A REVIEW OF THERAPEUTIC INTERVENTIONS FOR VISUAL IMPAIRMENT AFTER STROKE

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Abstract

Stroke is the leading cause of disability in the United States. As modern medicine improves the survival rate of cerebral vascular accidents (CVA), such as stroke, the lingering effects can be debilitating for survivors. A significant population of stroke survivors experience visual impairments and there is a lack of research regarding management and therapeutic interventions aimed at alleviating the effects of stroke-related vision loss. The OBJECTIVE of this study is to evaluate the scope of visual impairments following stroke, to assess various intervention methods used to treat stroke-related visual impairments, and to report their effect on quality of life and fall risk. A systematic review of the literature was conducted to extract, identify, and summarize intervention descriptions and methods from the online databases CINAHL, Sportdiscus, PubMed, and Google Scholar. Three branches of therapeutic interventions emerge from the information collected: Optical aids (OA), Compensatory therapy (CT), and Restorative Visual Training (RVT). Sudden vision loss after stroke is widely underreported and undermanaged. An encompassing set of functional and objective standards need to be developed in order to accurately screen and diagnose visual impairments. Optical aids provide a preliminary step for visual acuity correction and possibly visual field and perceptual deficits. Compensatory interventions offer the greatest amount of research in favor of objective and functional outcomes making them the modality of choice for many clinicians. Restorative interventions appear promising, particularly combined with transcranial direct current stimulation (tDCS), but the efficacy of this intervention remains questionable.

Table of Contents

Introduction

Objective

The primary objective of this research was to assess the various therapeutic interventions implemented by clinical professionals and researchers to treat visual impairments after stroke. The secondary objective of this research was to evaluate the visual impairments that are being targeted and how these interventions affect functional outcomes relating to Quality of Life (QoL) and fall risk.

Background Information

Strokes are the leading cause of serious, long-term disability in the United States of America. Cerebrovascular accidents, such as stroke, can damage the primary visual cortex of the brain and disrupt links to retinal receptor cells (Hazelton et al., 2019a). This damage leads to debilitating visual impairments that may affect an estimated 20% to 92% of stroke survivors (Hepworth et al., 2016; Rowe et al., 2009). However, there is a lack of studies regarding care and management for visually impaired stroke survivors. Visual impairments after stroke are associated with loss of independence, greater risk of fall, reduced Quality of Life (QoL), and higher rates of depression. Alleviating some of the challenges faced by visually impaired stroke survivors will benefit stroke survivors in local and global communities.

Classification of Visual Impairments and Prevalence

Visual impairments secondary to stroke affect peripheral or central vision, eye movements, and perception (Hepworth et al., 2016). Visual field defects occur when the primary visual pathway is damaged behind the optic chiasma (Dundon et al., 2015). This type of vision commonly presents as homonymous, meaning that the same portion of vision in each eye is lost.

The prevalence of visual field defects in the general stroke population is estimated to be 5-57% (Hepworth et al., 2016; Jones & Shinton, 2006). Ocular motility and strabismus are disordered eye movements that can lead to depth perception problems and difficulty coordinating eye movements (Jones & Shinton, 2006). Eye turning, double vision, or unsteady saccades are all common symptoms of eye movement disorders. The prevalence of eye movement disorders among stroke survivors is estimated to be 33% (Hepworth et al., 2016). Perceptual losses commonly found amongst stroke survivors are visual agnosia, visual inattention, and neglect. Neglect is caused by damage to the parietal cortex in visual processing areas which lead to inattention in peripersonal or extrapersonal space (Pierce & Buxbaum, 2002). In these instances, visual stimuli is ignored or unrecognized on the contralesional side. The prevalence of visual neglect in stroke survivors is estimated between 8-82% (Jones & Shinton, 2006; Liu et al., 2019).

The prevalence of visual impairments after stroke are only estimates given that there is no research available that directly measured their prevalence (Hepworth et al., 2016), less than half of stroke units assess vision (Hanna et al., 2017), and there is no standard visual screening tool that accurately assesses all potential stroke-related visual impairments (Hanna et al., 2017). Additionally, instances of Anosognosia, Anton’s syndrome, and asymptomatic cases are well documented (Hepworth et al., 2016). In these cases, patients were unaware of their deficits even when presented with evidence of their visual impairments (Pierce & Buxbaum, 2002). The challenges of identifying and reporting stroke-related visual impairments warrant consideration that the prevalence of stroke-related visual impairments are often underestimated given unreliable assessment tools and subjective reporting.

Fall Risk

Fall risk depends on individual and environmental factors such as age-related changes, cognitive deficits, gait and balance problems, sensory deficits, assistive device use, medications, and caregiver support (Phelan et al., 2015). Visually impaired stroke survivors not only present with age-related changes, but may also have a combination of cognitive, sensory, and gait and balance deficits that lead to increased risk for falls and injury (Bonan et al., 2004; Lotery et al., 2000; Patel et al., 2002; Rowe et al., 2009). Balance is controlled by visual, proprioceptive, and vestibular feedback and this sensory information influences motor control. After a cerebrovascular accident (such as stroke) the brain’s ability to process visuospatial and proprioceptive information may be compromised. As a result, there is a misalignment with spatial orientation that affects weight-bearing symmetry and these asymmetries contribute to balance deficits (Jones & Shinton, 2006; Padula et al., 2015). For example, individuals with perceptual deficits, such as visual neglect or inattention, will often lean or twist away from the affected visual field causing a shift in their center of mass. This shift in posture affects the individual's ability to counterbalance and maintain their base of support which further increases their risk for falls and subsequent injury (Padula et al., 2009). Reducing the risk and incidence of falls for visually impaired stroke survivors is important to reduce injury, especially given that most stroke survivors are being prescribed blood thinners.

