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Strobe Glasses in Neuro-Optometric Rehabilitation of Homonymous Hemianopsia Following Severe Traumatic Brain Injury: A Case Report

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ABSTRACT

Background: Homonymous hemianopsia (HH) is a common visual consequence of traumatic brain injury (TBI), significantly affecting spatial awareness, visual scanning, and mobility. Neuro-vision rehabilitation (NVR) addresses visual efficiency and perceptual deficits; however, the integration of strobe glasses as an adjunctive modality in this population remains underexplored.

Case Report: This case report describes a 22-year-old female patient with severe TBI and right HH who presented with impaired visual tracking, reduced scanning efficiency, and compromised mobility. Initial treatment included therapeutic anti-fatigue lenses (+0.85 D OU) with 3 base-up yoked prism, followed by 48 weekly in-office NVR sessions and home-based activities. NVR initially targeted core oculomotor, accommodative, binocular, and perceptual functions, later integrating strobe glasses to enhance scanning and engage residual vision near the scotoma.

Strobe therapy began with full-lens strobe stimulation to support visual-motor coordination. Subsequently, a bi-left lens occlusion setting was applied, blocking the left half side of each lens, to promote further compensatory rightward scanning. The intervention aimed to improve perceptual awareness, reaction time, and adaptive spatial processing.

While the visual field did not improve, the patient demonstrated functional gains, including enhanced scanning toward the blind field, improved navigation confidence, increased reading endurance, and better eye-hand coordination.

Conclusion: Strobe glasses may be a valuable adjunct to conventional NVR for TBI patients with HH, supporting compensatory strategies and neuroplasticity. Further research is warranted to standardize protocols and investigate long-term outcomes across varied clinical populations.

Keywords: homonymous hemianopsia, neuro-vision rehabilitation, strobe glasses, spatial scanning, traumatic brain injury, visual field deficit, visual-motor integration, visual perception

Introduction

The Visual System and Homonymous Hemianopsia in Severe Traumatic Brain Injury

Severe traumatic brain injury (TBI) is defined by a Glasgow Coma Scale (GCS) score of 3–8, loss of consciousness over 24 hours, and post-traumatic amnesia lasting more than seven days. It often involves structural brain injury and may require prolonged rehabilitation due to multi-system trauma. In contrast, mild and moderate TBIs (GCS 13–15 and 9–12, respectively) typically result in less-extensive damage. According to the Centers for Disease Control and Prevention (CDC), among severe TBI survivors over five years, 30% worsen, 26% improve, 22% remain unchanged, and 22% die from injury-related causes.[1] Recovery from TBI doesn't always reflect injury severity. Outcomes depend on individual health, the nature of the trauma, and secondary effects like edema, inflammation, and autonomic dysfunction.

Visual Processing Impairments and Dysfunction in TBI

Efficient visual processing relies on the integration of central (parvocellular) and peripheral

Table 1. Visual Processing (Location, Structure, Function)

Visual Processing Pathway						
Retina-Parvo & Magnocellular	Optic Nerve Tract	Lateral Geniculate Nucleus (LGN)	Primary Visual Cortex (V1)			
Eye	Optic tract	Thalamus	Occipital lobe			
Captures light; Begins signals: Parvocellular (detail/color) Magnocellular (motion/contrast)	Transmits retinal signals to thalamus	Relay center for visual information	Encodes fundamental visual features (edges, contrast, orientation) Sends information to higher visual areas: Ventral stream-object recognition-"What" Dorsal stream-motion processing-"Where" Communicates with FEF + superior colliculus for eye movement			
Smooth Pursuit Pathway						
Temporal lobe	Frontal lobe	Pons (brain stem)	Cerebellum	Brain stem: Midbrain, Pons		
Temporal Eye Fields	Frontal lobe	Dorsolateral Pontine Nuclei	Flocculus and Vermis	Vestibular Nuclei to CN III, IV, VI		
Detect target direction & motion	Initiate pursuit signals	Relay pursuit signals	Refines eye movement	Activate extraocular muscles		
Saccade Pathway						
Parietal lobe	Frontal lobe	Basal Ganglia	Midbrain	Brainstem	Cerebellum	Brain stem: Midbrain, Pons
Parietal Eye Fields	Frontal Eye Fields	Caudate	Superior Colliculus	Pons, Midbrain	Vermis, fastigial	CN III, IV, VI
Locate target, Drive reflexive attentional saccades	Initial voluntary saccades	Suppress unwanted saccades	Integrates sensory input Plans saccadic movement	Pons: horizontal saccades Midbrain: vertical/torsional	Refines accuracy, timing, adaptation	Final saccadic direction to the extraocular muscles
SNr						
Parietal lobe	Frontal lobe	Midbrain	Basal Ganglia	Cerebellum	Brain stem: Midbrain, Pons	
Parietal Eye Field	Frontal Eye Fields	Superior Colliculus	Caudate-SNr	Vermis and Flocculus	CN III, IV, VI	
Direct attention to the target	Sustain fixation Suppress saccades	Stabilize fixation; Block unwanted eye shifts	Suppress competing saccades	Refine stability Prevent drift	Superior Colliculus Caudate-SNr Vermis and Flocculus CN III, IV, VI Stop saccade bursts; Maintain muscle tone	

(magnocellular) pathways, oculomotor control, vestibular input, and optokinetic mechanisms. Flow charts of visual processing are found in Table 1. These systems coordinate to support visual tracking,[2] reading, spatial orientation, and stable navigation. TBI can disrupt any of these components, leading to impaired visual integration, scanning inefficiencies, disorientation, and reduced functional mobility.

With nearly 70% of the brain devoted to vision processing, impairments are common after TBI. Post-trauma vision syndrome (PTVS) affects sensory-motor, cognitive, and perceptual function, disrupting reading, mobility, work, and rehabilitation. Early

Table 2. PTVS Signs and Symptoms[35]

Visual Signs	Associated Symptoms
Accommodation	Constant or intermittent blur
Ocular Motility	Slower, less-accurate reading, difficulty sustaining or shifting gaze, tracking difficulties
Binocular Vision	Constant or intermittent eye strain, diplopia eliminated with monocular occlusion
Visual Vestibular	Disequilibrium worsened in a visually stimulating environment
Visual Processing	Slower processing speed, impaired visual memory and visual-spatial processing, unstable ambient vision
Visual Motor	Eye-body coordination, unbalanced posture
Visual Field Integrity	Missing a portion of visual field or restriction of field
Tear Film Integrity	Distorted clarity, gritty sensation varying with blinking
Light-Dark Adaptation	Elevated light sensitivity

Table 3. Post-TBI Visual Dysfunctions, Causes, Symptoms, Therapy options[36]

Visual Dysfunction	Primary, secondary injury impact on visual system	Symptoms	Therapy Option
Visual Acuity -Cerebral cortical blindness -Refractive changes	-Visual pathway, occipital lobe damage -Focal injury to the refractive structures -Visual processing pathways damage -CN III injury: accommodation-ciliary dysfunction injury -Altered tear film or low blink rate, inflammation-keratitis	-Vision loss -Blur -Decreased night vision	-Lens correction, prism, tinted lenses -Dry eye treatment
Hypersensitivity -Photophobia -Visual motion sensitivity	-Co-morbidity with migraines and pain -Overload visual stimulation	-Light sensitivity -Glare -Dizziness, nausea	-Photochromatic lenses -FL-41 tinted lenses -Binasal occlusion
Binocular Vision -Convergence insufficiency -Phoria/tropia -CN palsy, version restriction	-Neurological damage affecting binocular coordination -Oculomotor nerve damage affecting eye misalignment -Impaired eye movement control	-Reduced stereopsis, double vision -Eye strain, headaches, fatigue -Intermittent blur -Movements of words/lines of text	-NVR -Prism lenses, mini prism -Yoked prism -Partial occlusion
Visual Field -Partial visual field loss -Restricted visual field loss	-Damage to any portion of the visual pathway	-Mobility issues: bumping, imbalance, slow -Reading difficulties -Trouble locating items -Partial blurry vision in affected areas	-NVR -Prism expansion
Pupillary Function -APD+ -Alpha-Omega pupil -Fixed pupil/sluggish reaction	-Impaired response to light due to optic nerve damage -Damaged parasympathetic/sympathetic pupillary pathways -Intracranial pressures on the autonomic nervous system	-Mydriasis: blur, photophobia	-Monitor pupillary response, intracranial pressure -Syntonic glasses
Accommodation -Insufficiency -Amplitude -Infacility	-Damage to neural circuits responsible for lens adjustment	-Constant/intermittent blur at near and far -Visual fatigue, asthenopia -Reading difficulties, headaches after near tasks -Squinting, diplopia	-Compensatory lenses -Therapeutic lenses: enhance accommodation -NVR
Oculomotor -Pursuit, saccades, fixation	-Focal frontal lobe or diffuse brain pathways injuries -Pursuits and saccades pathways damage	-Reduce reading abilities: tracking, speed -Spatial disorientation, dizziness w/ general tracking	-NVR
Vestibular-Ocular Reflex	-Vestibular-ocular somatosensory pathways damage: semicircular canals, cranial nerve III, VI, VIII brain stem injury, cerebellum-parietal	-Dizziness, vertigo, nausea, balance problem -Motion sensitivity -Blurry vision after head movement	-Vestibular rehabilitation -NVR -Binasal occlusion
Nystagmus	-Cerebellum, brainstem, inner ear (vestibular) injury	-Dizziness	-Vestibular rehabilitation -NVR
Visual-Perception -Visual spatial perception -Visual idline shift -Visual spatial inattention -Visual motion	-Mismatch/injury between ventral and dorsal pathways Occipital-Temporal lobe: Identification Occipital-Parietal lobe: Orientation	-Difficulty navigating: Avoid crowded/busy places -Slow processing, reduced learning ability, memory -Poor organization, sense of orientation -Veering during mobility, poor balance, posture -Head turn, spatial disorientation	-NVR -Partial occlusions -Binasal occlusion -Yoked prism
Visual Hallucinations	-Subcortical region damage -Poor VA and cognitive disturbances -Visual field loss	-Visual hallucinations of shapes, objects, lights	-Monitor -Adjust lighting/contrast to reduce hallucination triggers

