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Title: Therapist-assisted vision therapy improves outcome for stroke patients with homonymous hemianopia alone or combined with oculomotor dysfunction

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Abstract

Objective: To improve visual performance and perception in stroke patients suffering from visual impairments by the use of therapist-assisted vision therapy.

Methods: This study was an interventional efficacy open-label investigation. The vision therapy was designed to enhance binocular vision, saccadic ability and vergence ranges maximally, and for patients with hemianopia to improve peripheral awareness. The vision training consisted of one lesson per week for 12 weeks carried out by an optometrist and a vision therapist. Between lessons, patients trained at home for a minimum of 15–20 minutes daily.

Results: Twenty-four patients completed the course. Comparing results before and after the intervention, improved visual performances were measured for all test parameters. The Canadian Occupational Performance Measure (COPM) results improved both in terms of satisfaction with the completion of a task and with the way the task was carried out (p=0.001). Groffman's Visual Tracing Test results improved from median 7.5 to 16 (p=0.002), reading speed in words increased (p=0.0004), and peripheral awareness of visual markers improved (p= 0.002).

Conclusion: Therapist-assisted vision therapy increased peripheral visual awareness, and patients felt safer in both the traffic and outdoor activities. Reading speed increased, and the ability to keep a moving object in focus improved.

Keywords: Stroke, Vision therapy, Oculomotor dysfunction, hemianopia.

Introduction

Acquired brain injury usually is caused by traumatic or vascular events, the latter including in particular ischemic or haemorrhagic stroke. Stroke is the second most common cause of death and the third most common cause of disability worldwide [1]. In 60–80% of cases, stroke results in oculomotor dysfunction [2-3]. Stroke rehabilitation consists of retraining the cognitive and physical functions, but in many cases problems with vision are overlooked. Other studies have indicated that the number of cases with vision impairments in patients with acquired brain damage may be even higher than 60-80%, as 87% of cerebral vascular accidents may result in some form of vision reduction/impairment. It is therefore vital that specialists become aware of this problem [4].

Moreover, investigators found that 100% of patients with cerebral vascular damage improved after vision therapy and the results were stable after 2–3 months [5]. In patients with hemianopia the choice of training was important, especially training using of exploratory eye movements improved outcome compared to eye fixating [6].

Such investigations are challenging because the patient, relatives and health care personnel rarely have sufficient information of the different kinds of sight impairments which might be experienced or anticipated. Common and well-known problems include loss the field of vision, double vision and reduced clarity of vision. Oculomotor dysfunction, disruption in perception, and reduced stereopsis can be disabling and are even more common consequences of acquired brain injury [7-8].

Plasticity is a central part of neurorehabilitation, from speech and language to motor control, cognitive and vision rehabilitations therapies [9]. Vision has very great influence on movement and behaviour [10-12], and it is difficult for a brain-damaged patient to make appropriate movements before his/her vision can give understanding of what, how and where to. About forty percent of the brain is involved with vision or visual processing, and brain injuries such as strokes can affect many aspects of vision some of which are not obvious to the patient or the treating physician or neurologist [11]. For example, cognitive rehabilitation and language/speech rehabilitation involve fast changes in glance direction (saccades), searching and visual scanning combined with precise and stable fixation.

The aim of our current study was to improve visual performance and perception in adult stroke patients suffering from visual impairments by the use of therapist-assisted vision therapy, which was designed to enhance binocular vision, and saccadic ability, and vergence ranges maximally. Furthermore we aimed to improve peripheral awareness for patients with hemianopia.

Methods

Patients

Patients were recruited by an optometrist, a vision specialist, and a speech therapist at the Centre for Special Education in Slagelse, Denmark, between June 30 2012 and May 26 2016.

The following inclusion criteria were applied: adult stroke patients, who complained of vision impairment as a result of the stroke and who were referred by their local authority via the Centre's brain injury coordinator, rehabilitation therapist, or speech therapist; ability to move independently with or without assistance, including wheelchairs; ability to provide informed consent; ability to understand Danish language; ability to write and draw in order to participate in tests; and symptoms of oculomotor dysfunctions, for example deficiencies of saccadic eye movements and smooth pursuit movements.