Rehabilitation Outcomes & Cognitive Impairments

Post-stroke visual impairments, such as visual neglect and poor visual acuity, have been shown to lead to decreased success during rehabilitation by exacerbating other symptoms and overall disability (Jones & Shinton, 2006; Lane et al., 2008; Rowe et al., 2009). The presence of visual impairments suggests a strong link to cognitive impairments and the prevalence of both cognitive and visual impairments is estimated to be 38% (Patel et al., 2002). Cognitive impairments interfere with an individual's ability to participate in rehabilitation programs and their rate of recovery. For example, memory is commonly affected in cortically visually impaired stroke survivors (Taylor et al., 2012). Memory is an important functional component in compliance during exercise programs and safety protocols established during rehabilitation. The severity of cognitive impairments can be linked to community placement with more severe cases of impairments leading to higher rates of disability, institutionalization, and mortality during the next few years (Patel et al., 2002). The compounding nature of both visual and cognitive impairments greatly challenges patients, their caregivers, and therapists during rehabilitation and highlights the need for therapies targeted at improving vision or compensatory strategies to improve patient outcome success.

Post-Stroke Quality of Life

Visual ability is often related to the level of care and satisfaction in life after stroke (Jones & Shinton, 2006). Patients with visual field deficits report lower vision-related quality of life (VRQoL) and health-related quality of life (HRQoL) following stroke (Gall et al., 2010). Larger deficits lead to greater stress and lower scores on VRQoL and HRQoL tests (Gall et al., 2010). Lower subjective ratings of visual-related and health-related aspects may be linked to higher rates of depression (Rowe et al., 2009; Taylor et al., 2011), heightened feelings of fear and anxiety (Hazelton et al., 2019b; Taylor et al., 2011), and feelings of apprehension (Hazelton et al., 2019b; Rowe et al., 2009) found within the visually impaired stroke community. Practical difficulties and accidents lead to loss of self-assurance using stairs, working in the kitchen, walking outside, and crossing roads. Leisure activities such as driving and reading become tedious leading to the loss of social roles and hobbies and decreased self-sufficiency. This has a profound effect on the emotional well-being of visually impaired stroke survivors (Hazelton et al., 2019b; Lotery et al., 2000). Addressing post-stroke visual impairments could greatly improve the QoL of stroke survivors and reduce the rate of depression, anxiety, and fear reported by this population by improving their QoL, confidence in mobility and navigation, and involvement in social roles and activities.

Spontaneous Recovery

Over time cognitive, visual, proprioceptive, and language deficits may be spontaneously ameliorated. The rate and degree of recovery is often limited depending on comorbidities, the extent of damage, age, lesion size and location, and neuroplasticity of intact areas of the brain. Most visuospatial recovery takes place during the first 5 to 6 months following stroke (Cassidy & Cramer, 2017). In cases of homonymous hemianopia, the chances of improvement decrease over time with time being the primary factor for determining extent of recovery (Zhang et al., 2006). The target of many therapeutic interventions resides in the neuroplasticity of the penumbra and functionality of homologous neuronal pathways in the brain (Cassidy & Cramer, 2017). Spontaneous recovery during the acute stages of stroke is theorized to be attributed to re-perfusion and reduced swelling and edema in lesioned areas of the brain. Recovery during the chronic stage is attributed to diaschisis and neuronal pathway remodeling (Brodtmann et al., 2015). It wasn’t until recently that high levels of cross-modal plasticity of the visual system was revealed by researchers. This has renewed interest in implementing restorative and compensatory interventions that utilize the plasticity that was once thought to be minimal (Brodtmann et al., 2015).

Therapeutic Interventions

The purpose of this research was to assess the various therapeutic interventions implemented by clinical professionals and researchers to treat visual impairments after stroke, to report on which visual impairments are being targeted, and how these interventions affect functional outcomes relating to QoL and fall risk. Therapeutic interventions mentioned in this review were categorized into three broad categories: Optical aids, Compensatory, and Restorative interventions.

Optical Aids

Optical aids are external devices used to artificially expand the visual field by shifting stimuli into intact visual areas where it can be processed (Lane et al., 2000; Liu et al., 2019). Jones & Shinton (2006) emphasized the importance of early referral during the sub-acute phases of stroke during their review of literature documenting the types of visual impairments, their impact, and prognosis for recovery. Gaber (2010) reported sensory rehabilitation specialists implementing lenses to salvage varying degrees of vision of cortically blind stroke patients. Lotery et al. (2000) implemented refractive correction by inquiring about existing lenses or referring patients to an ophthalmologist who could prescribe lenses. A quarter of participants did not have their prescription lenses at the rehabilitation hospital or their lenses were in unacceptable conditions (dirty, scratched, or broken). After ophthalmologic assessment, Lotery et al. (2000) found that 14% of patients had better visual acuity after refractive correction. Lotery et al. (2000) did record the occurrence of homonymous hemianopia in 19% of participants but neglected to record if these individuals benefited from refractive correction.