neuro-visual assessment and targeted therapy are critical for recovery.[3]

According to the AOA TBI Resource Manual,[4] 40–51% of patients show oculomotor dysfunction, 10–47% have accommodative disorders, 38–42% display binocular issues (mainly convergence insufficiency), and 14–32% exhibit visual field loss. Other dysfunctions include visual-perceptual deficits, poor vestibular integration, and cranial nerve palsies. Ocular complications may involve light adaptation issues, cataracts, optic atrophy, dry eye, and eye diseases.

A study by Armstrong found visual dysfunction in 69% of concussion patients and in 60% of those hospitalized with TBI.[5] Ciuffreda et al. report that about 90% of mild TBI patients with visual symptoms exhibit at least one oculomotor dysfunction during recovery.[6] Tables 2 and 3 summarize PTVS signs, etiologies, and treatment options.

Table 4. HH Symptoms

- Blurred vision on the side of the field loss
- Bumping into, stepping on, or tripping over objects on the affected side, resulting in bruises – over misplaced objects, door frames, or a moving pet
- Difficulty navigating through crowds and unfamiliar spaces
- Difficulty crossing a street, driving a car
- Missing objects on their desk or plate
- Being startled by people appearing from the affected side
- Reading and comprehension difficulties: with LHH, difficulties following lines; with RHH, difficulties scanning for the next word, not finishing the whole line

Homonymous Hemianopsia

Homonymous hemianopsia (HH) is a type of visual field loss caused by damage to the post-chiasmal visual pathway, resulting in loss of the same side of the visual field in both eyes—opposite to the side of the brain lesion. Left occipital damage causes right HH, and right occipital damage causes left HH. It is a common visual dysfunction of PTVS.

Motor vehicle accidents are the leading cause of HH in severe TBI (57.1%), followed by violence (17%), falls (15.2%), and other blunt trauma (10.7%). Lesions are most often found in multiple brain areas (53.6%), the optic radiations (23.2%), occipital lobe (12.5%), and optic tract (10.7%).[7]

The sudden visual field loss in HH often leads to visual and neurological impairments, including oculomotor dysfunction and visual-spatial processing. HH leads to oculomotor deficits and impaired spatial processing, significantly affecting independence, employment, and legal driving status. Patients often experience insecurity in public spaces, frustration and emotional distress due to these limitations (Table 4). Spontaneous recovery occurs in about 50% within 3 months and only 20% by 6 months, usually with limited improvement (~5–7° at the field border). Improvement in visual-spatial function, underlying diseases, or increased reliability in visual field testing likely influences recovery. Full resolution is rare, occurring in just 5.3% of cases.[8]

Table 5. Neuro-Vision Rehabilitation (NVR) for TBI- Main Goals

Visual Dysfunction	Optical Solution	In-Office Therapy Goals
Oculomotor		-Improve and stabilize efficient eye movements in all directions to support tracking and gaze stability: Range Of Motion (ROM), Pursuits, Saccades, Fixation, Vestibular-Ocular Reflex (VOR)
Binocular Vision	-Ophthalmic lens (low plus near lenses) -Prism (mini, yoke, Neurolens) -Sectoral occlusions (Binasal, partial occlusion)	-Stabilize the binocular visual system from the fusion point toward all distances and gazes -Improve fusional ranges and facility with awareness and voluntary control -Reduce and/or recover diplopia (tropia, palsy, decompensated phoria)
Accommodation	-Compensatory low plus near lenses	-Improve the ability to relax and stimulate the accommodative system at varying distances -Expand accommodation ranges and facility (through lenses via monocular, bi-ocular, and binocular activities)
Visual Perceptual	-Behavioral low plus near lenses (+0.12 D to +0.95 D) -Binasal occlusion -Yoked prism -Tint lenses -Syntonic glasses	-Improve all forms of visual perception (discrimination, form perception, closure, figure-ground, spatial relation, spatial orientation, visual cognition, information processing speed, memory, sequential memory) -Expand central and peripheral awareness -Improve scanning toward the field loss -Improve eye-hand/body coordination and reaction time -Align visual spatial midline shift

Note: Once the patient achieves in-office therapy goals, follow-up activities integrate these goals with tasks that engage auditory, vestibular, and proprioceptive systems to facilitate a stable recovery (e.g., metronome, cognition, movement, trampoline, balance board).

NVR Assessment and Management for TBI with HH

HH is often identified during hospitalization via confrontation testing or with portable virtual reality visual field devices. Early diagnosis is key, especially when conditions like unilateral spatial inattention (USI) or visual midline shift syndrome (VMSS), also called abnormal egocentric localization (AEL), are present. USI affects spatial attention despite normal vision, while VMSS distorts the perceived midline, or more precisely, one's sense of straight ahead, often combining with HH. Clinical tools like pointer tests, hallway walks, line bisection, and pursuit tests help differentiate these conditions. In-office, automated perimetry assesses field loss, while Flicker-Defined Form (FDF) evaluates functional vision. Management may include yoked prisms and spatial training.

HH Treatment Strategies

Management of HH typically involves behavioral, substitutive, and restorative approaches. Behavioral strategies focus on education and training in compensatory scanning and eye movements to help patients increase awareness of their blind field during daily tasks. Substitutive tools include prism lenses and assistive devices that shift images from the blind side into the intact visual field. Yoked prisms shift spatial input globally (base left for left HH, base right for right HH), while sectoral, Fresnel, and Peli prisms help expand peripheral awareness or promote compensatory head and eye movements, though sectoral prisms may be less effective for patients with USI. Restorative NVR targets visual efficiency, spatial processing, and neuroplastic recovery through structured interventions (Table 5), such as in-office therapy, scanning tasks, prism adaptation, partial occlusion, and tinted lenses. Additionally, emerging technologies like the SideSight device provide tactile alerts to unseen obstacles, improving safety. Senaptec, NovaVision, Read-Right, EyeBab, and Our Visual Brain offer interactive training platforms that support visual recovery through personalized scanning and reading exercises. This case report examines strobe glasses as a novel adjunct to these strategies in the rehabilitation of TBI patients with HH.

Figure 1. Strobe glases

Background and Clinical Application of Strobe Glasses

Strobe glasses (Figure 1) are specialized eyewear alternating between transparent and opaque states at set intervals, creating a stroboscopic effect. This intermittent visual occlusion challenges the visual and motor systems, training them to function efficiently despite restricted visual input. During and after their use, this adaptation enhances visual-motor coordination, spatial awareness, and sensory integration through neuroplasticity.[9]

The concept of stroboscopic training dates back to the 1950s, when researchers experimented on performance with stationary strobe lights in dark environments. Over time, professional athletes, psychologists, and scientists investigated how these strobe effects influence visual processing and sensory integration. By the early 2010s, professional athletes had begun adopting strobe lights as a training tool due to their reported benefits in enhancing sports performance. Some physical therapists also incorporated them to introduce visual challenges that promote coordination and quick adjustments in patients recovering from injuries.

Companies such as Nike, Senaptec, and Vima developed portable strobe glasses for active use. These devices feature liquid crystal lenses that alternate between transparent and opaque states at adjustable frequencies and locations, enabling users to train under variable visual conditions. Current models are lightweight, customizable, and operated via onboard buttons or mobile applications.[10]

Strobe glasses are considered safe for most users, including those with photosensitivity, as their standard frequency range (1–6 Hz) remains well below the seizure-inducing threshold of 15–20 Hz. However, they are contraindicated in individuals with a history of light-induced seizures.[11] Session durations typically range from 5 to 50 minutes, although standardized protocols for frequency and duration have yet to be established.