The exclusion criteria were patients with reduced ability to perceive visual impressions correctly (apperceptive agnosia – defect in perception); ability to see clearly, but without the ability to associate what is seen with what is known. Reduced ability to recognise an object (associative agnosia – defect in association); inability to recognise more than one letter at a time or to recognise the form of a word. Simultanagnosia (the patient sees only individual parts of a picture, but not the picture as a whole); patients with cognitive or physical problems lacking the motivation required to receive teaching or training in stereopsis; and patients with markedly low scores in cognitive tests such as the Montreal Cognitive Assessment (MoCA) [13], Multidimensional Fatigue Inventory (MFI-20) [14-15] or the Rivermead Behavioural Memory Test [16], which would indicate an inability to complete the training or dementia. Furthermore it was expected that patients could take care of themselves in their own homes and not have memory problems preventing them from understanding or taking part in lessons.

Primary endpoint

The patient's perception of his/her problems in connection with carrying out activity was tested using the Canadian Occupational Performance Measure (COPM) [17]. COPM is an individualised tool for measuring a person's own perception of his/her problems. COPM aims at promoting an activity-focused, evidence-based, client-centred practice of high quality. This is where the patient has weighted the activities that matter most and give most satisfaction when carried out. Every patient selected three personal items of special importance and weighted the items on a scale from 1 to 10 (10 being the highest score indicating highest importance). Then the patients estimated how well they carried out these activities on a scale from 1 to 10 (10 indicating optimal performance). To make the data processing easier, we have combined these three groups in COPM into one group. Improving COPM results for patients were the primary endpoint in this investigation.

Secondary endpoints

Multidimensional Fatigue Inventory (MFI-20) is a test for screening for tiredness/energy after a brain injury. MFI-20 consists of 20 questions to examine dimensions of general fatigue, physical fatigue, reduced activity, reduced motivation, and mental fatigue. For each dimension, a score of 4–20 points is given. The higher the score, the greater is the degree of fatigue. A score of 12 or more for general fatigue indicates a disabling degree of fatigue [15].

The Montreal Cognitive Assessment (MoCA) test was used to estimate cognitive abilities [18]. A score > 26 is regarded as normal.

The Rivermead Behavioural Memory Test is a so-called "ecologically valid" memory test, i.e. the test involves various everyday tasks, such as remembering names, picture and face recognition, route recognition, remembering oral agreements, remembering personal belongings, and recalling a short story [19]. There is a maximum of 24 points, and it is normal to achieve at least 20 points.

For patients with hemianopia, the field of vision was measured using a campimeter screen with 10 mm white light at one meter's distance (10/1000).

Peripheral visual awareness was tested with the patient walking down a corridor with 26 star-shaped markers located at various heights (Star Test). This exercise measured the time taken and how many markers were noticed.

To make an exact examination of oculomotor functionality we used the Groffman Visual Tracing Test [20].

Reading speed was measured by the time taken to read a text with a LIX readability of 43. LIX is a readability measure to calculate the difficulty of reading a foreign text.

Intervention before the start of vision training

Before the vision training, patients were examined by a multidisciplinary and interdepartmental intervention team with responsibility for the coordination and selection of relevant candidates.

The multidisciplinary team consisted of a neuro-optometrist, a vision therapist, and a speech and hearing therapist with experience in the treatment of acquired brain injury. The vision specialist was responsible for the collection of data for use in the investigation. The vision specialist's intervention is therefore included below under "Data collection".

The aim of the neuro-optometrist's vision tests was to determine the status of the patient's binocular vision. In the event of measurements in the border area or beyond, the aim was to investigate. The vision tests therefore varied and were tailored to the patient's sight functionality. Other aims included a thorough mapping of symptoms, including previously provided treatments and general health conditions; status of stereopsis and motor skills – including freedom of movement, hidden strabismus, and fusional vergence; finding the optimal spectacle strength and evaluation of ability to focus; evaluation of load capacity and endurance in open space (sensitivity threshold and symptom provocation; measurement of field of vision; glare testing and measurements of contrast sensitivity; and measurements of colour vision and night vision (twilight vision). The speech and hearing therapist used tests to examine cognition and fatigue levels in order to evaluate if a patient could benefit from the vision training.