Prisms are another common, inexpensive therapeutic intervention for stroke survivors and most commonly used to treat hemianopia and spatial neglect. For individuals with hemianopia, prisms shift stimuli from blind fields to intact hemifields. In a recently published Cochrane systematic review, Pollock et al. (2019) found some evidence that optical aids improved scanning training although Rowe et al. (2017) and colleagues failed to find any significant improvements in visual field size or functional activity for Fresnel Prisms. Giorgi, Woods, & Peli (2009) evaluated the effectiveness of peripheral prism glasses for patients with hemianopia alone that had an estimated 22 degrees of visual field expansion in upper and lower quadrants. Subjective improvements were reported for ⅔ of patients while navigating in crowds, supermarkets, and during walking, although two participants reported prisms hindered navigation.

In cases of perceptual deficits, prisms may be particularly useful. Traditional therapies for visual and spatial neglect have relied upon bringing awareness to one's deficit and implementing conscious motor control of affected limbs. Rather than relying on awareness of a deficit whose root is inattention, implementing prisms adapts spatial biases to automatically correspond more effectively to visual stimuli (Liu et al., 2019; Pisella et al., 2006;). The direct mechanism of action is unknown for this treatment, however some theories postulate that performance is altered by neuroplastic remodeling of visuo-proprioceptive information (Pisella & Mattingley, 2004). This mechanism may explain why prisms may be most appropriate for improving visuomotor aiming tasks (Barrett, Goedert, & Basso, 2012; Pisella et al., 2006); although some research asserts that prisms may alter higher level organization and spatial representation as well (Frassinetti et al., 2002). Frassinetti, Angeli, Meneghello, Avanzi, Ladavas (2002) reported improvements in BIT series tests, room description, and object reaching tests in their treatment group compared to their control group which received traditional occupation and physical therapy. These results were maintained fully during the 5-week post-treatment period. In Datié et al.'s (2006) prospective study, they found increases in gaze performance but not neglect behavior indicating objective outcome improvements without functional improvements.

Since hemianopia and spatial neglect are common comorbidities, some argue that concurrent treatment using prisms may be beneficial (Giorgi et al., 2009; Liu et al., 2019). However, in Liu, Hanly, Fahey, Fong, & Bye (2019), their results were inconclusive regarding non-activity based approaches (prisms) to treating spatial neglect and hemianopia given the lack of research using only prisms.

The implementation of optical aids on QoL for patients with visual field deficits was explicitly assessed in Rowe et al. (2017) who reported no significant changes in VFQ-25, a functional assessment of vision-related QoL. Similarly, Turton, O'Leary, Gabb, Woodward, & Gilchrist (2010) found no improvements during self-care or Behavioral Inattention Tests (BIT) after prism adaptation for patients with neglect. Mizuno et al. (2011) and colleagues assessed the impact of prism adaptation for patients with spatial neglect using the BIT, the Catherine Bergego Scale (CBS), and the Functional Independence Measure (FIM). Compared to their control group who wore sham prisms, they found significant improvement of BIT and FIM tests relating to improved aspects of spatial neglect as well as motor and cognitive improvements. Liu et al. (2019) found no significant improvements in ADLs with optical aids for patients with spatial neglect or hemianopia. Similarly, Pollock et al. (2019) found very low to low quality of evidence demonstrating improvement in QoL or functional completion of ADLs. None of the articles reviewed explicitly stated improvements in fall risk classification after optical aids were implemented, however one reported improvements in navigation which would eliminate some environmental contributors to fall risk (Keane et al., 2006) while another reported decreased motility for hemianopic patients which may increase their risk for falling (Rowe et al., 2017).

Compared to other interventions, there are higher rates of reported adverse side effects with corrective prisms that can impede with compliance such as headaches, double vision, dizziness, and fatigue (Rowe et al., 2017; Lane et al., 2008). Rowe et al. (2017) cautioned against prescribing prisms for patients with hemianopia and breaking up treatment duration to avoid adverse events.

Compensatory Interventions

Compensatory interventions encompass a broad range of strategies aimed at reducing the effects of vision loss after stroke by fine tuning intact visual processing mechanisms. Compensatory strategies include visual search training, environmental modifications, limb activation training, and head-, eye-, and shoulder movements. The bulk of compensatory training strategies included in this review targeted visual field defects, cortical visual impairments, and perceptual deficits, or a combination of visual field and perceptual deficits.