General Potential Benefits of Strobe Glasses

Strobe glasses, or stroboscopic visual training (SVT) leverages intermittent visual occlusion to stimulate the brain's adaptive responses during motor tasks. Research suggests three primary mechanisms through which strobe glasses may enhance performance and rehabilitation outcomes:

1. Enhanced Visual and Visual-Motor Processing: By limiting continuous visual input, strobe glasses increase demand on the visual system, promoting more efficient processing. This adaptation may improve visual tracking, reaction time, visual memory, motion sensitivity, and depth perception.
2. Increased Sensory Compensation: The reduction in visual information heightens reliance on non-visual sensory systems such as proprioception and vestibular, thereby enhancing balance, body awareness, and motor coordination.[12]
3. Facilitated Neuroplasticity and Sensory Integration: Intermittent visual deprivation alters spatial perception and encourages the development of new neural pathways, contributing to improved integration across multiple sensory systems.[13]

Review of Scientific Evidence Supporting Strobe Glasses Among Various User Groups

Multiple studies across disciplines have examined the effects of SVT:

Sports and Athletic Training

Stroboscopic training challenges athletes to perform under restricted visual conditions. Studies highlight their positive impact in badminton, baseball, cricket, football, ice hockey, tennis, volleyball, and rock climbing.[5]

- Enhanced Visual, Visual-Motor, and Visual Perception Processing: Wilkins and Appelbaum[4] summarize various research reports indicating that strobe glasses force reliance on limited visual information, prompting faster, more efficient motor responses in catching performance. Hulsdunker et al.[14] and Wilkin and Garry[15] indicate that athletes using strobe glasses demonstrate superior visual memory, motion sensitivity, and three-dimensional vision both during and after use. This leads to better foveal vision and increased proficiency in tasks such as tracking a ball or following opponents.
- Load-Based Training: A Duke University study[16] compared hockey players using strobe glasses to runners wearing ankle weights. Post-stroboscopic training, athletes reported improved reaction times and an increased perception of ball size and motion speed. Training felt easier and more manageable as targets appeared larger and moved more slowly.
- Postural Stability: Research by Harper et al. suggests that strobe glasses enhance balance and postural control of athletes by modifying visual input disruptions. Adjusting flicker rates influences how the brain processes visual and vestibular information, with changes in postural stability reflected in the Romberg Ratio assessment, supporting their role in recalibrating balance mechanisms.[17]

High-Stress Professions

In professions like the military, law enforcement, and aviation, strobe glasses improve reaction time and spatial awareness by enhancing the brain's ability to process limited visual input. Key benefits include:

- Enhanced Anticipation and Compensatory Temporal Processing: Studies suggest that stroboscopic training enhances visual cognition speed, training users to "fill in" missing visual information and react faster in dynamic environments.
- Reduction of Motion Sensitivity and Visual-Motor Conflict: Training the visual system to process intermittent cues reduces symptoms of motion sensitivity and visual-motor issues, improving comfort and performance in high-stress professions.[18]
- Contrast Sensitivity and Low-Light Adaptation: Dim lighting can hinder object tracking in visually complex environments. Research by Ballester et al.[19] finds that strobe training may enhance contrast sensitivity, aiding object tracking and better anticipation in dim environments, a critical skill in tactical and aviation settings.[20]

Physical Therapy and Sensory Processing Neuro-Rehabilitation

Strobe glasses are increasingly used in neuro-rehabilitation to improve motor control, balance, and sensory integration. Key benefits include:

- Proprioceptive and Postural Control: Limited visual input increases reliance on balance/vestibular and motor coordination, benefiting patients with postural instability (e.g., Parkinson's, stroke, ankle instability).[21] A four-week dynamic balance training program by Hyunwook demonstrated significant postural control improvements in individuals with chronic ankle instability during drop-landing tasks.[22] Similarly, another study highlighted enhanced balance in patients with Parkinson's disease using this approach.[23]

- Reducing Visual Overload in Overstimulated Patients: Bi-nasal strobe settings simulate bi-nasal occlusion therapy,[24] as the limited visual input rebalances peripheral and central vision. This setting may help recalibrate sensory responses and alleviate symptoms of visual overstimulation or visual-motor mismatch in patients with sensory processing issues, ADHD, or autism spectrum disorders.

Cognitive and Perceptual Training

Strobe glasses load visual-perceptual processing, improving cognitive function and visual memory. Key benefits include:

- Memory and Spatial Processing Improvements: Appelbaum et al.[25] found that individuals trained with strobe glasses demonstrated enhanced short-term memory retention 24 hours after training, suggesting potential application in cognitive rehabilitation.
- Focus and Precision: Zavlin et al.[26] reported that medical students using strobe glasses improved spatial awareness and fine motor control, indicating potential benefits for surgeons and other precision-based professions.

Clinical Applications and Mechanisms of Strobe Glasses in NVR for HH

Strobe glasses may serve as a promising tool in NVR, particularly for individuals with HH following TBI. By introducing intermittent visual occlusion, they challenge the visual system to function more efficiently under altered sensory conditions. This controlled disruption aligns with NVR goals such as enhancing scanning, restoring spatial orientation, integrating multisensory input, and improving visual-motor coordination.

Through brief visual interruptions, strobe glasses increase demand on visual attention and processing systems, which is assumed to promote adaptive changes in oculomotor control, accommodation, and sensory integration. While users may initially experience blurred vision or disorientation, repeated exposure often leads to functional gains, especially valuable for patients with HH, where impaired scanning and spatial awareness affect independence and safety.

Three key mechanisms support the clinical application of strobe glasses in NVR:

1. Enhancing Visual Processing Efficiency: Strobe glasses increase the brain's demand for efficient visual performance, which may improve:
   - Oculomotor control: improving saccades, pursuits, and fixation, essential for reading, scanning, and navigation
   - Visual-motor integration: supporting faster reactions, better coordination, and dynamic acuity
   - Visual perception: memory, figure-ground discrimination, and target recognition toward the blind field
   - Sensory filtering: reducing visual overload and improving sustained visual attention in complex environments
2. Improving Multisensory Integration: By limiting continuous visual input, strobe glasses help recalibrate the brain's reliance on other sensory systems:
   - Vestibular and proprioceptive coordination: supporting postural stability and spatial orientation, especially in patients with HH who experience postural instability due to multiple scanning demands or individuals with visual-vestibular mismatch.
   - Sensory reweighting: encourages greater reliance on somatosensory input under reduced visual conditions, which may improve postural control, as reflected in Romberg ratio performance[17]
3. Promote neuroplasticity and Adaptive Visual Strategies: The stroboscopic effect may trigger meaningful changes in how visual information is processed and integrated:
   - Reorganization of cortical and subcortical visual pathways: similar to the adaptive response seen with yoked prism therapy
   - Cognitive-perceptual processing: improved spatial awareness and problem-solving[28,29]
   - Stimulation of residual vision: may activate nonfunctional areas near the scotoma, or the visual processing circuits
   - Compensatory scanning behavior: more consistent gaze shift toward the blind field, supporting safer mobility and navigation

These mechanisms address key deficits in HH after TBI, including impaired scanning and visual perception. When integrated into a structured NVR program, they may support improvements, independence, mobility and overall visual performance.

Neurophysiological Basis and Research Support of Strobe Glasses in NVR for HH

The scientific evidence supporting strobe glasses among various user groups and the summary in

Table 6. Applications and Benefits of Strobe Glasses Across Diverse Fields

User Groups	Key Benefits
Sports and Athletic Training	Enhanced visual and visual-motor processing Load-based training Postural stability
High-Stress Professions: military, police, pilots, race car drivers	Enhanced anticipation and compensatory temporal processing Reduction of motion sensitivity and visual-motor conflict Contrast sensitivity and low-light adaptation
Physical Therapy (PT): mainly postural, ankle injuries Neuro Sensory Processing Rehabilitation: autism, ADHD	Proprioceptive and postural control Reducing visual overload in overstimulated patients
Cognitive and Perceptual Training: neurological injuries, surgeons, musicians	Memory and spatial processing improvements Focus and precision

Table 6 may provide strong support for strobe glasses use in NVR, with improvements in visual attention, motion sensitivity, reaction time, coordination, contrast sensitivity, and short-term visual memory. In addition to these findings, a separate review by Julia Das et al.[30] examining 15 cases shows significant gains in both visual and motor domains following stroboscopic training.

