Visual Snow Syndrome in Traumatic Brain Injury: Effect on Driving

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INTRODUCTION

Visual snow syndrome (VSS) has received considerable attention over the past decade (White et al, 2018; Puledda et al, 2018, 2020; Ciuffreda et al, 2019). However, it was reported as early as 1944 related to digitalis intake for heart problems (Carroll, 1944). Interestingly, the primary etiology of VSS is traumatic brain injury (TBI) (Tannen et al, 2022). VSS has a constellation of visual and non-visual symptoms, which are listed and defined in ***Table 1***. Essentially, visual snow (VS) (Table 1, item 1) refers to the pixelated, dynamic visual "noise" (like a detuned television) that is perceived to be in front of, and overlaying, the entire visual field (***Figure 1***). Driver Rehabilitation Specialists who suspect that a client may be experiencing visual snow (VS) should refer to an eye doctor to confirm the diagnosis and prescribe treatment. Per the current diagnostic criteria for VSS (White et al, 2018; Puledda et al, 2018, 2020), the individual must report VS plus two or more of the following four visual symptoms: palinopsia, photosensitivity, enhanced entoptic imagery, and "nyctalopia" or difficulty seeing at night (***Table*** 1, items 2-5). In addition, they typically report one or more of the remaining symptoms in Table 1 (items 6-13), such as tinnitus and photopsia.

VSS presents with an interesting and unusual range of sensory, motor, and perceptual, visual and non-visual, symptoms. Hence, it behooves the clinician (e.g., optometrist and/or occupational therapist) to consider the possible effects of these symptoms on driving, especially in certain environments (e.g., night driving). Furthermore, these symptoms and their driving ramifications are compounded by the comorbid condition of TBI and its own constellation of visual dysfunctions, some of which are also important in the context of driving (e.g., abnormal egocentric localization andoculomotor problems) (Ciuffreda and Rutner, 2022).

DRIVING WITH VSS AND TBI

The majority of symptoms presented in Table 1 (~75%) have the potential to impact negatively on driving in these patients (***Table 2***, items 1-10). The impact can be either direct or indirect on vision and visual/general sensory processing.

The key symptom of VS may adversely affect one's driving in a number of ways. First, the pixelated overlay produces two competing and conflicting depth planes, which could result in visual confusion and an attentional distractor, as well as impair depth/distance perception. In addition, in the younger individual (<40 years of age, pre-presbyopic), VS may increase the eye's focusing error (i.e., increased accommodative error) at distant points (Stark and Atchison, 1998). The result would be slight blur, and thus present difficulty detecting small details in the complex, dynamic distant visual scene (Stark and Atchison, 1998). Fortunately, the adverse effects may be reduced with a chromatic tint (Ciuffreda et al, 2019; Tannen et al, 2022) (***Table 2***).

Figure 1: Visual Snow over right side of the scene, normal on the left side.

1.	**visual snow**: pixelated, dynamic visual "noise" overlaying and in front of the entire visual scene
2.	**palinopsia**: persistence of a visual image (i.e., an afterimage), sometimes with a comet-like trail
3.	**photosensitivity**: light sensitivity
4.	**enhanced entoptic imagery**: perception of ocular floaters and other ocular debris not normally visible to others
5.	**"nyctalopia"**: difficulty seeing at night or in very dim illumination
6.	**photopsia**: perception of light arising without an external light stimulus; random flashes of light
7.	**balance problems**: sensation of bodily unsteadiness
8.	**hyperacusis**: a disorder of loudness perception, overly sensitive to sounds, reduced tolerance to sounds, sometimes only very specific sounds
9.	**phonophobia**: unwarranted fear of sound including common ones in the environment and home, may elicit a sympathetic "fear" response
10.	**migraine**: severe headache usually unilateral, may cause transient light sensitivity, transient scotomas, and nausea
11.	**tremor**: small, involuntary, rhythmic muscle contractions
12.	**tinnitus**: ringing in the ears
13.	**cutaneous allodynia**: pain sensation from normal touching of the skin

Table 1: Visual and non-visual symptoms in visual snow syndrome

The other four critical diagnostic, criterion-based, primary visual symptoms could also adversely affect one's driving performance, and hence one's safety (***Table 2***, items 2-5). For example, in the case of palinopsia, the persistent afterimage with or without trailing, can exert a disruptive and confusing effect when superimposed on the dynamic driving scene, especially along with the concurrent overlay of VS. Similarly, the presence of photosensitivity can produce a visual/attentional distraction, a sense of annoyance, watering of the eyes, and eyelid "squinting" to reduce the light intensity entering the eye via the pupil. Fortunately, both can be reduced to some extent with a chromatic tint;

