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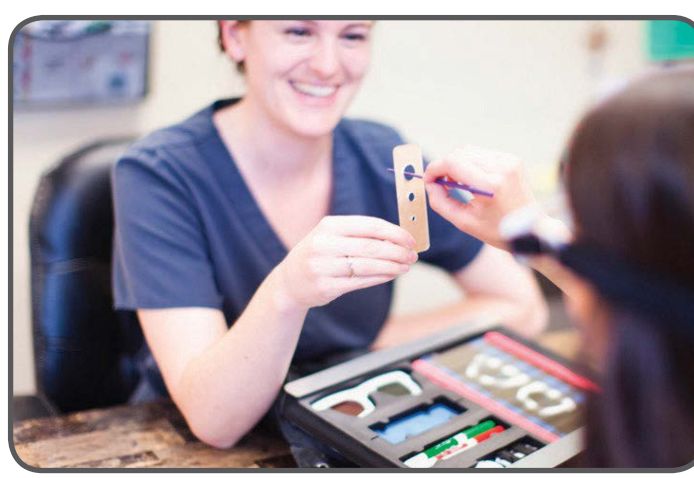

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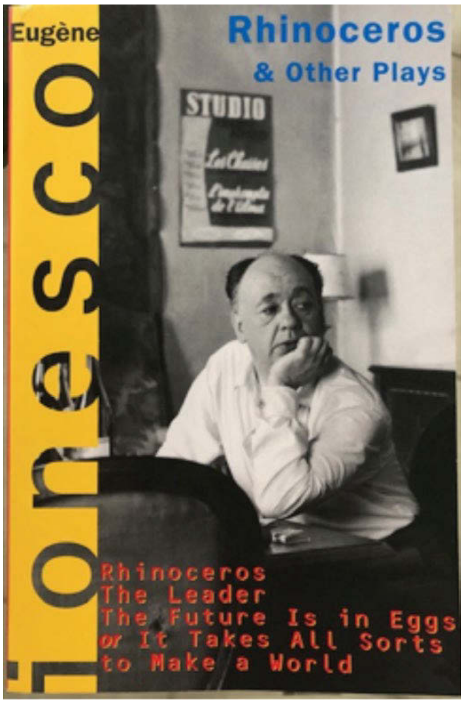
EDITORIAL

The Rhinoceros in the Room

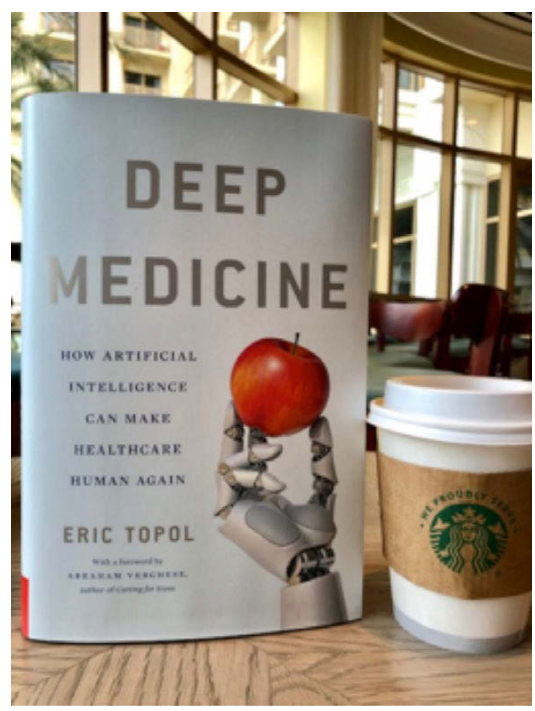
Leonard J. Press, OD, FAAO, FCOVD, *Editor-in-Chief*



Rhinoceros[1] is a masterpiece penned by the renowned international playwright Eugène Ionesco, which opened to wide acclaim in Paris during the first month of 1960. Its London opening in April of that year produced by Orson Welles featured Laurence Olivier in the starring role of Berenger. Big theater names imparting a large principle in the theater of the absurd. A rhinoceros moves swiftly through town one Sunday morning, trampling a cat and sending chills through some townspeople while others deny its existence.

Gradually at first, a strange transformation begins to occur. One by one, the townspeople metamorphose into rhinoceroses. Early signs signaling this transformation are subtle. Voices start to deepen. The skin of affected humans turns a shade of green and gradually thickens, followed by a small bump on the forehead. As the voice of reason, Berenger calls out these changes, while shrinking into the minority of individuals who retain their human-like features and qualities. Townspeople remain in denial, disputing the evident as absurd, as one by one they turn into rhinos, joining the nightly stampede. At the end Berenger is the last man standing, fiercely clinging to his humanity, ultimately refusing to capitulate.

For healthcare practitioners, the rhinoceros in the room has been Third Party Care. Dating back more than forty years, when I first entered practice, Third Party Care has continued to proliferate. The relationship between patient and doctor has shifted, with doctors progressively becoming more accountable to the entities issuing the bulk of payment for their services. Despite earlier warnings signs that this transformation may not be entirely healthy, practice management pundits encouraged their clients to jump on the bandwagon. The tendency to follow the herd enabled practitioners to rationalize how their identities were changing, and to accept the tradeoff in their services becoming increasingly commoditized.