For individuals with HH, strobe glasses may help engage residual vision and enhance perceptual efficiency. Studies on critical flicker frequency (CFF) suggest that intermittent stimuli support neural reorganization in visual processing pathways. Although much of this research focuses on mild TBI, the underlying mechanisms likely extend to more severe cases involving field loss.[31]

Thus, strobe glasses hold clinical promise across diverse NVR applications (Table 7), including visual-spatial deficits, oculomotor dysfunction, amblyopia,[32] visual snow syndrome,[33] and complex injuries such as concussion, stroke, and severe TBI. This case report highlights their relevance in a patient with HH following severe TBI, where impaired scanning, spatial orientation, and visual motor ability significantly limited functional independence.

Table 7. Strobe Glasses Characteristics

The Concept of Strobe Glasses	• Enhance visual cognitive motor performance	- stimulate the brain to compensate for reduced visual input, improving visual-motor integration
	• Modulate visual processing	- reduce contrast sensitivity input, facilitating adaptation and improving post-use visual function
	• Alter spatial perception	- create an illusion of increased image size and reduced motion speed, aiding spatial processing
	• Manage visual overload	- reduce excessive visual stimulation in patients with hypersensitivity
	• Enhance multisensory integration	- encourage reliance on vestibular and proprioceptive feedback for overall sensory coordination
Advantages of SVT Training	• Portable tool	- lightweight and easy to use in various rehabilitation settings
	• Ergonomic design	- comfortable fit on the face for extended use during therapy
	• Customizable training setting	- adjustable strobe frequency and occlusion pattern to target specific visual and cognitive therapy goals
Enhancements Observed in SVT Users (Summary of Published Research)	• Enhances central visual attention and performance	- improves the ability to detect finer visual details
	• Improves visual-motion processing	- enhances prediction of speed and trajectory of moving objects
	• Facilitates faster anticipation and reaction skills	- supports quicker decision-making in visually demanding situations
	• Increases responsiveness in dynamic environments	- enables faster visual-motor reactions to changing surroundings
	• Expands visual processing capacity	- strengthens the ability to track multiple objects simultaneously
	• Heightens visual attention and alertness	-enhances sustained focus and reduces distractions
	• Enhances spatial processing	- makes objects appear larger and move more slowly, aiding task performance
	• Improves postural stability and balance	- increases grounding and postural control
	• Reduces visual overstimulation symptoms	- provides relief for individuals with hypersensitivity to excessive visual input
	• Enhances visual-cognitive processing	- strengthens short-term visual memory and visualization skills
	• Reduces motion sensitivity	- decreases discomfort in motion-heavy environments
	• Accelerates lower extremity injury recovery	- facilitates faster motor adaptation and rehabilitation outcomes

Table 8. Initial Optometric Evaluation

Refractive Status	
Visual Acuity- Distance Unaided	OD: 20/20, OS: 20/20
Visual Acuity- Near Unaided	OU: 20/20
Aided	+1.25 D OU reader 20/20
Autorefraction	OD: +0.50-1.00x150 OS: +0.75-0.25x005
Manifest	OD: plano 20/20, OS: -0.25 20/20
Oculomotor Evaluation	
Extraocular Motility	Full range of motion OD, OS, OU
Fixation	OD, OS unstable fixation
Pursuit	2-3+ jerky, head movements, greater difficulty with oblique
Saccades	2+ head movements, jerky movement
Accommodation Evaluation	
Amplitudes of Accommodation	OD: 5 D, OS: 5 D (Donders push-up)
Accommodation Facility (+/-2.00D)	Unable to clear; with +/-1.00: 3 cpm- difficulty with the minus side
Fused Cross Cylinder (FCC)	+1.25 D
Binocular Evaluation	
Stereopsis	RDS: 250", Wirt circles 40", Animals: 3/3 100"
Cover Test	Distance and near: orthophoria, tested in all fields of gaze
Near Point of Convergence	3" w/suppression. NPC with red/green glasses and flashlight: OS out
Distance Phoria- Von Graefe (VG)	Lateral: ortho, Vertical: ortho
Near Phoria- VG	Lateral: 4 exo, Vertical: ortho
Near PRV, NRV- VG	BI: suppression, BO: suppression
Vergence Facility (12BO/3BI)	8.5 cpm; after 40 sec could not fuse BO anymore
Worth 4-Dot	Flat Fusion (FF) at distance, intermediate, and near
Saladin Test	Horizontal: 4 exo, Vertical: ortho
Ocular Health	
Color Vision- Ishihara	Normal
Pupil Test	OD, OS: equal round, reactive to light with no afferent pupillary defect
Anterior Examination	Brown irises – unremarkable findings (Slit Lamp biomicroscope)
Internal Examination	Unremarkable other than mild temporal pallor OD
	Cup-to-disc ratio: OD 0.2, OS 0.2 (dilated fundus exam)
Tonometry iCare	OD: 23 OS: 21 @ 1:46 PM
Confrontation Visual Field	Abnormal- OD: restriction temporal, OS: restriction nasal
Confrontational Visual Field Extinction	Right field restriction; no extinction
Humphry Visual Field 30-2 test	Right homonymous hemianopsia
Neuro-Sensory Tests	
Developmental Eye Movement Test	A: 21.45 sec B: 19.93 sec C: 75 sec <1%
Clock Test	Normal
Line Bisection Test	Normal
Eye Dominance	Right eye
Hand Dominance	Right hand (the injured hand)
Body Posture	Sit straight in a wheelchair
Head Posture	Chin up, slight turn to the left
Gait	Unable to test; in a wheelchair
	left foot in ankle brace, can walk very slowly with a cane
	transition from sitting to standing with a device that stimulates the left leg
Therapeutic Lens Trial Feedback	
+0.85/+0.75 OU	+0.85: Bigger print, felt comfortable
3BU/3BD	BU improved her head posture from the chin up to normal
2BU/3BU	Preferred 3BU over 2BD
Binasal occlusion	Felt uncomfortable
Tint and filters	Not trialed; she was not complaining of photophobia
Impact Test: Neuro-Cognitive Evaluation (composite scores):	
Memory composite- verbal	63%
Memory composite- visual	47% below the norm
Visual motor speed composite	14.68 slow
Reaction time composite	1.16 slow
Impulse control composite	0
VEP: 32x32-85%	OD: 8.90 uV OS: 7.94 uV OU: 6.94 uV
(1 repetition each msmnt at time of testing: today X 3)	No lens 3BU 3BD 1BI
16x16-85% Amplitude	10.95 uV 20.81 uV(not reliable) 9.63 uV 6.33 uV
Latency	115.1 ms 104.3 ms 127.7 ms 107.3 ms
16x16-10% Amplitude	12.42 uV 7.79 uV 11.19 uV 10.66 uV
Latency	123.8 ms 104.3 ms 107.3 ms 137.5 ms

Case Report

Patient History: AS, a 22-year-old college accounting student, presented for a neuro-optometric evaluation due to persistent visual symptoms, including right visual field loss and blurred vision, following a TBI sustained in a T-bone automobile accident two years prior. AS remained in a coma for 31 days following the accident. She subsequently entered a vegetative state that lasted an additional two months. CT imaging revealed diffuse axonal injury, multiple skull fractures, cerebral hemorrhages, and lesions predominantly affecting the frontoparietal regions of both hemispheres. She was also diagnosed with right homonymous hemianopsia (RHH). Following a one-year hospital stay of extensive rehabilitation, addressing physical injuries, relearning basic functions, and with some complications such as sepsis, pneumonia, and one seizure episode, AS returned home. She needed assistance for behavioral/social daily living activities and continued outpatient rehabilitation, including physical, vestibular, occupational, and speech therapy. Concerns about persistent visual difficulties affecting her daily functioning and academic performance prompted a referral for neuro-optometric evaluation.

Symptoms: AS reported occasional headaches, tracking issues affecting academic performance, visual memory problems, and reduced visual field awareness on the right side. She described her right visual field as blurred from the nose outward, fading to complete loss. Under stress or distraction, she experienced fluctuating lights in the blind field and occasional visual hallucinations (Charles Bonnet syndrome), though these had decreased over time.

Medical History: AS had a history of migraines, seasonal allergies, and routine health follow-ups with a physiatrist. Her medications included Keppra (for seizures), Trazodone (for sleep), Neosporin (for allergies), and various monitored supplements. Routine ophthalmological evaluations resulted in the prescription of over-the-counter reading glasses and LacriLube eye drops for occasional dry eye symptoms.

Patient's Goals: Pursue a treatment option to address the persistent right visual field loss. Despite an early diagnosis of RHH, she received no interventions to manage the condition adequately.