Visual scanning training (VST) comprises the bulk of compensatory strategies and uses repetitive visual stimuli to train saccadic eye movement patterns to improve tracking and field of view (Dundon et al., 2015; Nelles et al., 2009). Some theories attribute scanning training to higher level head-centered spatial representations (Pierce & Buxbaum, 2002) and others attribute it to transcallosal shifts caused by axonal sprouting and pathway reorganization (Nelles et al, 2009). A variety of strategies were used by researchers to train scanning strategies for their participants. Hazelton et al. (2019a) described ten compensatory scanning training tools for visually impaired stroke survivors which included pen and paper tasks, specialist equipment, and online and downloadable software programs. Hazelton et al. (2019a) further described key motor, language, and cognitive abilities required by participants to complete those scanning tasks. Rowe et al. (2017) had participants with visual field deficits scan for targets on an A4 landscape card and found significant improvements in VFQ25 after scanning treatment. In de Haan, Melis-Dankers, Brouwer, Tucha, & Heutink (2015), horizontal triad scanning saccades were taught to participants with hemianopia. Their results revealed subjective improved ratings on questionnaires relating to mobility and VRQoL, reduced reaction times in blind and intact visual fields, and improved mobility through an obstacle course. Mödden et al. (2012) used a computer program that implored scanning saccades from the left to right for participants with visual field deficits. Their results suggested that compensatory scanning strategies lead to significant improvements in visual conjunction search compared to restoration or occupational therapy.

Taylor, Poland, Harrison, & Stephenson's (2011) treatment program for patients with visual field loss consisted of both education and scanning strategies that showed significant improvements in the Nottingham Adjustment Scale compared to traditional occupational therapy. In Liu et al.'s (2019) systematic review and meta-analysis, they found that compensatory interventions, particularly optokinetic and smooth pursuit training, significantly relieved symptoms for patients with unilateral spatial neglect and improved functionality completing ADLs. Liu et al. (2019) further reported that patients with hemianopia were found to have significant improvements in visual search, reading, and visual field size. However, meta-analysis for both visual impairments revealed moderate to substantial heterogeneity in study interpretation from varying outcome measures and study designs (Liu et al., 2019).

Visually impaired stroke survivors may benefit from environmental compensatory strategies such as personalized luminance, task-specific scanning tasks, and obstacle removal in order to improve mobility and functionality in their surroundings. In Green, Barstow, & Vogtle's (2018) case report they demonstrated that increased luminance improved in time to complete a grooming task and FIM scores. The feasibility of implementing luminance is suggested by the methods the researchers used to install dimmers which were both inexpensive and easy to install. Additionally, one of the participants suffered from both memory and cortical visual impairments and luminance changes were a task that required little cognitive carry over from day to day. In Turton et al.’s (2015) observational study, environmental manipulations were used for task-specific compensatory attention training. Rooms and tabletops were used to systematically search for items dispersed throughout the environment with the patient's goals in mind. The difficulty of these tasks was adjusted using distracting items and size of searchable area while task performance was given feedback and cueing by the occupational therapist. Gaber’s (2010) review of medical records documented luminance changes, obstacle removal, and increases in color and contrast as environmental adaptations used by sensory rehabilitation specialists for patients with cortical visual impairments. During the post-intervention period, Gaber (2010) divided the population into two groups: those who could tolerate the interventions and those who could not. Those who could tolerate the intervention saw improved rehabilitative success after joint assessment and goal setting. The group that could not tolerate therapy was unable to maintain community placement. Mödden et al.’s (2012) randomized controlled trial observed occupational therapists giving therapy in a variety of settings that consisted of both scanning and tracking strategies and room rearranging, pen and paper, and reading tasks. Pre/Post comparisons of occupational treatment showed some improvements in the Extended Barthel Index (EBI), a functional assessment, but no other outcome measures.

In Taylor, Poland, & Stephenson’s (2012) quasi-experimental feasibility case study, a treatment program designed by the researchers was tested simultaneously with traditional occupational therapy. The treatment program aimed to isolate shoulder movement from head movement in order to improve scanning strategies hindered by the brain compensating for visual field deficits. They found limited evidence of correlation between eye movements and head and shoulder movements but found significant increases in the Nottingham Adjustment Scale (NAS).

Limb activation is a modality of treatment that uses a limb activation device (LAD) in order to reestablish proprioceptive and external feedback unilateral visuospatial neglect patients using audio cueing (Robertson et al., 2002). Using scanning training coupled with a LAD device attached to the left side of the body, Robertson, McMillan, MacLeod, Edgeworth, & Brock (2012) found significant left ipsilateral limb activation after treatment which was sustained at 18 and 24 month follow up. Priftis, Passarini, Pilosio, Meneghello, Pitteri (2013) compared scanning training, limb activation treatment, and prism adaptation for individuals with left sided neglect. VST was administered through black and white images on an A4 landscape card in which participants were asked to complete images with small black dots. Limb activation treatment was administered using a LAD during a similar task described above. Prisms adaptation was implemented during pointing tasks while wearing prismatic goggles. The results of Priftis et al. (2013) were measured using various outcome measures within the context of personal, peripersonal, and extrapersonal space. They found positive effects for all treatments in peripersonal space and on the Catherine Bergego Scale (CBS) indicating relief of neglect symptoms.

Nelles et al. (2009) explored the cortical saccades of patients with homonymous hemianopia after compensatory VST using functional magnetic resonance imaging (fMRI). VST was performed on a large training board where exploratory eye movements were encouraged. Physical therapy was also prescribed which focused on reaction and walking exercises and occupational therapy which trained functional ADL tasks. In healthy controls, Nelles et al.

