Vincent, R., Dhar, S., Biswal, B. B., & Barrett, A. (2012). Concurrent vision dysfunctions in convergence insufficiency with traumatic brain injury. *Optometry and Vision Science, 89*(12), 1740-1751.
- Barnett, B., & Singman, E. (2015). Vision concerns after mild traumatic brain injury. *Current Treatment Options in Neurology, 17*(5), 329. doi: 10.1007/s11940-014-0329-y
- Barrett, B. T. (2009). A critical evaluation of the evidence supporting the practice of behavioural vision therapy. *Ophthalmic & Physiological Optics, 29*(1), 4-25.
- Ciuffreda, K., Kapoor, N., Rutner, D., Suchoff, I., Han, M., & Craig, S. (2007). Occurrence of oculomotor dysfunctions in acquired brain injury: a retrospective analysis. *Optometry, 78*, 155-161.
- Ciuffreda, K., & Ludlam, D. (2011). Conceptual model of optometric vision care in mild traumatic brain injury. *Journal of Behavioural Optometry, 22*(1), 10-12.
- Ciuffreda, K., Rutner, D., Kapoor, N., Suchoff, I., Craig, S., & Han, M. (2008). Vision therapy for oculomotor dysfunctions in acquired brain injury: a retrospective analysis. *Optometry (St. Louis, Mo.), 79*(1), 18-22.
- Greenwald, B., Kapoor, N., & Singh, A. (2012). Visual impairments in the first year after traumatic brain injury. *Brain Injury, 26*(11), 1338-1359.
- Horwood, A., Toor, S., & Riddell, P. (2014). Change in convergence and accommodation after two weeks of eye exercises in typical young adults. [Research Support, Non-U.S. Gov't]. *Journal of Aapos: American Association for Pediatric Ophthalmology & Strabismus, 18*(2), 162-168. doi: <http://dx.doi.org/10.1016/j.jaapos.2013.11.008>
- Richardson, W., Wilson, M., Nishikawa, J., & Hayward, R. (1995). The well-built clinical question: a key to evidence-based decisions. *ACP Journal Club, 123*, A-12.
- Suter, P., & Harvey, L., (eds). (2011). *Vision rehabilitation. Multidisciplinary care of the patient following brain injury*. CRC Press Taylor & Francis Group.
- Thiagarajan, P. (2012). *Oculomotor rehabilitation for reading dysfunction in mild traumatic brain injury*. Doctorate, State University of New York, New York.
- Thiagarajan, P., & Ciuffreda, K. (2013). Effect of oculomotor rehabilitation on vergence responsivity in mild traumatic brain injury. *Journal of Rehabilitation Research & Development, 50*(9), 1223-1240.
- Thiagarajan, P., & Ciuffreda, K. (2014a). Versional eye tracking in mild traumatic brain injury (mTBI): effects of oculomotor training (OMT). *Brain Injury, 28*(7), 930-943.
- Thiagarajan, P., & Ciuffreda, K. (2014b). Effect of oculomotor rehabilitation on accommodative responsivity in mild traumatic brain injury. *Journal of Rehabilitation Research & Development, 51*(2), 175-191.

- Thiagarajan, P., Ciuffreda, K., Capo-Aponte, J., Ludlam, D., & Kapoor, N. (2014). Oculomotor neurorehabilitation for reading in mild traumatic brain injury (mTBI): an integrative approach. *Neurorehabilitation*, *34*(1), 129-146.
- Ubukata, S., Tanemura, R., Yoshizumi, M., Sugihara, G., Murai, T., & Ueda, K. (2014). Social cognition and its relationship to functional outcomes in patients with sustained acquired brain injury. *Neuropsychiatric Disease and Treatment*, *10*, 2061-2068.
- Ventura, R., Balcer, L., & Galetta, S. (2014). The neuro-ophthalmology of head trauma. *The Lancet Neurology*, *13*, 1006-1016.

## APPENDIX A – CRITICAL APPRAISAL

Table 2: Critical appraisal of primary studies on effectiveness of optometric vision therapy in rehabilitation of TBI patients.