Development and rehabilitation thankfully defies commoditization. Its practice is indicative of what futurist Eric Topol describes as deep medicine.[2] A cardiologist by training, Dr. Topol champions deep medicine as an antidote to its shallow counterpart. Shallow medicine is characterized by relatively brief encounters with patients that set the stage for misdiagnosis. Confirmation bias is another feature of shallow medicine that can result in individual physicians overestimating the benefit of what they themselves do, and downplaying what others have to offer. Proprietary electronic health records, reduced time for encounters with patients, and minimal eye contact due to data entry obsession are just a few of the many factors that contribute to shallow medicine.

Deep medicine, in contrast, is characterized by empathy. Surveys repeatedly show that what patients value most in their doctors and caretakers is the sense of being present during their interaction. As the old saying goes, patients don't care how much you know until they know how much you care. Conveying this sense of caring takes ample time for the practitioner to hear the patient's concerns, and to assimilate clinical test data into what she or he is seeing. Part of presence, as Topol notes, is the power of careful, detailed observation. In proof he cites a fascinating article published in the journal Ophthalmology,[3] whose opening paragraph reads as follows:

"Observation is a key component of physical examination and clinical diagnosis in medicine and is particularly important in the practice of ophthalmology. It is a difficult but pivotal skill to teach, especially for beginner students and residents who must rely on their descriptive abilities to convey ophthalmologic examination findings. Several studies have demonstrated inadequacies in the general physical examination skills of medical students, residents, and physicians, which may be owing to lack of explicit teaching of observation and description. Physical examination courses in medical schools tend to emphasize identification of memorized clinical signs rather than formally teaching students how to observe and describe. Observation is not only important for clinical diagnosis, but it is also a first step in being empathetic. To be able to empathize, one must be able to recognize emotions, which inherently requires the skill of observation."

The article proceeds to contrast medical education with visual arts education that helps to build visual literacy, or the ability to interpret and find meaning in images. The investigators sought to evaluate the effect of observation training in the visual arts on the general and ophthalmologic observational skills, and secondarily the emotional recognition skills, of medical students. Critical thinking skills were identified as follows:

1. Observing – what something is or is not, naming or identifying something, what is happening, how it looks, where located, counting things, how it is made.
2. Interpreting – use of object, characteristics or feelings related to object, identity and relationships, intentions.
3. Evaluating – based on personal preference and on perceived merits of work or artist.
4. Associating – relating the object/situation directly with prior experience or knowledge; making clear connections to personal experience.
5. Problem-Finding – notes or requests information or identification; identifies information needed to form a conclusion/opinion; may propose a hypothesis in conjunction with stating the problem.
6. Comparing – what is similar or different; noticing relationships between situations/objects; noticing patterns.
7. Flexible Thinking – about multiple possibilities; seeing things from different perspectives, revising thinking.
8. Providing Evidence – offering specific, clear, and reasonable support for statements, most often drawing from the object or situation rather than personal opinion.

The authors conclude from their study that art training places students in an environment where they are afforded the opportunity to listen to their peers, learn from multiple viewpoints about an unfamiliar subject matter with no clear correct answer, and thereby improve their ability to appreciate the opinions of others.

Topol cites an accompanying editorial in the same issue of Ophthalmology co-authored by the acclaimed journalist, Malcolm Gladwell, and David Epstein.[4] Known for his global perspectives, Gladwell draws proof of concept from what has been written about luminaries such as Galileo whose genius, in part, was built upon his training in the arts. It seems almost obvious that someone who is trained to see, and who thinks about the process of seeing, sees more and sees better. That sort of preparation, as argued by Gurwin et al, is what is missing in ophthalmology. Cognitive psychologists have repeatedly shown that observational skills rather than algorithmic learning are crucial for handling novel clinical challenges. Is this evidence of pedagogical negligence on the part of medical education? Gladwell and Epstein acknowledge that would be much too harsh of an indictment. But what we are witnessing are the practical limits to what or how much any one discipline can teach its students.

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What is Visual Motion Hypersensitivity?

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Symptoms of visual motion hypersensitivity (VMH), also known as visual vertigo and/or motion sickness, can be provoked by motion of the individual through the environment (riding in a car, boat, or plane), or motion of the environment (visual surroundings) while a patient stands still (standing in an active shopping center or driving on a busy road).[1,2] Symptoms of VMH include dizziness, nausea, vomiting, vertigo, imbalance, diplopia, headache, and disorientation.[3,4] There are several theories regarding the origin of VMH. It is thought that a combination of a vestibular disorder and a strong visual reliance on the magnocellular system and peripheral visual field are contributory.[1] A link between VMH and visual abnormalities such as unsteady fixation in a moving visual background and binocular visual dysfunction has also been found.[2] Diagnosis such as traumatic head injury and concussion increase the incidence of motion sickness.[5] The leading theory, however, is that there is a mismatch in the information received by the brain between the visual, vestibular, and somatosensory systems.[1-6]