(2009) observed stable bilateral activation in the frontal eye field (FEF), peripheral eye field (PEF), and supplementary eye field (SEF). In the treatment group, researchers observed additional areas of activation in contralesional prestriate cortex, decreased activation in the FEF, and increased activation in SEF Brodmann area 6. Nelles et al. (2009) suggests that these areas are responsible for compensatory improvements of adaptive saccades. Nelles et al. (2009) further connects SEF activation found in both compensatory and restitution therapy and postulates that a coactive treatment program using both interventions may elicit positive results.

Quality of Life appears to be one of the most significant subjectively improved outcome measures used in studies evaluating the efficacy of compensatory strategies (de Haan et al., 2015; Rowe et al., 2017). Improved ratings of QoL were reported in compensatory strategies utilizing VST increased luminance, environmental adaptations, head and shoulder movements, or combination of strategies. After compensatory scanning training, Rowe et al. (2017) and de Haan et al. (2015) recorded significant increases on VFQ-25 scores indicating improvements in emotional and social well-being, as well as level of participation in leisure activities. Taylor et al. (2011) reported significant improvements on the NAS for patients with visual field deficits. These improvements suggest these patients were better adjusted to symptoms of their stroke after receiving both VST and occupational therapy. However, Pollock et al. (2019) did report very low to low quality of evidence in favor of scanning training leading to functionally important improvements in QoL in their systematic review.

An important component of a satisfactory QoL is the ability to complete ADLs. In Mödden et al. (2012), researchers found that ADL performance increased significantly with intragroup comparisons of compensatory, restoration, and occupational therapy. Further comparisons of patients who improved in ADL performance vs. those that did not, revealed that visual search (which had significant improvements after VST) were correlated to ADL improvement. Green et al. (2018) observed improvements in FIM scores and grooming times after luminance changes signifying improved functionally completing ADLs. Liu et al. (2019) found limited evidence of functional improvements completing ADL's in patients with hemianopia but found significant improvements for unilateral spatial neglect after compensatory training. Compensatory strategies may also induce saccades that improve reading accuracy and/or rate (de Haan et al., 2015; Liu et al., 2019). These improvements may lead to improved functionality completing financial or leisure activities. De Haan et al. (2015) reported decreased reaction times during a dual-task driving assessment which may support decreased caregiver reliance and improve independence of patients with visual field defects. De Haan et al. (2015) also reported significant improvements on the Cerebral Visual Disorders Questionnaire which indicates improved subjective ratings of level of difficulty completing activities. Prifitis (2013) saw improvements in functional picture scanning, menu reading, card dealing, and serving tea which they attributed to improved peripersonal attention. They further saw a significant increase in accuracy during the Fluff Test which suggested some evidence of improved personal space attention which could translate to functional grooming tasks such as hygiene and dressing.

There is some evidence to suggest that compensatory strategies may reduce the fall risk for visually impaired stroke survivors. De Haan et al. (2015) showed that participants with hemianopia had significant improved detection of peripheral stimuli which improved navigation through an obstacle course. The obstacle was representative of everyday navigation and improvements could reduce fall risk from bumping into environmental hazards. Furthermore, de Haan et al. (2015) reported subjective improvements of impairment on the Independent Mobility Questionnaire which indicated alleviation of impairments on mobility situations. Mödden et al.

(2012) suggested that improvements in visual search may reduce risk of falls by improving environmental scanning during ambulation. Robertson et al. (2002) found significant improvements in limb strength using the Motricity Index which may also reduce the risk of falling by increasing muscular strength that supports the body and supporting healthy bone mineral density through increased loading.

Adverse side effects of utilizing compensatory strategies were minimal. Those reported were headache and fatigue which were noted in 6.7 % of participants (Rowe et al., 2017). Gaber's (2010) study revealed limitations of compensatory interventions to those who could tolerate therapy. Several patients in their study failed to complete any treatment and were institutionalized as a result. Common manifestations of patients who were unable to tolerate therapy were the inability to orient themselves in time or space, akathisia, and sleep disturbances. Dundon, Bertini, LÃ davas, Sabel, & Gall (2015) also suggested the limitations of compensatory interventions for those who have memory impairments given the top-down approach of compensatory strategies that rely on cognition. Compensatory strategies implored by researchers and therapists could be distorted or forgotten completely, hindering the patient's ability to utilize them. Although, environmental adaptations such as the luminance changes used by Green et al. (2018) were effective in improving a grooming task for a cortically visually- and memory impaired patient.