Initial Evaluation: During the evaluation, AS was alert, and her mood and orientation were normal. However, she displayed some physical limitations, including restricted right-hand mobility. Due to a left foot injury, she was able to walk slowly with a cane but required a stimulation device for leg movement. Additionally, she exhibited a slight leftward head turn and elevated chin posture, a compensatory pattern that deviated from the expected rightward orientation typically seen with right homonymous hemianopia. This atypical posture may reflect underlying musculoskeletal limitations related to her injury. Her evaluation also revealed speech and language processing difficulties, reflecting broader sensory deficits.

The initial evaluation (Table 8) included thoroughly examining the oculomotor and binocular visual systems, ruling out any involvement of injured cranial nerves that could affect eye movement for versions and ductions. Her complaints of blurred vision prompted further investigation of the accommodation system. To address the right homonymous hemianopsia, testing with confrontation fields and computerized visual field assessments established a baseline measurement of the right visual field loss.

To plan an effective rehabilitation program for visual field loss, tests for spatial localization, egocentric visual midline shift, and USI identified no abnormalities, with all results falling within normal limits. AS reported reduced academic performance as a college student, a common symptom following TBI involving multiple lobe injuries, prompting further assessment of visual perception processing using the Developmental Eye Movement (DEM) and the ImPACT tests. A trial of therapeutic lenses aimed to improve visual comfort, enhance spatial awareness, and support postural realignment. Her external and internal ocular health were within normal limits, confirming the ophthalmologist's findings.

Diagnosis: Based on neuro-optometric testing, AS was diagnosed with:

- Right homonymous hemianopsia
- Oculomotor dysfunction
- Binocular vision dysfunction
- Accommodation insufficiency and infacility
- Visual-spatial disorientation

Treatment Plan: Following the evaluation, a structured neuro-vision rehabilitation program (NVR) was developed and presented to AS in a detailed written and oral report for coordination with other healthcare providers. The rehabilitation program initially excluded strobe glasses but later incorporated them as an advanced intervention. The treatment plan included two stages:

1.Therapeutic lens prescription

AS was prescribed 3 base-up yoked prism combined with anti-fatigue bifocal lenses with a near addition power of +0.85 D OU. The anti-fatigue lenses were selected based on positive subjective trial lens feedback between 0.75 D and 1.00 D flippers and improved accommodation performance. The 3 base-up yoked prism was determined by the patient's subjective feedback indicating reduced visual stress. This response aligned with the prism's properties to shift images downward and reduce visual information load. The VEP results and observed improvement in head posture alignment further supported this decision. AS declined the use of Peli-prism lenses for potential field expansion.

2. In-Office Neuro-Vision Rehabilitation

The NVR program aimed to enhance visual efficiency, perception, and right-side scanning while addressing functional confidence in compensating for right visual field loss and reduced visual processing due to TBI.

The prognosis was positive through an estimated 24–48 one-hour weekly sessions, supplemented by 15-minute daily home activities. Progress evaluations occurred after every 12-session unit, totaling 2–4 units.

AS was initially unable to proceed with stage two of in-office NVR due to insurance denial and a busy rehabilitation schedule. Over the next year, she attended four additional evaluations, maintaining stable optometric data. During her last visit, she reported discomfort with her therapeutic glasses, leading to a recommendation for near-task use only. A month later, a neuropsychological evaluation revealed reduced visual perception processing, significantly affecting her academic performance. As a result, she received additional school accommodations and financial approval for in-office vision therapy. After completing the outpatient neuro-rehabilitation day program, she was ready to proceed with stage two of neuro-vision rehabilitation.

NVR Goals and Unit Progression

The rehabilitation plan progressed through four structured units, with Table 9 displaying the activities performed based on each visual goal and notes on ability. Unit 1 activities were primarily monocular, using black and frosted patches while AS was seated in her wheelchair. The goal was to establish accurate awareness and control of basic visual skills. RHH impaired her awareness of physiological diplopia, a topic discussed further in the report. Unit 2 progressed to binocular activities, with some performed while standing, as AS could use her cane for support. The focus shifted to improving visual efficiency, right-side scanning, and enhancing visual perceptual abilities while raising awareness of head and body posture. Unit 3 introduced sensory-loaded movements,

Table 9. NVR Goals and Activities

UNIT 1 Category	Goals	Activities	Ability Initial Unit	End Unit
Oculomotor	- Establish accurate eye control w & w/o metronome	Eye Stretches Saccades, Pursuits Vestibular-Ocular tracking	Unstable, shaky	more stable
Accommodation	- Improve monocular stimulation and relaxation of accommodation (MAR) - Learn how to be in control of accommodation - Improve accommodation amplitude	MAR w/ V. Perceptual materials Near-Far Hart Chart OD/OS Bull's Eyes Hart Chart Look-Hard-Look-Soft Mental Minus Monocular Letter Tromboning Coin Circles	difficulty clearing (+) F: 10 ft N: 5″ Cleared print 9″	clear +2.75-6.00 F: 10ft N: 3″ 3″
Binocular	- Appreciate physiological diplopia - Improve NPC - Gain awareness and control of binocular vision	Phys-Dip- sticks and strip Brock String- near bead fusion Pencil Push-ups Tranaglyph BO VTS-4 smooth BO, BI	Difficulty seeing phys-dip 20″ 4 BI/BO BI: x/08/06, BO: x/04/04	 3″ w/effort 3″ BI: x/08/06, BO: x/20
Visual Perception	- Enhance periphery awareness and scanning right - Improve visual perceptual speed - Improve visual tracking at all distances (sitting, moving the head, eyes, upper trunk) - Use metronome and timer as a load for some activities	CP Saccades 4 Corners Hart Chart 2, 3 Wall Saccades Wall and floor Search 2, 3 Strip Saccades MT with timer Saccadic Near Reading	All activities slow but accurate	

Table 9. NVR Goals and Activities (cont)

UNIT 2 Category	Goals	Activities	Ability Initial Unit	End Unit
Oculomotor	- Load the oculomotor activities with proprioceptive (perform standing up with awareness of a balanced head and body posture)	Gaze Stabilization		Able to perform
		Saccades- Standing up		
		Pursuits- Standing up		
		VOR- Standing up		
Accommodation	- Improve Binocular Accommodation skills (BAR)	BAR +/-2.00 flipper w/ V Perception materials	able to clear only w/Polaroid- not RG	
	- More challenging N-F activities	Near-Far reading facility		
		Hart Chart Decoding	Slow	switch faster
Binocular	- Improve BI, BO ranges	Tranaglyphs BI, BO	Not successful	
		Brock String - Bug on a string and jumps	Good performance	
		Brock String at different gazes	3" w/effort	3"
		NPC Push-ups w/ letter target	2"	2"
		Prism Jumps 4^	Slow	Slow
		VTS-4 smooth, jump BI, jump BO		No improvements from Unit 1
Visual Perception	- Eye-Hand standing	Bean Bag Toss- sitting, standing		
	- More demands on R Visual field	SVI- Eye Hand, Saccades, Rotator	Struggled with right hand but highly motivated	Improved performance
		Marsden Ball Bunting, Punching		
		Marsden Ball 3 Circles		
		Bench Fixation		
	- V. Scanning- w/loading	Wall Floor Search w/flashlights		
		Walk and Scan by command		
		Near Saccadic reading	Slow reading	
		Neurotracker	Score speed 1.1- Difficulty tracking the balls	
	- Visual Memory	Going on a picnic, Memory Match	Reduced memory, needed clues while playing	

UNIT 3 Category	Goals	Activities	Ability Initial Unit	End Unit
Oculomotor	- Load the oculomotor activities with proprioceptive (perform standing up with awareness of a balanced head and body posture)	Gaze Stabilization		
		Saccades- Standing up	Good performance	
		Pursuits- Standing up		
		VOR- Standing up		
Accommodation	- Maintenance MAR, BAR, AA w/ V. Perceptual materials	BAR		
		Near-Far Charts-Saccadic Reading	Stable	
		Bull's Eyes- faster clearing		
Binocular	- Fusional targets at all distances	Barrel Card- alternate fixation		
		Paper Brock String w/look away		
	- Vergence facility BI/BO	2 Sticks Convergence Rock	NF 15 jumps	30 jumps
		Brock String- rope slightly left		
		Distance GTVT w/RG glasses	7ft	9ft
		VTS-4 BI/BO	BI: 6, BO: 10	BI: 5, BO: 13
Visual Perception	- Enhance tracking speed and spatial processing	Dynamic Reader- computer game	1st grade	5th grade
		EyeCanLearn website- Perceptual		
		Visual Search Packets w/timer	Improved reading speed	
		Pyramid Reading, Maze Packets	Fast and accurate	
		Stroop Charts	Fast and accurate	
		Slap Tap	Fast and accurate	
	- Load activities with cognitive, proprioceptive, auditory, motion stimulation	I See Image-You See Number		
		See the Grid	Cannot recall details	Call full grid
		Parquetry Blocks w/V. Memory	Good performance	
		Neurotracker- score speed	Score speed: 1.7	Score speed: 1.4
	- Improve peripheral awareness	Elevate- phone application		
	- Strobe Glasses- Emphasize Right VF Tracking	Strobe Glasses- Eye Hand Beanbag Toss	Strobe Speed 1	Strobe Speed 6