	Symptom	Effect on Vision	Vision Remediation
1	Visual Snow	visual and attentional distraction, presence of two conflicting depth planes, accommodative errors, depth/distance perception errors	chromatic tint
2	Palinopsia	persistent afterimage with possible comet trail, disruptive and confusing to visual scene	saccadic tracking, chromatic tint
3	Photosensitivity	visual and attentional distraction, eye squinting, eye watering	chromatic or achromatic tint, large brimmed hat
4	Enhanced Entoptic Imagery	visual interference	none
5	Nyctalopia	visual interference	none
6	Photopsia	visual and attentional distractor	chromatic or achromatic tint
7	Balance Problems	overall bodily instability	visual/vestibular vision training, accurate refraction
8	Hyperacusis	auditory distraction	none
9	Phonophobia	attentional distraction	none
10	Migraine	visual and attentional distraction	chromatic or achromatic tint as needed
11	Tremor	none	none
12	Tinnitus	none	none
13	Cutaneous Allodynia	none	none

Table 2: Visual snow syndrome symptoms in TBI and their potential effect on driving.

moreover, the palinopsia can be reduced further with simple vision therapy, saccadic tracking procedures (Tannen et al, 2022). The enhanced entoptic imagery can also act as a visual distraction and annoyance, with its overlay of internal eye debris/structures upon the visual scene, and it likely contributes to the vague symptom of "nyctalopia" along with the concurrent presence of VS. Unfortunately, there is no treatment for either disturbing visual symptom. However, one may elect to limit driving to daytime hours when these problems may be less evident.

Regarding the secondary visual and non-visual symptoms in VSS (items 6-13), the scenario is mixed. Regarding photopsia, which can act as an intermittent visual distraction, a tint might be helpful during an active episode. The frequent balance problems and overall bodily instability when driving can be helped in two ways: first, with vestibular/vergence-interactive vision therapy provided by the optometrist and others (e.g., the physical or occupational therapist with a vestibular specialty), and second, with a careful refraction to reduce any residual retinal defocus/blur that can adversely affect overall bodily stability, especially in the elderly (Elliott, 2014). The next three symptoms (items 8-10) can each produce a sensory distraction (i.e., visual, auditory, and/or attentional), and hence may contribute to adversely affecting driving safety. Only the symptom of migraine may benefit from a tint, as needed, for the transient periods of photosensitivity and visualized scotomas, especially during the active phase of an attack. Of course, there are a variety of medications that may alleviate migraine symptoms. The remaining non-visual symptoms (items 11-13) do not have any effect on driving and also have no vision-based treatment.

Thus, the patient with VSS and TBI has a number of options for remediation of the constellation of their VSS symptoms per se. Furthermore, the prescription of a tint alone can provide some relief for many of these symptoms, including the VS, palinopsia, photosensitivity, photopsia, and migraine, which is encouraging. However, it becomes more complicated when their TBI-related visual symptoms are factored into the overall driving picture (e.g., abnormal egocentric localization causing veering to one side, increased eye-foot reaction time causing delayed responses) (Ciuffreda and Rutner, 2022). For example, a recent investigation demonstrated that simulated blur influenced the estimated time-to-contact in normal subjects, an important higher-level skill needed for safe driving (Hecht et al, 2021); interestingly, simulated wintry snow conditions had the same adverse perceptual effect (Hecht et al, 2021).

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However, once again, there are many neuro-optometric solutions for remediation, with some degree of overlap between the VSS and TBI visual symptomatology; for example, photosensitivity is common to both, thus one tint may solve the problem. In addition, there is another important factor, namely employing an occupational therapist driving rehabilitation specialist to teach, support, direct, and assess the patient's driving ability, using simulated driving conditions followed by on-road training and evaluation. This therapy could be performed in conjunction with the neuropsychologist to evaluate and train the requisite cognitive skills necessary for safe driving. Thus, the future is encouraging for the patient with VSS and TBI using a multidisciplinary approach: the occupational therapist, neuropsychologist, physical therapist with vestibular specialty, and neuro-optometrist, and others, in an integrative team approach.

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