Restorative Interventions

Restorative interventions exploit neuroplasticity to train alternative visual networks when the primary visual cortex is damaged after stroke. Interest in restorative interventions peaked after publications were released about "blindsight," the ability of patients with visual field defects to detect and distinguish visual stimuli in their blindfields without conscious perception of it (Cowey, 2010; Jobke et al., 2009; Stoeright, 2006). In research, patients with blindsight are presented with binary options when responding to stimuli. The accuracy of their responses increases with high luminance, contrasted backgrounds and decreases with blurred or dimmed stimuli (Cowey, 2010). One theory reasons that localized detection of reflexive responses, isoluminant gratings, and blink responses are responsible for blindsight because they are still intact even after primary visual cortex damage (Cowey, 2010). Campion et al. (as cited in Cowley, 2010) challenged these theories and hypothesized that blindsight was caused by surviving extra striate cortex or "islands" of intact primary visual cortex. Chokron et al. (2008) furthered this argument by suggesting that intact dorsal (spatial) and ventral (object) pathways (extra visual cortical areas) were responsible for visual detection and distinction in hemianopic patients. Similarly, Sabel, Henrich-Noack, Fedorov, & Gall (2011) put forward the "residual activation theory" in which they contended that visual field borders, "islands" of surviving tissue in the blind field, extrastriate pathways, and intact higher-level neuronal networks "downstream" from damage contributed to blindsight. Vision restoration therapy thus overhauls the efficiency of within-system visual centers and downstream synaptic transmission and synchronization (Sabel et al., 2011) leading to functional gains.

Vision restoration therapy (VRT) commonly uses computer programs to train the borderzone of hemianopic blind visual fields to detect visual stimuli (Chokron et al., 2008). It relies on mechanisms of blindsight and neuroplasticity to functionally adapt visual field response. Marshall et al. (2008) found attentional shifts in the blind borderzone which was mediated by the anterior cingulate, dorsolateral frontal cortex, and other higher occipitotemporal and middle temporal regions after VRT. Chokron et al. (2008) used neurovisual training consisting of shape comparison, detection, judgement, and orientation to treat hemianopic patients. Chokron et al. (2008) asserted that objective improvements of borderzone blind hemifields capitalizes on “implicit” vision leading to “explicit” localization and identification of complex visual stimuli. Results of this study showed significantly improved visual detection (decrease in non-seeing zones of visual field), behavioral visual tests (motor and verbal localization, letter identification), and functional recovery (subjective ratings of confidence, mobility, and reading). Behavioral visual tests were found to have the most significant improvements after motor localization tasks.

In Alber, Moser, Gall, & Sabel’s (2017) pilot study patients with visual field deficits secondary to posterior cerebral artery strokes received VRT and transcranial direct current stimulation (tDCS) in hopes of reducing the session time of VRT. The author’s hypothesized that implementing tDCS would induce brain excitability which would further the effects of VRT in the subacute stage when the neuroplasticity would be at its peak. Alber et al. (2017) demonstrated that the feasibility and safety of the intervention which was easily replicated by a therapist with minimal side effects (itching and tingling where electrodes were placed). Their control group, who received compensatory therapy, and participants in the treated group showed visual field recovery. Patients in the VRT/tDCS group also showed improvement in light detection and detection accuracy. Alber et al. (2017) compared their results with those that only used VRT and found that improvements at a much quicker pace than traditional VRT. Furthermore, Alber et al. (2017) found decreased absolute defects and constant relative defects. The authors suggest that relative defects may be salvageable early in stroke recovery using VRT that would otherwise become absolute.

In Jobke, Kasten, & Sabel’s (2009) double-blind randomized study, researchers tested extrastriate-VRT (eVRT) followed by traditional VRT and vice versa (eVRT/VRT vs.

VRT/eVRT). Researchers wanted to explore the extrastriate pathway theorized to be responsible for blindsight. Jobeke further hypothesized that perception of motion may still be intact (Riddoch phenomenon) which they exploited by performing VRT with a massive moving spiral in the absolute blind field and standard VRT in the relative residual vision. Jobke et al. (2009) saw significant improvements in detection performance for both groups before and after treatment that mostly occurred in the absolute blind hemifield. Compared to VRT/eVRT, detection performance in the e-VRT/VRT group was twice as high and had significantly improved detection in the blind field. Improvements were also noted for both groups on the Zahlen-Verbindungs Test (ZVT) which measures the speed it takes to connect numbers. Jobke et al. (2009) asserts that patients that responded to the spiral motion may be due to the magnocellular visual pathway which is thought to bypass the primary visual cortex. Exploiting the use of this pathway could lead to enhanced excitability and the effects of VRT.

Sabel, Kenkel, & Kasten (2004) evaluated the efficacy of VRT for patients with complete and incomplete hemianopia/scotoma. The researchers found significant improvements in detection performance, fixation quality in the complete hemianopic group, reaction time in incomplete hemianopia group, detection performance (L eye in the complete group; both eyes in incomplete group), however perimetry results were inconclusive.. One method of perimetric analysis, the standard ophthalmoscope (SLO), found no significant increases in visual field, however High Resolution (HRP) and Tubingen Automatic Perimeter (TAP) found some significant improvements in the borderzone of the blind field. The authors speculate that blind field border discrepancies may be caused by underlying mechanisms that SLO is not sensitive to or perhaps received no positive effect from VRT.