The vestibular sensory system is responsible for providing us with information about motion,head acceleration, deceleration and position, and spatial orientation, as well as allowing us to balance, maintain posture, and stabilize the head and body during movement.[1,2] The vestibular system uses several organs to fulfil its function. The complex set of integrated sensorimotor-control systems which regulate balance have interlacing feedback mechanisms from the inner ear, eyes, muscles, and joints. Any disconnect or conflict between the vestibular, visual and/or musculoskeletal proprioceptive systems will cause symptoms of visual motion hypersensitivity (motion sickness).[6-7]

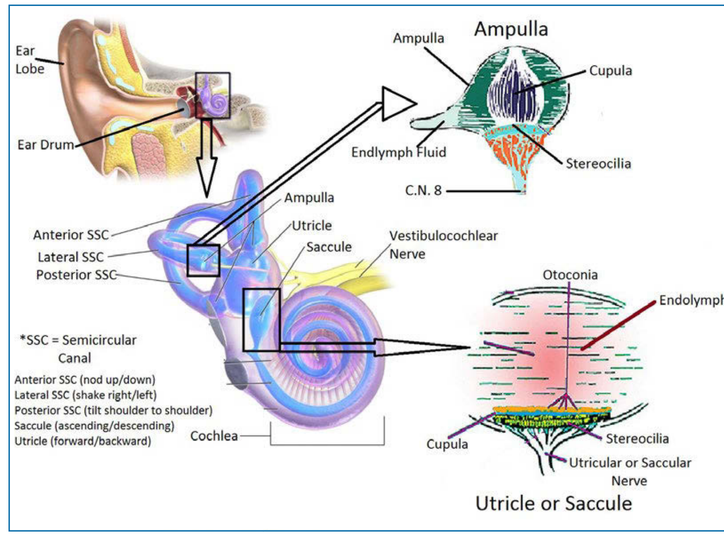

Figure 1. Representation of the vestibular labyrinth

The vestibular labyrinth, which is continuous with the cochlea, is a system of compartments found in each inner ear. The brainstem gains information from the vestibular system about the head's position and movement as well as what the body needs to maintain or regain balance.[8-10]

- **Angular acceleration** – Inside the labyrinth are three interconnected bony fluid filled tubes, called **semicircular canals,** which are each situated in a plane corresponding with head movement (Figure 1). The *anterior* (a.k.a. superior) semicircular canal is sensitive to movement and rotation in the lateral plane (nodding up and down/ pitch), the posterior semicircular canal is sensitive to movement or rotation in the anterior-posterior plane (tilting shoulder to shoulder/roll), and the lateral (a.k.a.horizontal) semicircular canal is sensitive to movement or rotation in the transverse plane (shaking right and left/yaw). The **endolymph fluid** inside each semicircular canal moves through the canal corresponding to the plane of movement when the head is either moved up and down, side to side, or right and left. As the fluid moves with the corresponding head movement, it flows into an outpouching at the end of the canal, called the **ampulla**. The ampulla houses a thick gel, called the **cupula**. The sensory hair receptor cells (**stereocilia**) of the vestibular system sit within the cupula gel. As endolymph fluid moves into the ampulla and causes movement of the gelatinous cupula, the sensory stereocilia hair cells nestled inside the gel deflect and move. As the stereocilia move, they convert mechanical energy into electrical energy and neurotransmitters are released with information about that specific plane of movement to the brain via the vestibulocochlear nerve (C.N. 8). The stimulation of one canal in the right ear results in the inhibition of the same canal in the left ear (and vice versa) allowing sensation of all directions of rotation. If the movement becomes continuous without any acceleration or deceleration, the endolymph fluid stabilizes and stops applying pressure on the cupula and stereocilia - stopping the signal. If the continuous movement is then suddenly stopped, you would feel as though you were turning in the other direction as the endolymph fluid rushes out of the ampulla. This same 'stimulation' and 'inhibition' process is true for all coupled canals.

- **Linear acceleration** – The **otolith organs**, which lay inside the vestibule just between the semicircular canals and cochlea, are two fluid-filled pouches that help detect forward and backward movement, up and down movement, as well as gravitational force (where the head is with respect to gravity – sitting up, laying down, leaning back...). The vestibular labyrinth has two otolith organs: the **utricle** (responsible for detection in the horizontal plane) and the **saccule** (responsible for detection in the vertical plane). Calcium carbonate crystals called **otoconia** move and shift in response to horizontal movement in the utricle or vertical movement in the saccule. The shift of the otoconia crystals is detected by specialized sensory hair cells (stereocilia and kinocilium) inside the utricle and saccule.