Reference Study design SIGN grade	Participants	Intervention	Outcome measure(s)	Limitations	Results and conclusions
<p>Ciuffreda, Rutner, Kapoor, Suchoff, Craig, &amp; Han (2008)</p> <p>Retrospective Single Cohort Study</p> <p>Level = 2+</p>	<p>33 TBI patients who were prescribed and completed an optometric vision therapy programme in one optometry clinic.</p> <p>All patients had accommodative, versional and/or vergence oculomotor dysfunctions following TBI.</p> <p>Age range 11-66 years.</p> <p>Range of years post-injury 0.25-20.17 years.</p>	<p>Conventional vision therapy: vergence, version, and accommodative therapies.</p> <p>The number of sessions per participant: from 10-14 to 26-30.</p> <p>The sessions were conducted over 2-8 month period.</p>	<p>Measured symptoms and signs before and after the intervention.</p> <p>Most common self-reported symptoms: ocular motility when reading, eyestrain, diplopia, headaches and visual fatigue.</p> <p>The most common signs detected by optometrists:</p> <p>Preceded nearpoint convergence; abnormal developmental eye movement (DEM); reduced near convergence range.</p> <p>Success defined as improvement in at least one primary symptom and sign.</p>	<ul style="list-style-type: none"> <li>no control group</li> <li>no information on the severity of TBI</li> <li>no follow-up beyond 3 months</li> <li>no measurements of the impact of the improvements in signs and symptoms on quality of life or functional outcomes</li> <li>no method for excluding those who had had visual difficulties before their mTBI</li> <li>the selection of cases and assessment of success was not blinded but done by a single therapist; hence researcher's bias can't be discounted.</li> </ul>	<p>Improvements or normalisation of symptoms and signs were recorded in 90% of sample.</p> <p>Improvements remained stable at retesting 2-3 months later.</p> <p><b>Authors' conclusions:</b> Optometric vision therapy can be an important modality in the vision rehabilitation for oculomotor dysfunctions subsequent to TBI.</p> <p><b>Reviewers' comments:</b> This study shows that nearly all participants had an improvement in at least one clinical sign and/or symptom after several weeks of conventional vision therapy. It doesn't measure the impact of this intervention on quality of life or effects on activities of daily living or vocational rehabilitation.</p>

Reference Study design SIGN grade	Participants	Intervention	Outcome measure(s)	Limitations	Results and conclusions
<p>Thiagarajan &amp; Ciuffreda (2014a)</p> <p>PhD research</p> <p>Single-blinded individual cross-over interventional experimental design</p> <p>Level = 1-</p>	<p>12 participants (8 females; 23-33 years old), diagnosed with mTBI, 1-10 years post-injury.</p> <p><b>Inclusion criteria:</b> TBI at least 1 year post-insult to control for natural 6-9 months neurological recovery. At least one symptom (eg diplopia) and 1 clinical sign (eg receded nearpoint of convergence). Intact cognition and no other significant co-morbidities.</p> <p><b>Exclusion criteria:</b> Age over 40 as in older age accommodation can't be measured reliably. Vision acuity is poorer than 20/30 in either eye.</p> <p>Strabismus, amblyopia or ocular disease.</p> <p>Medications affecting oculomotor function and/or attention.</p>	<p>Each subject received oculomotor training (OMT) (Treatment A), as well as placebo training (P) (Treatment B) in two separate phases – 6 weeks each, 2x45 min sessions a week. 15 min was allocated to training three oculomotor functions: version, vergence and accommodation.</p> <p>Version (fixation, predictable saccades and simulated reading) was trained via the computerised oculomotor rehabilitation (COR) software.</p>	<p>Measured version:</p> <p>Binocular central fixation</p> <p>Saccadic gain</p> <p>Saccadic latency</p> <p>Saccade ratio.</p>	<ul style="list-style-type: none"> <li>• small sample size</li> <li>• no data on whether the subjects had vergence problems before the mTBI</li> <li>• no follow-up beyond 1 week after treatment (authors indicated that a follow-up at the 3rd and 6th months was on-going)</li> <li>• the problem with using patients as their own control in this cross-over pattern is that it assumes that those who have the active treatment in the first 6 weeks don't carry over any change (better or worse) into their 2nd control period</li> <li>• Symptoms may have been erroneously attributed to mTBI, and patients not screened for other diagnoses, such as orbital fractures or depression.</li> </ul>	<p>Significant reduction in horizontal fixational error.</p> <p>Saccadic gain increased horizontally and vertically.</p> <p>Saccade ratio for the simulated reading, multiple-line paradigm reduced significantly.</p> <p>No measures changed significantly following the P training.</p> <p><b>Authors' conclusion:</b> Versional tracking significantly improved with the oculomotor training.</p> <p><b>Reviewers' comments:</b> Authors commented that the 6-week course of OMT was not sufficient to normalise oculomotor control in many cases. They suggest the need for further research to determine the optimal duration of training.</p>