Jobke et al. (2009) used the NEI-VFQ and subjective reporting to gauge how their restoration therapy affected patient QoL and ratings of defect before and after treatment. No significant changes were described during treatment, however six months after the training period had ended significant improvements in 6/12 scales were reported. Improvements were noted in distance activities, social functioning, mental health, role difficulties, dependency, and perception of color. Sabel et al. (2004) observed significant increases in visual function scores with positive effects in sub scales of general visual function, visual field enlargement, and ADLs. During interviews, researchers reported general visual field improvement, improved reading accuracy, and leisure activity engagement while some participants reported no improvements. Fall risk was not explicitly indicated in any of the restorative articles mentioned during this review, but subjective improvements during interviews performed in Sabel et al. (2004) found improved confidence during navigation and mobility.

Discussion

Stroke is one the leading causes of disability in the U.S and causes debilitating visual impairments. Individuals with newfound visual impairments find almost every facet of their daily lives changed. Visual impairments interfere with stroke survivor's fall risk, QoL, ADLs, rehabilitation outcomes, mental health, and community placement. The prevalence of stroke related visual impairments, and frequency of underreporting, highlights a clinical population whose impairments are undermanaged. When previously thought to be irreversible, the ability of the visual system to adapt and reorganize has now been broadly recognized (Jobke et al., 2009). The newfound resurgence in research regarding clinical management of visually impaired stroke survivors has unearthed therapeutic interventions that may improve objective and subjective visual impairments. The purpose of this research was to review recent literature in order to evaluate the scope of interventions strategies, inform on the type and prevalence of visual impairments that occur secondary to stroke, and report how these interventions improve functional outcomes like QoL and fall risk.

Three branches of interventions emerged from the research: Optical Aids, Compensatory, and Restorative interventions. Optical aids appear to be the best possible preliminary measure that can be taken early during acute and subacute phases of stroke. Developing healthy relationships with ophthalmologists or optometrists during acute recovery in stroke units, or subacute referral during inpatient or outpatient therapy, could provide early treatment for visual impairments. Hospital and rehabilitation staff should inquire about existing lenses and monitor for signs of impaired vision. Even with the presence of already prescribed lenses, the patient may require modification or updating of the prescription for new or worsening visual symptoms. Additionally, lenses should be inspected for inadequate quality or damage (scratched, broken, ill-fitting).

The bulk of the research has tested the effect of prisms on visual field deficits (to expand visual field) and perceptual deficits (alter motor biases). Positive results were reported in general lens prescription (Lotery et al., 2000), visual field deficits (Giorgi et al., 2009), and for spatial neglect (Frassinetti et al., 2002; Datié et al., 2006). No significant changes were reported for Rowe et al. (2017) or Liu et al. (2019). There was limited evidence of optical aids' effect on fall risk with one study indicating that fall risk may be eased by improvements in navigation (Keane et al., 2006) and one study indicating that motility decreased (Rowe et al., 2017). Assessment of optical aids effect on QoL was moderately explored with no effect reported in all studies (Liu et al., 2019; Rowe et al., 2017; Turton et al., 2010) except one (Mizuno et al., 2011). The limited evidence of the efficacy of objective and subjective outcomes for implementing optical aids appears to hinder conclusions about utilizing them as a primary therapeutic intervention. However, there is evidence that warrants further investigation, particularly for neglect patients, which could offer a preliminary bottom-up approach that doesn't rely on high degrees of cognitive function or attention. Implementation of lenses should be evaluated by eye care professionals on a case-by-case basis. Consultation with eye care providers may be needed if prisms are causing adverse reactions such as headache, fatigue, optical glare or diplopia as reported in Rowe et al. (2017) and Lane, Smith, & Schenk (2008).

Compensatory VST comprised the bulk of compensatory strategies with positive findings reported in a variety of studies (Gaber, 2010; Green et al., 2018; Liu et al., 2019; Mödden et al.; Nelles et al., 2009; Priftis et al., 2013; Robertson et al., 2002; Rowe et al., 2017;Taylor et al., 2011;; and Taylor et al., 2012). Significant improvements were reported in visual conjunction search (Mödden et al., 2012), spatial neglect symptoms (Liu et al., 2019), QoL (de Haan et al., 2015; Green, et al., 2018; Liu et al., 2019; Mödden et al., 2012; Priftis et al., 2013; Rowe et al., 2017; Taylor et al., 2011), navigation or mobility (de Haan et al., 2015; Mödden et al., 2012; Robertson et al., 2002), peripersonal perception and attention (Priftis et al., 2013), and limb activation (Robertson et al., 2002).

Compared to other interventions, compensatory strategies had the upperhand in both quantity of research powered for outcomes relating to QoL (de Haan et al., 2015; Green et al., 2018; Liu et al., 2019; Mödden et al., 2012; Priftis et al., 2013 Rowe et al., 2017; Taylor et al., 2011) and fall risk (de Haan et al., 2015; Mödden et al., 2012; and Robertson et al., 2002) with positive results. The implications of greater positive outcome measures and higher frequency of reported functional improvements in QoL and fall risk indicates that compensatory strategies appear to be superior modality compared to optical aids or restorative therapies in terms of practical benefits. The mechanisms of compensatory strategies use both top-down (VST) and bottom-up approaches (environmental adaptations, limb activation training) through computerized, pen and paper, or task-specific modalities and can work with a range of cognitive/physical ability levels (Hazelton et al., 2019a). This diverse cohort of strategies offer a customizable approach to post-stroke care and the various manifestations of visual impairments that stroke survivors may present with.