The baseline examination was carried out immediately before the patient joined the course.

Before the start of the vision training course, the team organised a conference for the patients to make sure the patients were both willing and able to participate. An individual plan was made for each patient based on his/her vision problems and rehabilitation targets, which meant that the exercises were checked and tailored to the individual patient's abilities. The exercises were integrated based on oculomotor and will-based control and perception, as in the following examples of vision training exercises: reflex integration exercises, vestibular exercises, tactile stimulation, kinaesthetic stimulation, coordination exercises, field of vision, reading endurance, vertigo/judgement of distance/space/direction, double vision, and hand/eye coordination.

The success of the vision training depended on training being carried out at home for at least 20 minutes every day except the day when this training took place at the Centre's clinic in Slagelse.

Vision training

The vision training was performed with 2–4 participants either twice a week for 6 weeks or once a week for 10–12 weeks. We changed our original vision training set-up from twice-weekly training over six weeks to once a week over ten weeks. The reason for the change was that it was too exhausting and tiring for the patients to spend so much time on transport that they became unable to perform sufficient training at home. Each lesson lasted 45 minutes.

Intervention after the end of the vision training

After the vision training ended, every patient received a written plan for maintaining and continuing their rehabilitation on their own.

The neuro-optometrist carried out an examination of their vision. The vision specialist repeated the visual performance tests and the COPM interview with focus on the problems noted in the first interview.

The examination of vision, visual performance test, and the interview were all done shortly after, or in immediate connection with, the last vision-training lesson.

Power and sample size

At baseline we expected 30% of the maximum COPM score, which would increase to 50% after the intervention. These expectations were a hypothesis based on a few pilot observations. For the sample size calculation, we used $\alpha = 0.05$ and $\beta = 0.5$ resulting in a sample size of 14 participants. Due to age, transport difficulties, and the time-consuming course, we expected 25% dropouts, thus we needed to include at least 18 participants.

Statistical analysis

Data comparisons for ranked performances before and after the intervention were carried out using the Wilkoxon non-parametric test, because there were few participants and data could not be expected to be normally distributed. Unless otherwise stated, results are reported as median values with associated 25^{th} and 75^{th} percentiles in brackets. Statistically significant results are characterised by p-values < 0.05. Unused or incomplete data was not included in the statistical evaluation and was treated as missing data, i.e. no calculations were made using such data. Lack of data was accepted as long as an assessment of the primary endpoint was possible. Data from patients making it possible to assess the primary endpoint was used as a minimum. All analysis of data were carried out by a person who took no part in the data collection and had no personal knowledge of the patients.

Results

More than 100 patients were screened using the MoCA, MFI-20 and Rivermead Behavioural Memory Test and 24 were included in the investigation. The main results are shown in Table 1.

Test	N	Baseline	After intervention	p-value
Groffman Visual Tracing Test	24	7.5 (0 – 16.5)	16 (0.5 – 23)	0.002
Reading test	18	88 (62 – 112)	104 (76 – 134)	0.0004
Star test, seconds to carry out	20	101 (69 – 130.5)	118 (58 – 156)	0.24
Star test, number correctly counted	20	12.5 (9.5 – 15)	15.5 (14 – 17)	0.002
COPM Completion	22	9 (7 – 13)	15.5 (13.5 – 20)	0.0001
COPM Satisfaction	22	6.5 (4 – 10)	15.5 (11 – 18)	0.0001

Table 1. The main results from before and after the intervention and their associated p-values. Results are presented as median values with the associated 25th and 75th percentiles in brackets.

The median age was 56 (49 – 64) years, and the median number of days from the first symptoms to the intervention was 261 (144 – 938).

All 24 patients completed the course. Significant improvements in visual performance were measured for all test parameters after the intervention. The COPM results improved both in terms of satisfaction with the completion of a task and for the task-related performance. The Groffman Visual Tracing Test results improved together with reading speed in words per minute, and peripheral awareness of visual markers measured over time.