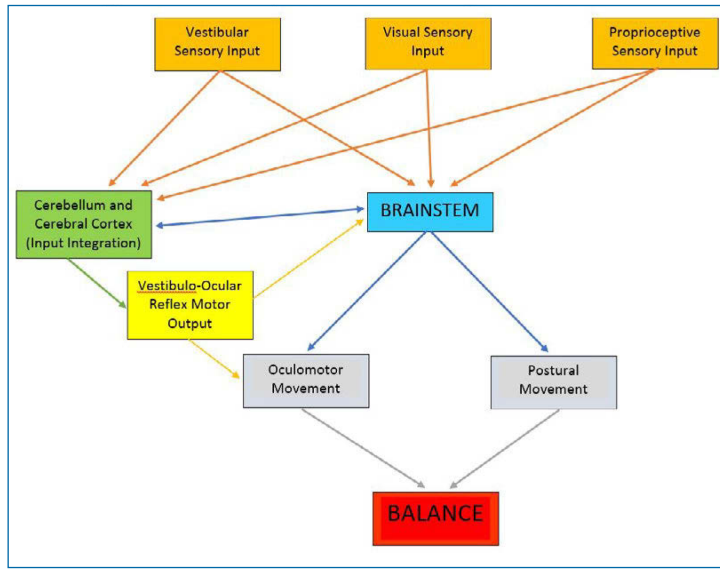

Figure 2. Sensory and Motor Integration for Balance

Information provided by the eyes, muscles, and joints is sent along with information from the vestibular system and is summated in the vestibular nuclei of the brainstem (Figure 2). The information is then analyzed and integrated with information sent to the brainstem from the cerebellum and cerebral cortex. The cerebellum sends information about learned movements which have become automatic through repetition (walking up stairs) while the cerebral cortex sends information about learned movements due to past experience (walking carefully when it is snowing because we know the ground is slippery and we may fall).[8-10]

The vestibulo-ocular reflex (VOR) keeps an image stable on the retina while the head is in motion (Figure 3). The VOR initiates eye movements in the opposite direction of

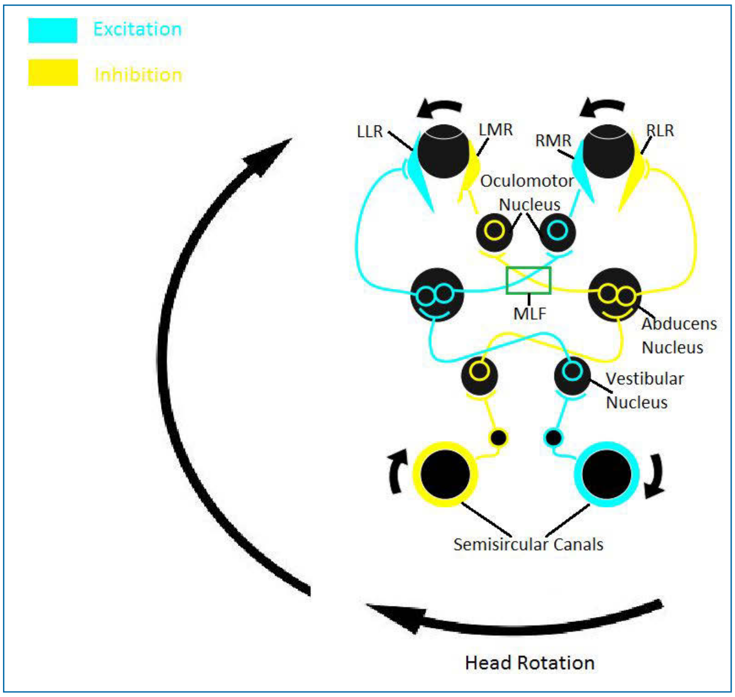

Figure 3: VOR to the LEFT during RIGHT head movement

Person turns head to the right -> excitatory signals from the right semicircular canal are sent through the right vestibular nerve to the right vestibular nuclei in the brainstem.

From the right vestibular nuclei, excitatory fibers leave the brainstem and cross to innervate the contralateral left abducens nucleus and go on to stimulate the left lateral rectus via the left abducens nerve (abducting the left eye). The excitatory fibers will also travel through the MLF and innervate the right oculomotor nerve which will then innervate the right medial rectus via the right oculomotor nerve (adducting the right eye).

Meahwhile, the inhibitory signals from the left semicircular canal are sent through to the left vestibular nuclei in the brainstem. Through the same pathway as above, they inhibit the right lateral rectus and left medial rectus.

As a result, both eyes will turn to the right while the head turns to the left.

head movement and prevents "retinal slip" of an image. There are horizontal, vertical and torsional components to the VOR. In the horizontal rotational VOR, the semicircular canals and otoliths become activated by head movement and send efferent information through the vestibular nerve (C.N 8) to the vestibular nuclei in the brainstem. After synapsing in the brainstem, fibers cross to the contralateral side and synapse in the contralateral abducens nucleus (C.N. 6). From the abducens nucleus, the fibers travel to (1) the contralateral lateral rectus via the abducens nerve and (2) project to the Medial Longitudinal Fasciculus (MLF) to synapse at the ipsilateral oculomotor nucleus (C.N. 3). From the oculomotor nucleus, the fibers go on to innervate the ipsilateral medial rectus muscle.[8-10]

The vestibular system continuously sends oculomotor control signals through the VOR. When the head is stationary, the number of impulses from the left and right vestibular system are equal. When the head is rotated, the number of impulses on that same side increase while there is a decrease of impulses or inhibition on the opposite side. For example, if a person rotates their head to the left, excitatory signals from the left semicircular canal are sent through the left vestibular nerve to the left vestibular nuclei in the brainstem. The fibers leave the brainstem and cross to innervate the contralateral right abducens nucleus and go on to stimulate the right lateral rectus via the right abducens nerve (abducting the right eye). They will also travel through the MLF and innervate the left oculomotor nerve which will then innervate the left medial rectus via the left oculomotor nerve (adducting the left eye). As a result, both eyes will turn to the right while the head turns to the left. The difference in the impulses sent from each side control eye movement to stabilize gaze and allow for stable viewing during head movement. Very similar pathways exist for the vertical and torsional VOR and involve the superior and inferior obliques and superior and inferior recti muscles.