Compensatory VST may be limited by some factors. For one, the negative effect of inducing scanning bias to one side leaves the other side vulnerable to undetected environmental stimuli (Dundon et al., 2015). However, in de Haan et al. (2015), participants were observed equally distributing their visual attention centrally and peripherally which undercuts these limitations. Secondly, there were a few reported adverse side effects during VST, but Rowe et al. (2017) recommended that headache and fatigue could be reduced with shorter session times. Thirdly, Gaber (2010) and Dundon et al. (2015) pointed out some of the cognitive limitations of compensatory interventions for patients with memory deficits or intolerance to therapy. Lastly, Pollock, Hazelton, & Brady (2011) reported that almost ⅓ of occupational therapists in their survey did not offer visual rehabilitation services which limits the accessibility of some patients to receiving compensatory therapy. Furthermore, Pollock et al. (2011) highlighted the lack of treatment protocols, clinical treatment options, and lack of specialist training that severely limit therapist/patient rehabilitation services.

Vision restoration therapy is based on mechanisms of blindsight, alternative visual pathways, and relative damage which researchers believe can be trained to be more sensitive to visual stimuli. The results of the articles reviewed in this paper show that VRT is a promising treatment during the subacute phases of stroke when improvements can be seen in relative and absolute defects (Alber et al., 2017). Patients that received VRT reported positive effects in visual detection (Alber et al., 2017; Chokron et al., 2008; Jobke et al., 2009; Sabel et al., 2004), vision-related behavioral tests (Chokron et al., 2008), visual field recovery (Alber et al., 2017), and functional recovery and confidence (Chokron et al., 2008). Although, results from visual field enlargement outcomes were relatively unclear (Sabel et al., 2004). Combining eVRT and VRT appears to drastically improve session gains in shorter time frames which highlights the feasibility of implementing treatment in a rehab setting where therapy needs to be distributed evenly across all physical, cognitive, and visual impairments (Jobke et al., 2009). Compared to compensatory interventions and optical aids, there was limited research supporting functional outcome measures. There was some evidence of subjective long-term improvements (Jobke et al., 2009) and positive interview feedback regarding visual function and ADLs (Sabel et al., 2004). Fall risk was not mentioned in any articles reviewed but improvements in Sabel et al. (2004) implicitly suggested subjective improvements during navigation and mobility.

Limitations of VRT remain within its theoretical underpinning. While the basis of additional visual centers within the brain is well established (Cowey, 2010; Chokron et al.,2008; Sabel et al., 2011, Stoeright, 2006) the efficacy of functional recovery from VRT remains under debate. Gains made during VRT perimetry measurements could be attributed to eccentric eye fixation during testing (Horton, 2005) which requires static eye fixation for accurate results. Sabel et al. (2004) countered these claims by including SLO perimetry which is more sensitive to excessive eye movements. However, the one test powered for this produced null perimetry results.

Limitations & Considerations for Future Studies

Systematic reviews of literature are only as strong as the rigor of the literature being reviewed. The current review has a wide range of evidence quality from randomized controlled trials to pilot studies and case reports. The quality of evidence being presented suggests that this review should be assessed with caution until more quality evidence is reported. Many of the studies included in this review had small sample sizes which limits their broad generalization across visually impaired stroke populations. Additionally, there was substantial heterogeneity amongst outcome measures and methods that further limit the conclusions drawn during this review.

Additionally, the data collection and synthesis was conducted by a single researcher which could have led to bias. Attempts to eliminate bias were included development of inclusion/exclusion criteria and private consultation through a thesis advisor. Future studies should focus on systematically reviewing RCTs as they become available. To eliminate possible bias, multiple researchers should be involved in data collection and synthesis and developing study design.

Conclusion

The subjective experience of sudden vision loss secondary to stroke is complex, debilitating, and undermanaged. Compensatory interventions were the most rigorously tested intervention with a superior number of positive results, particularly in functional outcomes relating to QoL and fall risk. Optical aids appear to be the best initial option for patients in acute and subacute stroke care settings but should be monitored for adverse side effects. Vision Restoration therapies appear to be a promising, yet controversial, form of therapy that can potentiate recovery into the subacute and chronic stages of stroke rehabilitation. We are limited to the conclusions drawn by research in this review, but other research may provide additional supporting evidence on the efficacy of the interventions mentioned. Combinations of interventions were rarely used in publications reviewed in this paper (Liu et al., 2019), which warrants consideration of the effect of combining therapies to treat visual impairments (as suggested by Nelles et al., 2009). Additionally, no articles were included that used pharmacological interventions which may also have a role in the rehabilitation process. The feasibility of implementing broad access to vision rehabilitation services depends on access to treatment and the rigor of treatment programs designed for stroke-related visual impairments. Stroke units, therapists, caretakers, and insurance companies should consider research, clinical experience, the role of eye care specialists, and the feasibility of recovery into designing treatment programs with an encompassing set of standardized outcome values that evaluate functional and objective measures powered for this population. Alleviating some of the challenges faced by visually impaired stroke survivors will only elevate the health status of stroke survivors internationally and globally and improve successful rehabilitation outcomes.

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