Table 9. NVR Goals and Activities (cont)

UNIT 4 Category	Goals	Activities	Ability Initial Unit	 End Unit
Oculomotor	- Eye Control w/ loading and extra scanning to the right and lower right field	Eye Stretches Pursuits Saccades HTS- Saccades, Pursuits	Good performance	
Accommodation	- Maintain MAR, BAR, AA skills	MAR +3.00-5.00 Monocular Letter Tromboning BAR +/-1.75 HTS- Accommodation	Stable	
Binocular	- Improve peripheral fusion - Maintain/improve vergence facility BI/BO - BIM/BOP	Brock String- Rope Rotation Keystone scale- RG glasses Prism Jumps BI/BO HTS-RDS smooth, jumps Paper Brock String- smooth, jump Brock String with +/-1.50 flipper	Good performance	
Visual Perception	- Improve visual perceptual processing activities - Load right side scanning Eye-hand coordination activities with or without the strobe glasses	Wall Scan- Spelling Words Estimate Distance Laterality, Directionality Charts McDonald Card Virtual Reality- Fruit Ninja Visual Memory, Mazes, I Spy Visual Logic Packets Visualization, Perceptual Packets Einstein- iPhone app Senaptec, SVI-Eye-Hand Marsden Ball, Multi-matrix (with Strobe glasses) Eye hand board games/Strobe glasses Daily living activities/strobe glasses at home	Good improving performance Strobe Speed 4 15 minutes at various strobe speeds 1-6	 Strobe Speed 6

incorporating strobe glasses as a therapy tool. Unit 4 transitioned to monthly sessions and integrated movement-based activities with strobe glasses, right-side scanning, and left-side occlusion. This final phase emphasized stable eye efficiency and advanced visual perception skills, including visual discrimination, form constancy, figure-ground perception, spatial relations, visual memory/visualization, and reaction time.

<u>NVR Outcomes:</u> During the fourth unit, AS began an adaptive driving evaluation designed to assess and train individuals post-TBI for safe driving. The evaluation presented an opportunity for her to regain her driver's license, contingent on completing two driving lessons. However, after one lesson, she determined that driving was unsafe for herself and others and chose to discontinue her pursuit of driving. Consequently, she also opted not to complete the fourth unit of NVR. After the eighth session, AS decided to pause NVR to prioritize hand therapy, which became the next focus of her rehabilitation. She reported achieving her primary NVR goals, including improved reading speed, enhanced academic performance, and increased confidence, balance, and safety in daily activities.

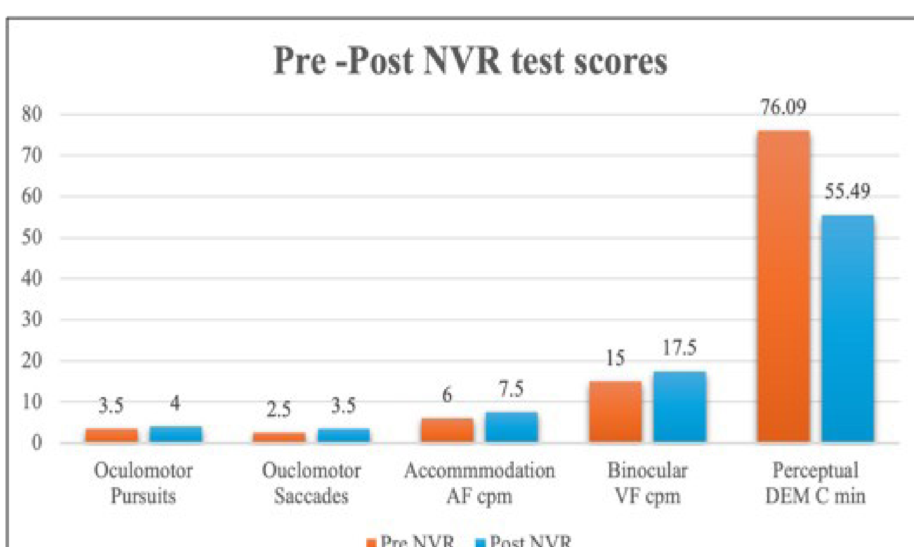


Figure 2. Pre-post NVR test scores

Table 10. Initial Evaluation and Re-Evaluations

	Pre-NVR	Reevaluation Post UNIT 1	Reevaluation Post UNIT 2	Reevaluation Post UNIT 3
Subjective Feedback	-difficulties focusing and fixating -struggles with academic tasks -slow reading speed -unstable peripheral vision -frequent headaches	-improved scanning ability -more comfortable attending movies -reduced headaches	-more attentive to R&L sides -struggles with reading (slow pace, misses end of lines) -added goal of driving	-improved visual awareness -able to read magazines -less fatigue at night -more confident in visually stimulating environments (e.g., college, theater)
Refractive Status VA- Distance (unaided) VA- Near (unaided) Subjective Refraction	 OD: 20/20- OS: 20/20 OU: 20/20 OD: -0.25 20/20+ OS:- 0.50 20/20+	 OD: 20/20 OS: 20/20 OU: 20/20	 OD: 20/20 OS: 20/20 OU: 20/20	 OD: 20/20 OS: 20/20 OU: 20/20
Oculomotor Evaluation: Fixation OD/OS Extraocular Motility Pursuit Saccades	 stable FROM 3-4+ 2-3+ overshoot to right gaze	 stable FROM 3-4+ 3+ overshoot to right gaze	 stable FROM 3-4+ 3-4+ overshoot to right gaze	 stable FROM 4+ 4+ w/cognition 3-4+ overshoot to right gaze
Binocular Evaluation Stereopsis Test: RDS Wirt Animals W4D: near, intermediate, far D- Cover Test N- Cover Test NPC NPC w/red light Vergence Facility Near BI (NFV) Near BO (PRV)	 250" sec of arc 30" 3/3 flat fusion 2 exophoria 6-8 exophoria 1" x3 times OS out 30 cpm-not reliable Not reliable x/20 OS suppression	 250" sec of arc 25" 3/3 orthophoria 6-8 exophoria TTN x3 times w/effort TTN x3 times OS out w/frequent alternate suppression 15 cpm (w/red light for accuracy) x/4/2 x/15/13	 250" sec of arc 20" 3/3 orthophoria 6-8 exophoria TTN x3 times 4-7" OS out, but TTN w/ effort cannot fuse BI- cannot see the right side with OS x/10/8 x/16/12	 250" sec of arc 25" 3/3 orthophoria 4-6 exophoria TTN x3 times TTN x3 times 17.5 cpm- not sure if reliable x/10/8 x/45
Accommodation Evaluation AF- OU w +/-2.00 D AA- OD/OS (Donders) NRA/PRA	 6 cpm 6.25 D / 6.25 D +1.25 D / -1.50 D	 5 cpm, 10.5 cpm w +/-1.00 10 D / 9 D	 5 cpm 11 D / 9 D	 7.5 cpm (+ side difficult) 9 D / 10 D
Neuro-Sensory Tests: Spatial Localizatio Body Posture Head Position Confrontation Field Visual Disc Midline Shift DEM: A/B/C	 normal using a cane-left leg not functional chin up restriction to the right normal A: 16.69 sec B: 16.87 sec C: 78.09 sec	 undershooting occasionally use of cane chin up at times restriction to the right normal C: 60.02 sec	 undershooting perform slowly w/o the cane normal slight VF on the top right w/OD normal C: 57.69 sec	 normal walk slow w/o cane, difficulty L leg normal slight VF on the top right w/OD 135 degrees normal C: 55.49 sec 1 substitution
Ocular Health External and Pupil Test Interior Exam- not dilated	normal unremarkable, C/D 0.50/0.50			
Plan	-estimated NVR 24-48 sessions 12 sessions=1 unit	-continue with unit 2	-continue with unit 3 -test RightEye- reading speed -Dynamic Reader program -Strobe glasses therapy	-ok to begin the driving program -once a month NVR as maintenance -Strobe glasses- Daily home practice for the right VF stimulation

Table 10 presents the pre-NVR and subsequent re-evaluation results. Figure 2 demonstrates measurable scores pre- and post-NVR.

Integration of Strobe Glasses Into The NVR Program

Strobe Glasses Treatment Goals

Strobe glasses were introduced based on evidence from studies demonstrating their effectiveness in enhancing visual perception, including improvements in visual memory, motion sensitivity, and eye-hand coordination[14] These benefits were particularly relevant for AS, who exhibited reduced visual perceptual processing, a common deficit in TBI patients, and diminished spatial awareness due to right homonymous hemianopia (RHH).