If the head movement to the side is short lived, the direct VOR path is sufficient to keep the eyes pointing in the opposite direction of head movement. If the head stays turned, however, the eyes will drift back to the center since the direct VOR does not maintain the signal. In this case, a tonic input (from the prepositus hypoglossi (PPH) via the indirect pathway) is required (Figure 4). The PPH nucleus converts the short lasting phasic vestibular input from the VOR into a long lasting tonic signal for the extraocular muscles.

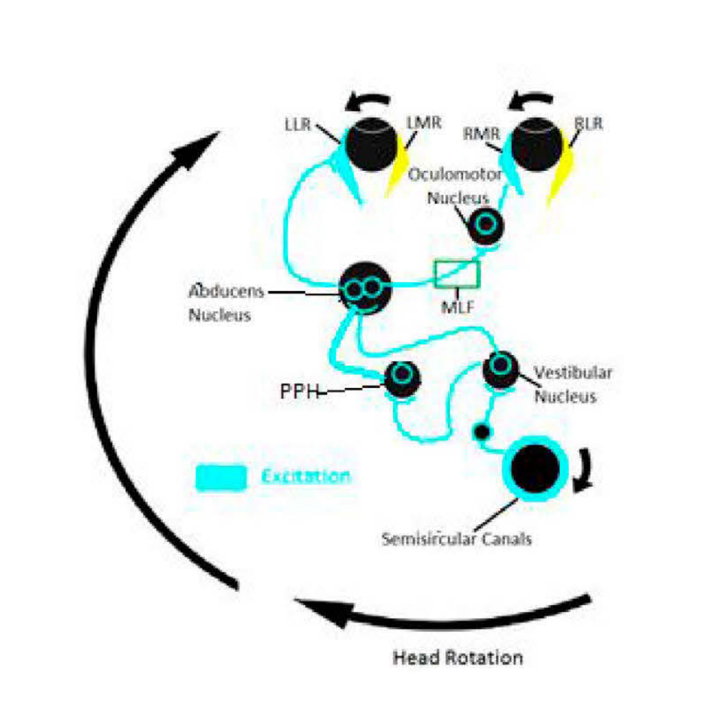

Figure 4. Tonic PPH pathway

As long as the head is turned and stays in the same location and the patient is fixating on a target, the pathway 'remembers' how far and at what angle the head is turned and stabilizes the eyes pointing in the opposite direction for stable fixation.

If a person starts to spin with their eyes closed, the cupula will initially move causing the stereocilia to send impulses to the brainstem. After prolonged rotation with stable velocity, the cupula gradually restores to its upright, stationary position and the stereocilia stop firing, and the VOR pathways stops as well. If they open their eyes at that instance, they will see that they are in fact moving (producing a disconnect between the vestibular and visual systems) and causing the sense of dizziness and nausea. The visual system can also drive the VOR and produce a sense of motion without any movement or vestibular drive via the optokinetic nystagmus (OKN). The OKN movements stabilize the eyes during tracking of a moving visual target which will cause an illusion and sensation of circular vection (feeling of motion when the body is stationary) in the opposite direction. If a person is stationary but something in their visual field moves, this will produce an optokinetic response and a false sense of motion.[8-10]

Any mismatch of information or conflict between the vestibular, visual and/or musculoskeletal proprioceptive systems will cause symptoms of dizziness, nausea, vertigo, motion sickness, double vision, and headaches. Visual motion hypersensitivity or motion sickness during transportation is a common symptom and occurs when the visual and vestibular systems are in conflict. If a person is in the cabin of a boat or reading in the car, the head/vestibular system feels the motion but the visual system does not see the world moving since it is concentrating on a stationary object. This disconnect is the cause of motion sickness during transportation and why looking at the horizon and seeing the world moving helps resolve them.[8-14]

Charles Darwin once wrote, "If it was not for sea-sickness, the whole world would be sailors." Depending on the type of vehicle, the prevalence of motion sickness ranges from 3-60% and the prevalence has increased since the creation of smartphones and tablets.[10-14] The car manufacturer, Citroën, is claiming to have developed the first glasses against motion sickness called LUNETTES SEETROËN (Figure 5).[15,16] We were unable to find any independent studies relating to the product and have not had any personal or anecdotal experience with the product, but it is important that the optometric community be aware of the products available to our patients.