Other findings and outcomes

The Groffman Visual Tracing Test measures eye movement during reading. Reading requires an ability for precise fixation and sliding eye movement to read sentences. At the same time, the fixation changes must be fast, precise and accurate. We measured a highly significant improvement in the reading test, a result reflected in a reading speed, which increased from 88 words to 140 words per minute.

The peripheral awareness test took more or less the same time and corresponded to time it takes to walk down a 200 meters long corridor with 26 star-shaped markers. Patients experienced a marked increase in the number of markers detected, which is a surprisingly positive result and which is backed up by later reports from patients who have become observant in traffic and no longer walk into objects etc.

The COPM test results indicate how the patient is able to perform important daily activities and these scores improved by the use of vision therapy, indicating an increase in visual performance. The COPM results are based on the personal evaluations by each patient, which could introduce a bias if answers are provided to please the interviewer (the vision therapist and the data collector were the same person). Results from performance-based tests like the Groffman Visual Tracing Test, the reading tests, target/star detection tests, etc., where the result cannot be exaggerated by a subjective bias, indicated that the patients' increased functionality in COPM reflected improved real-world performances.

Discussion

Our results indicate that vision therapy led to marked improvements among patients in several domains. Vision therapy increased peripheral visual awareness, and the patients became safer in traffic and in general outdoor activity. Reading speed significantly increased, and the ability to keep a moving object in focus improved. Thus even patients with neurologically stationary deficits were able to benefit from vision training.

Furthermore we observed that the first step in a patient's understanding of their own life situation with visual dysfunctions was to understand and relate to what is abnormal and to build a strategy to compensate for the dysfunctions. This is the primary focus for vision therapy, or any other form of rehabilitation, to initially make sense. Success is based on self-understanding and the increased quality of life that follows. If a vision diagnosis is not made, the patient's visual problems may continue and get worse, for example patients may continue to have difficulty reading and writing, and travel sickness and fatigue may endure.

Limitations

Our investigation was uncontrolled and participation was not randomised, which were major weaknesses. Moreover, the data collection and processing were carried out by the multidisciplinary team, thus the investigation was open-label. Still, single group studies evaluating outcomes longitudinally, like our current study, may be the only feasible method and provide interesting exploratory results [21]. In our current study, the patients' median time from symptoms onset to the start of the intervention was nearly 9 months (range 5 to 30 months), thus participants had chronic vision deficits unlikely to spontaneously improve or recover. Patients were difficult to recruit, and it took 4 years to include 24 participants. Having to include a control group, and needing at least twice as many participants, was not feasible for this study. Furthermore, the obtained results were highly significant, implying profound changes among patients that seem unlikely to happen spontaneously.

We were unable to describe some details about patient history, for example how patients differed in regard to the location of the brain damage including afflicted vessels. Although such information would be interesting, we did not obtain such information for all patients and were unable to compare patients in this regard. Some patients had brain infarcts several years before study inclusion, and obtaining records from correct hospitals was considered too time-consuming, difficult and with reduced chances of success, especially because many Danish hospital records provide limited information about exact infarct location and afflicted vessels.

Conclusion

Our aim was to examine whether therapist-assisted vision therapy could improve the patients' visual endurance, peripheral awareness and, not least, their own experience of how they carried out important everyday activities. We found that therapist-assisted vision therapy increased peripheral visual awareness. Reading speed was significantly increased, and the ability to keep a moving object in focus was improved. In addition, patients felt safer in the traffic and in general outdoor activity.

The results are more positive than we had hoped for, because patients improved in all test parameters except for the time to walk 200 meters. We conclude that visual therapy for patients with acquired brain injury can make a marked difference. Other investigators have found promising interventions for vision deficits after brain damage, but more investigations are needed. A new trial has recently been initiated to further evaluate outcome of vision therapy [22-23].

Disclosure statement

The authors report no conflicts of interest.

References

1. Feigin VL, Norrving B, Mensah GA. Global burden of stroke. Circ Res. 2017 Feb 3;120(3):439-448.

2. Lepore FE. Disorders of ocular motility following head trauma. Arch Neurol. 1995 Sep;52(9):924-6.

3. Schlageter K, Gray B, Hall K, et al. Incidence and treatment of visual dysfunction in traumatic brain injury. Brain Inj. 1993 Sep-Oct;7(5):439-48.