Reference Study design SIGN grade	Participants	Intervention	Outcome measure(s)	Limitations	Results and conclusions
<p>Thiagarajan &amp; Ciuffreda (2013)</p> <p>PhD research</p> <p>Single-blinded individual cross-over interventional experimental design</p> <p>Level = 1-</p>	<p>12 participants (8 females; 23-33 years old), diagnosed with mTBI, 1-10 years post-injury.</p> <p><b>Inclusion criteria:</b> TBI at least 1 year post-insult to control for natural 6-9 months neurological recovery. At least one symptom (eg diplopia) and one clinical sign (eg receded nearpoint of convergence). Intact cognition and no other significant comorbidities.</p> <p><b>Exclusion criteria:</b> Age over 40 as in older age accommodation can't be measured reliably. Vision acuity is poorer than 20/30 in either eye.</p> <p>Strabismus, amblyopia or ocular disease.</p> <p>Medications affecting oculomotor function and/or attention.</p>	<p>Each subject received oculomotor training (OMT) (Treatment A) as well as placebo training (P) (Treatment B) in two separate phases – 6 weeks each, 2x45 min sessions a week. The placebo treatment was rapidly changing the lenses in the test without changing the refractive power of the lens.</p>	<p>Measured vergence: a range of static and dynamic vergence responses.</p> <p>A single outcome only was tested for: whether the subjects improved. Worsening wasn't tested for, but this makes a difference to the statistical tests applied.</p>	<ul style="list-style-type: none"> <li>• small sample size</li> <li>• no information on whether the subjects had vergence problems before the mTBI</li> <li>• no follow-up beyond 1 week after treatment (authors indicated that a follow-up at the 3rd and 6th months was ongoing)</li> <li>• using patients as their own control in this cross-over pattern assumes that those who have the active treatment in the first 6 weeks don't carry over any change (better or worse) into their 2nd control period</li> <li>• symptoms may have been erroneously attributed to mTBI, and patients not screened for other diagnoses, such as orbital fractures or depression.</li> </ul>	<p>Significant improvement in most aspects of vergence eye movements affecting positively on nearwork-related symptoms and visual attention.</p> <p>None of the measures changed significantly following the P training.</p> <p><b>Authors' conclusions:</b> Vergence-based OMT is effective in improving abnormal measures of vergence. Reduction in symptoms and improvement in visual attention were attributed to the plasticity of neural visual system and oculomotor learning effects.</p> <p><b>Reviewers' comments:</b> The authors report that while most of the vergence parameters improved with OMT, many did not normalise. They suggest OMT needs to be increased two-fold or more to obtain a more robust result.</p> <p>This trial proves that training improves performance of tests, and any interest shown in a patient may improve their subjective feelings.</p>