The manufacturer claims that the new glasses are 95% effective in relieving motion sickness and online reviews have, so far, been positive. The "boarding ring technology" glasses consist of a central and peripheral round transparent frame that is half filled with a colored liquid. As a person looks at an immobile object in a moving car, the fluid moves around with the motion of the vehicle, providing a moving, virtual horizon in the

Figure 5. LUNETTES SEETROËN glasses[18]

peripheral visual field (in synch with the motion felt by the inner ear) in both the frontal (right / left) and sagittal (front / back) directions. As the colored liquid moves in the periphery, it re-creates an artificial moving horizon, re-synchronizing the senses and removing the disconnect between the auditory and visual systems. The glasses do not disrupt central vision and can be worn over prescription glasses.[15-17]

Citroën directs that the glasses should be put on at the first sign of motion sickness. They are to be worn for 10-12 minutes (until the auditory and visual systems resynchronize) and can be removed after symptoms have resolved to enjoy the rest of the trip without them. The glasses cannot be used on children under 10 years old, since the inner ear has not yet finished developing and should not be used in conjunction with anti-motion sickness drugs as they may negate the effects of the glasses. The glasses cost around $115 and may be ordered online at lifestyle.citroen.com. The company's product video can be viewed at https://youtu.be/CBqpTqc8Kpc.[19]

Given that motion sickness affects so many of our patients via the inability to ready or look at a smartphone while traveling, this product, though awkward in appearance and not yet independently verified, may prove to be quite useful in people's day to day commute. One can understand the mechanism when using this device on a smooth road with constant acceleration but it would be necessary to evaluate the effect on a vehicle with constantly changing direction and acceleration. Clinical testing of the device with people that experience visual motion hypersensitivity both during locomotion and during motion of the visual surroundings is warranted. On another note, vertigo and dizziness are a prominent complaint in many traumatic head injury and concussion patients. The pathogenesis for this differs vastly, but it would be interesting to evaluate the effect of this boarding ring technology in patients with traumatic brain injury who suffer from VMH.

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PERSPECTIVE

A Post Optic Neuritis World: Patient H69's Story

Vanessa Potter

Waiting to go on stage at the Guthy Jackson NMO (Neuromyelitis optica) conference in March 2018, held in the imposing ballroom at the Hilton LAX hotel, I was visibly trembling. This international patient day had been arranged to discuss the latest medical developments in the field of NMO. Also known as Devic's disease, NMO is a rare relapsing neurological autoimmune condition that commonly affects both the optic and transverse nerves, causing sight and mobility loss. It's also the disease I was diagnosed with after I woke up blind and paralysed one morning in 2012.

Even years after my recovery, I still had residual sight loss. To compensate for this I had surreptitiously mapped out my route onto the enormous stage during the morning's rehearsals. Mentally measuring the height of the steps (normal stair height) I scanned the surface and dimensions of the stage. It was covered with a white matte fabric that thankfully had no obvious shadows. However, looking helplessly over at the perspex lectern, set out for me to rest my notes on, I sighed. Perspex, really? Glass, Perspex, indeed anything transparent creates a kaleidoscope of problems for me. The reflections that bounce back off the surface often display a double or triple image. This means I often don't know where one objects starts or ends; or even what is real. Grimacing at the lectern, I conceded that I would be holding my notes that day.

I had been invited by The Guthy Jackson Charitable Foundation to talk about my NMO story and the book I published about my sight loss. The charity was established in 2008 By Victoria Jackson following her daughter's diagnosis with the illness. As an NMO patient I knew first hand the devastating effects this condition could have, yet I still considered myself one of the lucky ones. Sitting in the audience were a mixture of men and women in wheelchairs and in some cases, with well-behaved guide dogs at their sides. I could walk out on stage unaided, so I knew I was fortunate.

The moment I looked out at that sea of faces, I realized something that none of the eminent and expert doctors there could know. I knew what the people looking up at me saw. More importantly, I knew what they didn't see. The mishmash messed up visual landscape that we collectively inhabit is unique. We may know where we are, but we don't always recognise our environment. And, explaining that to eye-care specialists is one of the hardest challenges a patient has. We navigate intuitively, but with a conscious effort that normally-sighted people could not imagine. There is no obvious view, no visual picture that is taken for granted – it is all worked out and intimately mapped in a discreet, yet pragmatic manner.

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During the Q&A session after my talk a woman stumbled whilst trying to describe her vision to the room. As her voice trailed away I felt her frustration ripple across the room. Waving at the stage, I admitted my own careful planning earlier, describing how I'd mentally mapped my way onstage and how I'd blocked out the cacophony of irregular lines and colours around me. Pointing at a row of flags behind the stage, I explained these were a great example of visual overload. Those of us with reduced sight require flat, continuous tones and shapes, predictable lines and reliable surfaces to orientate ourselves. The flags were literally too much to take in; they were exhausting and overburdened my brain. But, the real elephant in the room was the carpet. Oh the carpet! We patients couldn't avoid that. Pointing at the whirling, swirling lilac and crimson maze that was like walking on a sea of serpents, my fellow patients erupted in united cheers. A visual hazard for all of us, we had all unconsciously navigated it.