After completing Unit 2 of NVR, the treatment plan was expanded to integrate strobe glasses. The primary objective was to improve scanning, spatial awareness, visual-motor integration, and reaction time toward her right visual field, thereby increasing her functional independence in daily activities.

Additionally, the intervention aimed to determine whether strobe light and motion-based visual stimulation, activating magnocellular cells in the retina and influencing the entire magnocellular visual pathway, which is responsible for motion detection, spatial localization and visual-motor coordination, could help reduce the perceived size of her visual field loss.

Strobe Glasses Protocol

The treatment plan followed a progressive protocol, gradually increasing the duration and complexity of strobe glasses activities based on AS's subjective feedback and objective performance (Table 11).

- AS began with simple eye-hand coordination tasks using full-lens strobing at a high flickering speed (speed 1).
- Over time, the flickering speed gradually decreased to level 6, increasing the visual challenge.
- Bi-left occlusion, which occludes the intact left visual fields, stimulated further right-side scanning. Initially, AS struggled with precision and reported discomfort, but with continued practice, her adaptation improved.
- Activities progressed from seated to standing and eventually incorporated movement-based tasks, promoting adaptability and scanning skill development.
- Eye-hand coordination techniques were performed with both the right and left hands to stimulate mobility in AS's injured right hand while facilitating bilateral brain stimulation and integration.
- Each session began with an eye-hand coordination activity, followed by a different eye-hand activity (Table 12) performed while wearing strobe glasses for five minutes. The session ended with repeating the initial activity without the strobe glasses to assess comparative performance. After each session, AS provided feedback on her experience and perceived improvements.

Initially, AS used the strobe glasses exclusively in-office, but as her proficiency increased, she incorporated them into her home practice. She reported heightened awareness of her right visual field, improved spatial perception, and greater confidence in navigating her home environment.

Subjective Feedback

AS reported that the strobe glasses enhanced her ability to notice and react faster with greater accuracy. She experienced significant improvements in focus and spatial awareness during and after strobe training. Her family also observed notable progress in her daily activities. Table 13 is a summary of AS's feedback following strobe glasses therapy:

Beyond strobe glasses therapy, AS noted an improved ability to read for extended periods, even small print, without fatigue, positively impacting her academic performance. She also resumed playing the violin, an activity she had previously abandoned. Despite her persistent right visual field loss, she reported feeling more balanced and secure in various environments, including at home, at college, and in public spaces. Although the strobe glasses alone may not have caused these improvements, the intervention likely contributed to her progress across multiple domains.

Outcome Measurements

While AS subjectively reported enhanced functionality and greater confidence in daily activities, objective findings showed mixed results. Visual field test measurements revealed mild but no significant positive changes (Figure 3). This case was initially managed as part of routine patient care and was not intended for publication. As a result, reaction time performance, a key parameter for assessing the impact of strobe glasses, was not recorded numerically.

Table 11. Strobe Glasses Protocol Used in This Case Report

	Goal	Strobe Location	Strobe Speed	Minutes Performed
Level 1	Get used to the strobe glasses	Binocular, full lens strobing	Speed 1: fast flickering	5 minutes
Level 2	Perform eye-hand activities with and without the glasses	Binocular, full lens strobing	Speed 1: fast flickering	5 minutes w/strobe glasses 5 minutes w/o strobe glasses
Level 3	Gradually reduce strobe speed once a week to a tolerable level Perform eye-hand activities 3 times: without, with, and again without the strobe glasses	Binocular, full lens strobing	Speed 2-6: slower flickering (reached speed 6)	1-2 minutes w/o strobe glasses 5 minutes w/strobe glasses 5 minutes w/o strobe glasses
Level 4	Force right scanning: block seen/left visual field	Binocular, Bi-Left occlusion, Bi-Right lens strobing	Speed 1-6	1-2 minutes w/o strobe glasses 5 minutes w/strobe glasses 5 minutes w/o strobe glasses
Level 5	Eye-hand activity with the glasses	Binocular, Bi-Left occlusion, Bi-Right lens strobing	Max strobe speed ability	15 minutes

Table 12. Activities Performed with the Strobe Glasses (flickering speed 1-6)

- Bean Bag Toss: just right hand, just left hand, from hand to hand, toss to helper, catch from helper
- Bean Bag Bucket Toss while walking
- SVI: eye-hand, rotator, saccades
- Multi-Matrix: all levels
- Marsden Ball: catch, bunt, punch, 3 circles ball tracking and catch
- Catch a Ball with a Cup
- Prepare the table for dinner
- Walk around the house, yard

Table 13. Feedback Following Strobe Glasses Use

- "Slightly disturbing," "comfortable," "very comfortable with the strobe glasses."
- "Makes me more conscious of what I can see."
- "The right occlusion forced me to scan." "I am scanning more."
- "The blinking (strobe effect) makes it dark, making me more observant."
- "I can scan more after wearing the strobe glasses."
- "It's easier to scan immediately after training with the strobe glasses."
- "I feel comfortable with the strobe glasses."
- "I am not bumping into anything while wearing them."
- "I see an after-image after wearing them—it helps me be more conscious of my right side, even after it disappears."

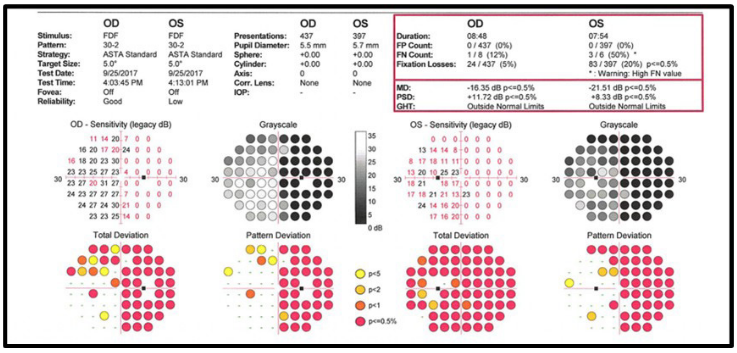
Discussion

The Importance of Early Neuro-Visual Screening in TBI Rehabilitation

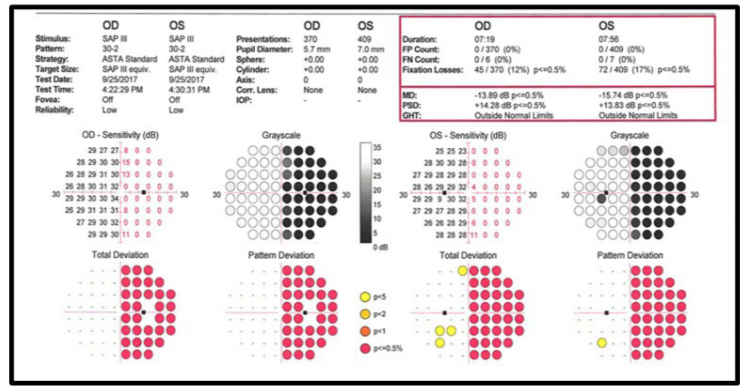
Early identification of visual dysfunction in TBI is essential to optimizing recovery and enhancing the efficacy of other therapeutic modalities. Despite the high prevalence of post-traumatic visual symptoms, many cases are overlooked or misdiagnosed as cognitive, vestibular, or behavioral disorders. According to the Neuro-Optometric Rehabilitation Association (NORA), up to 90% of TBI patients experience vision-related issues,[34] yet early TBI management often fails to include neuro-visual screening. This case underscores the value of incorporating neuro-optometric evaluations early in the rehabilitation timeline. In the case of AS, earlier assessment and intervention could have accelerated her progress in visual-motor processing, contributing more effectively to occupational therapy and daily task performance.