Reference Study design SIGN grade	Participants	Intervention	Outcome measure(s)	Limitations	Results and conclusions
<p>Thiagarajan &amp; Ciuffreda (2014b)</p> <p>PhD research</p> <p>Single-blinded individual cross-over interventional experimental design</p> <p>Level = 1-</p>	<p>12 participants (8 females; 23-33 years old), diagnosed with mTBI, 1-10 years post-injury.</p> <p><b>Inclusion criteria:</b> TBI at least 1 year post-insult to control for natural 6-9 months neurological recovery. At least one symptom (eg diplopia) and one clinical sign (eg receded nearpoint of convergence). Intact cognition and no other significant comorbidities.</p> <p><b>Exclusion criteria:</b> Age over 40 as in older age accommodation can't be measured reliably. Vision acuity is poorer than 20/30 in either eye.</p> <p>Strabismus, amblyopia or ocular disease.</p> <p>Medications affecting oculomotor function and/or attention.</p>	<p>Each subject received oculomotor training (OMT) (Treatment A) as well as placebo training (P) (Treatment B) in two separate phases – 6 weeks each, 2x45 min sessions a week. The placebo treatment was rapidly changing the lenses in the test without changing the refractive power of the lens.</p>	<ul style="list-style-type: none"> <li>• accommodation:</li> <li>• clinical measures using vision-related tests</li> <li>• laboratory measures of accommodative dynamics</li> <li>• subjective visual attention using a validated tool</li> <li>• near vision symptom-related scale (CISS).</li> </ul>	<ul style="list-style-type: none"> <li>• small sample size</li> <li>• no information if subjects had vergence problems before mTBI</li> <li>• no follow-up beyond 1 week post treatment (authors report ongoing 3 and 6 mth follow up)</li> <li>• using subjects as their own control in cross-over pattern assumes those doing active treatment first don't carry over any change (better or worse) into their 2<sup>nd</sup> control period</li> <li>• symptoms may have been erroneously attributed to mTBI, and subjects not screened for other diagnoses, such as orbital fractures.</li> <li>• authors report accommodation velocity and latency not tested for sensory processing.</li> </ul>	<p>Significant increase in the maximum accommodative amplitude both monocularly and binocularly.</p> <p>Near vision symptoms reduced along with improved visual attention. No measures changed significantly following P training.</p> <p><b>Authors' conclusion:</b> OMT was effective in improving nearly all of the abnormal parameters of accommodation.</p> <p><b>Reviewers' comments:</b> The authors report that this is the first objectively based study demonstrating positive effects of OMT on accommodative responsiveness for mTBI people. This study provides a very good starting point for future research. It highlights relevant factors in vision therapy such as task repetition, increasing complexity, participants' active participation, and motivation. It also sets out specific accommodation measures that may be used in future research.</p>

Reference Study design SIGN grade	Participants	Intervention	Outcome measure(s)	Limitations	Results and conclusions
<p>Thiagarajan , Ciuffreda, Capo- Aponte, Ludlam, &amp; Kapoor (2014)</p> <p>PhD research</p> <p>Single-blinded individual cross-over interventional experimental design</p> <p>Level = 1-</p>	<p>12 participants (8 females; 23-33 years) with diagnosed mTBI 1-10 years post-injury.</p> <p><b>Inclusion criteria:</b> TBI at least 1 year post-insult to control for 6-9 months natural neurological recovery. At least one symptom (eg diplopia) and one clinical sign (eg receded nearpoint of convergence). Intact cognition and no other significant co-morbidities.</p> <p><b>Exclusion criteria:</b> Age over 40 as in older age accommodation can't be measured reliably. Vision acuity is poorer than 20/30 in either eye.</p> <p>Strabismus, amblyopia or ocular disease.</p> <p>Medications that affect oculomotor function and/or attention.</p>	<p>Each participant received oculomotor training (OMT) (Treatment A), as well as placebo training (P) (Treatment B) in two separate phases – 6 weeks each, 2x45 min sessions a week. 15 min was allocated to training three oculomotor functions: version, vergence and accommodation.</p>	<p><i>Clinical parameters:</i></p> <p>Nearpoint of convergence (NPC)</p> <p>Nearpoint of accommodation (NPA)</p> <p>Reading eye movements</p> <p><i>Laboratory parameters:</i></p> <p>Binocular horizontal versional eye movements</p> <p>Saccade ratio</p> <p><i>Subjective visual attention test</i></p> <p><i>Symptom scale (CISS).</i></p>	<ul style="list-style-type: none"> <li>performed 9 hours training and suggested more training sessions are needed but unclear how many.</li> <li>small sample size.</li> <li>no information on whether subjects had vergence problems pre-mTBI</li> <li>no follow-up past 1 week post treatment (authors indicated 3 and 6 mth follow-up ongoing)</li> <li>using subjects as their own control in this cross-over pattern assumes those who do active treatment in the first don't carry over any change (better or worse) into their 2nd control period</li> <li>symptoms may be erroneously attributed to mTBI, and subjects not screened for other diagnoses such as orbital fractures.</li> </ul>	<p>Over 80% of abnormal parameters significantly improved. Reading rate, vergence amplitudes and accommodation improved markedly. Saccadic eye movements showed rhythmicity and accuracy. Improved reading-related oculomotor behaviour shown in reduced symptoms and increased visual attention. No parameters changed with placebo therapy.</p> <p><b>Authors' conclusion:</b> OMT resulted in significant improvement in oculomotor control, reading rate and overall reading ability.</p> <p><b>Reviewers' comments:</b> This is the only paper that reports improvement in a specific cognitive function (reading). The authors note that except for accommodative facility rate, the oculomotor significant parameters did not normalise; thus future research is needed to test therapeutic protocols. Only 7 out of 12 subjects complained of reading difficulty; however, all 12 were assumed to have reading difficulty, and same statistical methods were used.</p>



## APPENDIX B – METHODOLOGY

### Literature search strategy

#### *SCOPE*

The objective of the search strategy was to conduct a systematic search looking for primary studies that would answer the research questions:

1. Is vision therapy effective in rehabilitation of clients with TBI?
2. Is vision therapy better than no treatment in rehabilitation of clients with TBI?