The carpet may have caused error messages inside our brains, but we didn't talk about it. It was one of the few times in my life when for once, vision became a communal and shared experience. On the whole, seeing is a solitary act. We may stand in front of the same sunset or flowerbed, but how we place it into its environment, the depth of color, the detail, the feelings it imbues – is entirely personal. When vision goes wrong, it becomes even more difficult to explain. The very rules of seeing are rewritten. It is vision's very subjective nature and the difficulties patients have in describing it, that causes problems when identifying and treating visual disorders. In that one moment, it was these difficulties and the clever tactics that we had all employed to overcome them, that connected us.

Back in 2012 it took just three days for me to lose my sight completely. Optic neuritis is an inflammation of the optic nerve and can have a number of causes. It is commonly associated with Multiple Sclerosis and indeed with other autoimmune conditions, but it can also be caused by infection. The most identifiable symptoms are vision loss, in particular color loss and pain when moving the eyes. It also commonly only affects one eye, so as I experienced complete bilateral sight loss, it would appear I was not a common case.

Having suffered optic neuritis I know that my visual landscape has changed and that I have to engage with the outer world in new ways. One of my strategies is variety. My visual system is greedy; it wants stimulation, but stimulation in small doses. I walk different routes with my children to school, I avoid my vision becoming lazy and using old memory maps to navigate by. In the same way I read books on visual processing, I absorb new ways of seeing. Vision is habit. This is something you begin to realise once you have lost it. As humans we are routine based. We love regularity and our visual system is drawn to lines and predictable outcomes. It's good to mix up life, to throw in a challenge or an anomaly. In this way I throw in change for my visual system too. It is within the gaps of our knowledge that we grow – it's the very difficulties I encounter that translate eventually into resilience. We don't perhaps appreciate vision as a resilience tool, but it is. The more I see, the more I can do. And, that means the more I can get my children around too. The uncertainty that an optic neuritic episode can leave a patient with, can shrink their world very quickly.

As I write this article sitting in a South East London cafe, my daughter is at her drama class. My habit is to come and work for the three hours she is there. An old gentleman comes in every Saturday at 11am. Like clockwork, the staff put a reserved sign on his table (corner, by the window) as they know he will be there come rain or shine. He even has the same greeting – a short wave of his stick, a nod of the head. Such are our habits. I have to fight this desire for normalcy and sameness; I have to force my visual system to accept change. That could be driving down new streets, or making myself go to festivals. Curbs that blend seamlessly into the road, or cats that hide behind postboxes, I force myself to see it all. On high contrast sunny days, the black-and-white criss-cross shadows both dazzle my brain and illuminate the road. Grey misty days disguise the sidewalk, merging it into the road in front of me. The pedestrians, bikes and garbage bins. The discarded carpet I wasn't expecting to be sticking out. It is all of these incidental objects that help rebuild my processing ability and chip away at that fear.

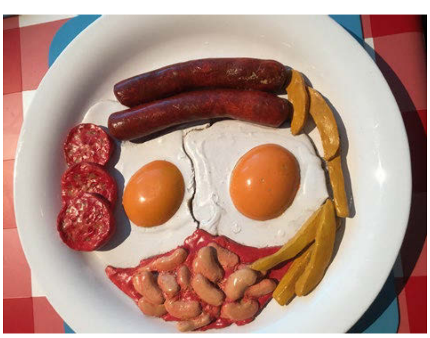
These days, I don't recall visual information in the way I used to. I have to adapt to not knowing where I have been and accepting I couldn't navigate my way back there again. Satellite navigation is my saviour. Visiting Saint Georges hospital in London for regular treatment a few years ago, I navigated not by the common visual cues, but by looking for Snappy Snaps and Barclays Bank. I knew that the street I needed was opposite these shops. I can't recall this route inside my mind now, nor can I fully visualise the shops in the way I could have done before. I have to follow these new rules of orientating every time I go. I no longer have a reliable internal mapping system. I can't conjure up the many landmarks, street names, houses and trees within a cohesive whole. My visual recall now is separate squares of information, a patchwork quilt of visual data, road signs, trees or traffic lights that I struggle to piece together.

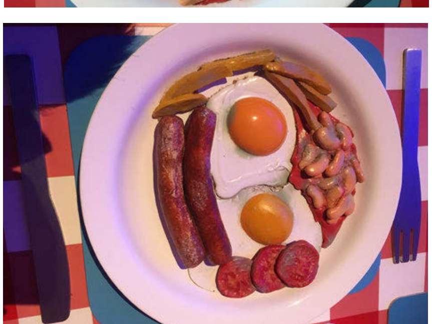
I have taken to photographing what I can't see – the gaping holes in my vision. I note when a step merges into the one below, or when I have to stare at an object in order to identify it. These photos show the glitches, the moments when my inner wiring comes loose and lets me down. It is by offering up the cracks in my perception, this faulty wiring, that allows insights into the life of a post-optic neuritis patient.

Sitting in my local cafe recently, a object in my peripheral vision caught my attention. Turning around, I stared at an orange shape that I could not identify as either a coat, small dog or bag. It turned out to be a plastic shopping bag, strangely inflated and not looking like a Sainsbury's shopping bag 'should look like'. I was aware that part of my identification process was waiting for it to move; or not.