HH and Challenges in Binocular Vision

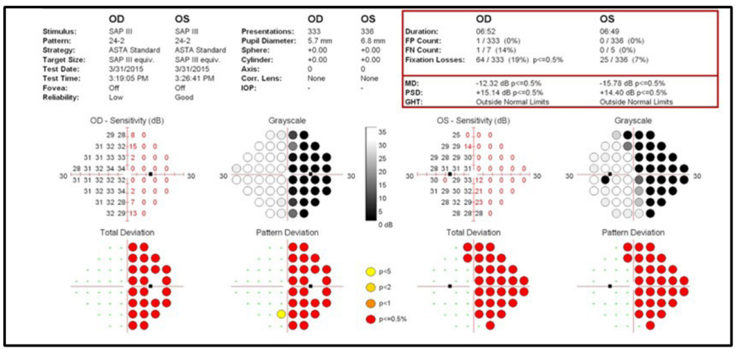
HH presents complex visual field limitations, often disrupting binocular fusion and depth perception. In AS's case, the right HH impaired her ability to perceive physiological diplopia, limiting success in vergence activities such as Brock string and the computerized vergence training. With increasing vergence demand, the fusion targets moved beyond the intact field, making them inaccessible, resulting in a loss of 3-D (Figure 4). To address these challenges, compensatory strategies included head turn, leftward string positioning, and a monocular check to ensure she could visualize the entire string with each



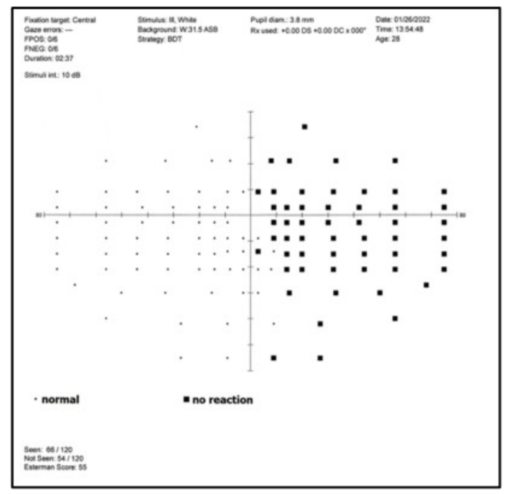
Pre -NVR



Post-NVR



Pre -Strobe



5 minutes Post-Strobe

Figure 3. Pre-/post-NVR as well as pre-/post-strobe

eye. These findings underscore the importance of accurately differentiating between suppression, field loss, and fusion limitations. Tailoring therapy based on these distinctions can reduce patient frustration and enhance binocular visual outcomes. These subtle fusional deficits and the resulting partial loss of 3D may significantly affect orientation, navigation, and mobility confidence.

Bridging Theory and Practice: Introducing Strobe Glasses in NVR

Although strobe glasses are well-documented in athletic and sensory rehabilitation contexts, their role in neuro-optometric therapy is still emerging, particularly as sports vision therapy to enhance perceptual processing and reaction time. Given AS's severe TBI, RHH, and limited mobility, the initial NVR program excluded strobe glasses. The primary focus was improving visual efficiency dysfunctions, including oculomotor control, accommodation, and binocular vision. However, two clinical goals guided their later introduction into therapy.

1. Enhancing Visual Perception and Spatial Scanning: Both professional athletes and patients with HH require rapid visual tracking, efficient spatial processing, and predictive scanning, reflecting their shared visual demands.

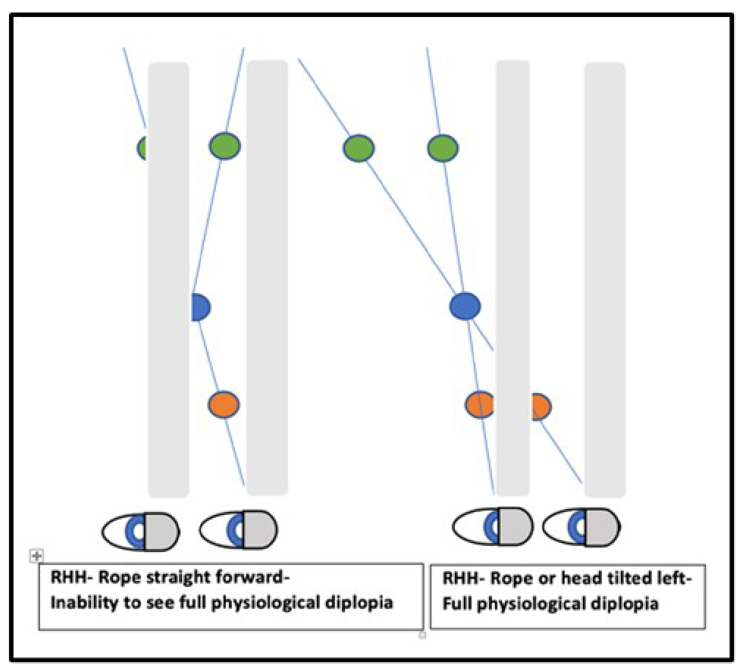


Figure 4. On the left is a demonstration of the inability to see phys-dip due to HH; on the right is the solution to overcome it.

In AS's case, training began with full-lens strobe stimulation to build foundational visual-motor coordination and processing speed. As therapy progressed, a bi-left occlusion setting challenged her compensatory strategies further. This modification selectively restricted her intact left visual field, prompting greater exploration of both the left and the affected right visual field. The result was improved perceptual awareness, spatial adaptability, and more efficient scanning behavior during and after strobe glasses use.

2. Exploring the Strobe Light Stimulation Effect on Scotoma Size: Although HH often carries a poor prognosis for visual field recovery, we considered it clinically relevant to investigate whether AS's scotoma contained partially functional or "silent" neurons that might respond to targeted stimulation. The intermittent flickering input from the strobe glasses may activate residual visual processing at the border of the scotoma. Additionally, if the field deficit was due more to disrupted cortical processing rather than complete neuronal loss, strobe-induced stimulation could support neuroplastic mechanisms and contribute to functional improvements in spatial perception. While visual field testing did not demonstrate measurable expansion in AS's case, she subjectively reported enhanced spatial anticipation and confidence during navigation, suggesting perceptual adaptation in response to the training.

Adaptation Challenges and Tolerance Variability

AS initially experienced discomfort using strobe glasses, especially with the bi-left occlusion setting. However, with gradual exposure and persistence, she adapted and later reported enhanced spatial awareness, increased rightward scanning, and greater confidence in daily activities. These outcomes highlight a key clinical consideration: many patients undergo an adaptation period before they fully experience the benefits of strobe training. Tolerance and response to strobe glasses can vary widely between individuals. The need for prescription lenses may compound challenges, as strobe glasses often do not fit well over existing eyewear, potentially leading to discomfort and reduced compliance. While some users may not perceive immediate benefits—or discontinue use due to sensory discomfort—others, like AS, can achieve meaningful functional gains over time. These variations underscore the importance of a patient-specific approach. Gradual integration, careful monitoring, and flexible protocols are essential for optimizing outcomes in neuro-vision rehabilitation using strobe glasses.

Limitations and Future Directions

While AS demonstrated functional improvements with strobe integration, limitations include the single-case design, absence of controlled pre/post visual field measures, and reliance on subjective outcomes for visual perceptual processing improvements. Objective performance metrics, like those used in the group trial, should be standard in future studies. Further research should standardize strobe frequency, duration, and quadrant occlusion protocols to define ideal parameters for patients with HH better.

It remains unclear whether AS's improvements in spatial awareness were explicitly due to strobe glasses or part of broader NVR gains. Future studies should isolate the effects of strobe training by incorporating control groups, standardized visual field assessments, and objective performance tracking. While current findings rely on subjective reports of increased spatial awareness, navigation confidence, and scanning efficiency, future research using varied strobe settings, durations, and diverse patient populations could provide deeper insights into their role in NVR.

Future Directions for Strobe Glasses in Neuro-Visual Rehabilitation

Conventional interventions for HH typically include prism lenses, compensatory scanning training (CST), and NVR. Prism lenses help shift visual input from the blind hemifield into the remaining intact visual field, making the blind area more accessible. CST, conversely, focuses on training patients to develop efficient scanning techniques and increase awareness of the affected side.

Strobe glasses represent a novel, complementary modality that introduces intermittent visual disruption to promote neuroplasticity and refine compensatory visual strategies. Unlike static visual aids, they dynamically challenge the brain's predictive and perceptual systems, aiming to enhance reaction time, visual-motor integration, and spatial adaptability.

While CST and prism therapy are well-established, integrating strobe glasses into NVR offers a potentially synergistic approach, particularly for patients with persistent deficits in scanning efficiency or spatial perception following TBI. Their targeted effect on multisensory integration and cognitive visual function warrants further investigation.

Future research should establish standardized clinical protocols, define optimal usage parameters, and evaluate long-term outcomes across varied neurological populations. As clinical experience grows, strobe glasses may emerge as a valuable adjunct in rehabilitating visual field loss, expanding the toolkit available to neuro-optometric practitioners.

Conclusion

This case illustrates the value of early NVR for patients with HH following severe TBI. Even without significant visual field changes, therapeutic lenses, prisms, and structured training can improve functional outcomes by enhancing visual efficiency and promoting visual-spatial and motor adaptation.

Strobe glasses, originally developed for sports vision, offer a novel and effective adjunct to NVR. By intermittently disrupting visual input, they support adaptive strategies that enhance scanning, visual-motor coordination, and spatial awareness. In this case, strobe training improved key daily functions such as navigation and reading.

While further research is needed, this case supports the use of strobe glasses to promote neuroplastic change and functional recovery across NVR populations, including patients with severe TBI and right homonymous hemianopsia.

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