The systematic literature search time period was January 2007 to May 2015. This search interval extends an ACC literature review on this topic completed in 2007. This literature search was open to all degrees of TBI severity.

A SIGN (2014) critical appraisal checklist was completed for each primary study identified and rated according to SIGN criteria.

#### *SEARCH CRITERIA*

This literature review is based on the following PICO (population, intervention, controls and outcomes) framework (Richardson, Wilson, Nishikawa, & Hayward, 1995) principles for formulating search criteria:

- Population of interest is open to gender, age range, ethnicity, socio-economic status, education, occupation, culture, and residential location.
- Intervention is vision therapy for cognitive dysfunction (eg reading, memory, attention) in relation to ocular dysfunctions (eg convergence insufficiency) related to mTBI.
- Where control/comparison groups are utilised in the research they will typically be a 'no vision therapy' control group or 'normal vision' comparison groups. Other control/comparison groups will be taken into account if they meet SIGN (2014) standards.
- Outcomes relate to improving ocular defects, which in turn improve cognitive functions such as reading, memory and attention tasks. Measures of these outcomes will be reliable and valid optical medicine tests.
- The time period is from January 2007 to 31 May 2015.
- The SIGN (2014) guidelines for quality of evidence-based medicine (EBM) research are to be adhered to.

#### *DATABASES SEARCHED*

1. Cochrane Library
2. OvidSP 1956 to current (bibliographic databases, academic journals, and other products, chiefly in the area of health sciences – MeSH terms). Includes MEDLINE(R) without Revisions 1996 to May Week 4 2015
3. PsycINFO (abstracts of literature in the field of psychology)
4. Scopus (scientific, technical, medical, and social sciences – including arts and humanities)
5. Web of Science (scientific and academic cross-disciplinary research citation indexing; highly cited articles and most recent publications)
6. EBSCO: MEDLINE, CINAHL Plus with full text, Biomedical Reference Collection: Comprehensive, Psychology & Behavioral Sciences Collection, PsycARTICLES, CINAHL Select
7. EBM Reviews – Cochrane Central Register of Controlled Trials
8. EBM Reviews – Database of Abstracts of Reviews of Effects
9. EBM Reviews Full Text – Cochrane DSR, ACP Journal Club, and DARE
10. All EBM reviews – Cochrane DSR, ACP Journal Club, DARE, and CCTR
11. ProQuest
12. References to relevant research listed in the referenced articles
13. References on the NORA website by the Australasian College of Behavioural Optometrists.

#### *SEARCH KEYWORDS*

traumatic brain injury (TBI), acquired brain injury (ABI), behavioural optometry, optometry, optometric vision therapy, optometric therapy, vision therapy, vision training, orthoptics, eye training, eye exercise, oculomotor rehabilitation, vision rehabilitation, oculomotor vision rehabilitation.

#### *SEARCH TIME-FRAME*

January 2007 to Week 4 May 2015

## EVIDENCE GRADING SYSTEM

Scottish Intercollegiate Guidelines Network (SIGN) Retrieved from  
<http://www.sign.ac.uk/guidelines/fulltext/50/annexoldb.html>

- 1++ High-quality meta-analyses, systematic reviews of RCTs, or RCTs with a very low risk of bias
- 1+ Well-conducted meta-analyses, systematic reviews, or RCTs with a low risk of bias
- 1- Meta-analyses, systematic reviews, or RCTs with a high risk of bias
- 2++ High-quality systematic reviews of case control or cohort studies  
High-quality case control or cohort studies with a very low risk of confounding or bias and a high probability that the relationship is causal
- 2+ Well-conducted case control or cohort studies with a low risk of confounding or bias and a moderate probability that the relationship is causal
- 2- Case control or cohort studies with a high risk of confounding or bias and a significant risk that the relationship is not causal
- 3 Non-analytic studies, eg case reports, case series
- 4 Expert opinion