4. Ciuffreda KJ, Kapoor N, Rutner D, et al. Occurrence of oculomotor dysfunctions in acquired brain injury: a retrospective analysis. Optometry. 2007 Apr;78(4):155-61.

5. Ciuffreda KJ, Rutner D, Kapoor N, et al. Vision therapy for oculomotor dysfunctions in acquired brain injury: a retrospective analysis. Optometry. 2008 Jan;79(1):18-22.

6. Nelles G, Esser J, Eckstein A, et al. Compensatory visual field training for patients with hemianopia after stroke.Neurosci Lett. 2001 Jun 29;306(3):189-92.

7. Suchoff IB, Petitto GT. The efficacy of visual therapy: accommodative disorders and non-strabismus anomalies of binocular vision. J Am Optom Assoc. 1986 Feb;57(2):119-25.

8. Lara F, Cacho P, Garcia A, et al. General binocular disorders: prevalence in a clinic population. Ophthalmic Physiol Opt. 2001 Jan;21(1):70-4.

9. Miltner WT, Liepert WH, Meissner W, et al. Rapid functional plasticity in the primary somato-motor cortex and perceptual changes after nerve block. Eur J Neurosci. 2004 Dec;20(12):3413-23.

10. Nauta WH, Feirtag M. Fundamental neuroanatomy. New York (NY): W H Freeman & Co; 1986.

11. Van Essen D. Functional organization of the primate visual cortex. In: Editor Peters A, Jones EG. Cerebral Cortex. New York (NY): Plenum Press; 1985: 259-329.

12. Yeterian EH, Pandya DN. Corticothalamic connections of extrastriate visual areas in Rhesus monkeys. J Comp Neurol. 1997 Feb 24;378(4):562-85.

13. Mast BT, Gerstenecker A. Screening instrument and brief batteries for dementia. In: Editor Lichtenberg P. Handbook of Assessment in Clinical Gerontology (Second Edition). London: Acedemic Press; 2010; 503-530.

14. Poulsen MB, Damgaard B, Zerahn B, et al. Modafinil May Alleviate Poststroke Fatigue: A Randomized, Placebo-Controlled, Double-Blinded Trial. Stroke. 2015 Dec;46(12):3470-7.

15. Christensen D, Johnsen SP, Watt T, et al. Dimensions of post-stroke fatigue: a two-year follow-up study. Cerebrovasc Dis. 2008;26(2):134-41.

16. Barker-Collo S, Theadom A, Starkey N, et al. Factor structure of the Rivermead Post-Concussion Symptoms Questionnaire over the first year following mild traumatic brain injury. Brain Inj. 2018;32(4):453-458.

17. Law M, Baptiste S, McColl M, et al. The Canadian occupational performance measure: an outcome measure for occupational therapy. Can J Occup Ther. 1990 Apr;57(2):82-7.

18. Nasreddine ZS, Phillips NA, Bédirian V, et al. The Montreal Cognitive Assessment, MoCA: a brief screening tool for mild cognitive impairment. J Am Geriatr Soc. 2005 Apr;53(4):695-9.

19. Wilson B, Cockburn J, Baddeley A, et al. The development and validation of a test battery for detecting and monitoring everyday memory problems. J Clin Exp Neuropsychol. 1989 Dec;11(6):855-70.

20. Groffman S. Visual Tracing. Journal of American Optometric Association, 1966; 37: 139-141.

21. Paulus JK, Dahabreh IJ, Balk EM, et al. Opportunities and challenges in using studies without a control group in comparative effectiveness reviews. Res Synth Methods. 2014 Jun;5(2):152-61.

22. Simpson-Jones ME, Hunt AW. Vision rehabilitation interventions following mild traumatic brain injury: a scoping review. Disabil Rehabil. 2018 Apr 10:1-17.

23. Rasmussen RS, Schaarup AMH, Overgaard K.Therapist-Assisted Rehabilitation of Visual Function and Hemianopia after Brain Injury: Intervention Study on the Effect of the Neuro Vision Technology Rehabilitation Program.JMIR Res Protoc. 2018 Feb 27;7(2):e65.