When we were driving in LA, my husband saw a poster and commented on it. For a beat or two I had no idea what he was talking about. A Vampire movie? All I could read was 'Santa Clarita Diet'. How did he get Vampires from that? It was only when he shot me a quizzical look that I realised I hadn't seen the faces next to the text. I know why I didn't 'see' the faces of course. It was nothing to do with the size or clarity of the image, it was purely because that section of information was in a separate visual box. My brain had blended the faces with several bushy trees situated directly behind the poster (I took this image later on). The couple's faces were tonally the same as the foliage, meaning that on a contrast level, they were very similar. My brain likes nice high contrast and so zooms in on stark examples of this – like the letters, even though they are smaller and in some ways less visible than the faces. This is the nature of seeing the world like a fragmented jigsaw puzzle, and processing each piece individually.

At a local exhibition educating children on their sensory system, an exhibit illustrating the way our vision allows us to stay safe (in this case from mouldy food) I failed the test completely. I still cannot tell which plate of food has the mouldy food on it. These days my children are my mould police, squealing if the bread has gone green and Mummy is about to toast it.





On the whole, I hide my visual loss very well. Occasionally it catches me out, but even then I find humour or distraction can divert any long lasting effects. At my daughter's sports day recently she saw I was scanning the four hundred girls there, trying desperately to locate her. Seeing my invisible struggle, she rushed over, risking the wrath of her teacher. 'Mummy I'm under the second gazebo, I'll wave when I go back.' At age ten, she is now primed to spot my surreptitious scanning and my not-so-nonchalant orientating in unfamiliar situations. She knows I have missed her in swimming galas, even though I was trying to see her. Now she has strategies of her own. Photographing my son at her sports day I did a double take (and indeed do the same double take every time I see this picture) as his blue hood blends so much into the umbrella behind him that he becomes unidentifiable. I can only really make sense of this image because I know how and where (and the context) of where it was taken.

This is an all too common occurrence. Living with the residue of optic neuritis, I often find myself trying to manage these situations; often feigning absentmindedness, distraction or some other more acceptable reason for missing huge chunks of visual data. It was at the conference in LA that I realised for the first time that I am not alone in that.

49 year old Jeanette McCourt has lived in Arizona for the past 20 years, and suffers from NMO and the after effects of optic neuritis. In this image she took as a passenger in a car, she describes the lines in the road as floating up above the ground. She felt like she was wearing 3D glasses, except of course she wasn't. This visual phenomenon is explained using the SILO response. If some visual information such as contrast and context is reduced, then the brain can start to take visual cues from the eye muscles instead. This then overrides the limited available sensory data. In Jeanette's case, her brain assumed incorrectly and posed a view of the world that she knew must be inaccurate.

The side effects of poor contrast sensitivity and low color are many — and often affect my assumptions of what I believe I should see. Of course we all have innate assumptions that help construct our visual landscape, but those rules of seeing have changed for me, so in turn I have to adapt. I live with the knowledge that any complex environment will inevitably swamp my senses. Part of my coping strategy is first knowing my limitations, identifying the situations that are likely to cause me discomfort and telling those around me. It's easy for my family and friends to forget my visual loss, particularly when outwardly I appear so capable. Half of managing sight loss is not the impairment itself, but the people you find yourself with and environments you find yourself in.

Acknowledgements

Patient H69: The Story of my Second Sight, published by Bloomsbury, 2017.

https://amzn.to/2UNiTHH

https://guthyjacksonfoundation.org

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Before becoming a self-experimenting science communicator, Vanessa Potter spent 16 years as an award-winning broadcast producer working within the London advertising industry. In 2012 she lost her sight due a severe illness called Neuromyelitis Optica Spectrum Disorder. Following her recovery, she collaborated with neuroscientists at Cambridge University to design an interactive immersive exhibition, based on her therapeutic use of meditation, and gave a TEDx talk about her experiences in Ghent in 2016. She documented her blindness and recovery in her memoir, *Patient H69: The Story of My Second Sight*, which was published by Bloomsbury Sigma in 2017 and won *The Times* best memoir of 2017. She's the recipient of an Inspiring Woman award, and has written pieces for *Mosaic Science, The Telegraph and Marie-Claire*. Vanessa lives in South-East London with her husband and two children.

ARTICLE

Advanced Neuro-Optometric Diagnostic Tests for Mild Traumatic Brain Injury/Concussion: A Narrative Review, Proposed Techniques and Protocols

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ABSTRACT

A range of visual deficits and related visual symptoms are common in those afflicted with mild traumatic brain injury (mTBI/concussion). Several basic neuro-optometric, diagnostic test protocols have been proposed over the past decade. However, none have specifically addressed and focused upon an advanced level of care. Thus, a comprehensive set of advanced, diagnostic vision tests of a sensory and motor nature is proposed, with all having a clinical and scientific rationale. These tests have been used by the authors for many years, with good success and providing important clinical insights into this population.

INTRODUCTION

One of the newest and most exciting areas of optometry is the care of vision problems in patients with traumatic brain injury (TBI), especially of the mild type (mTBI/concussion)[1], including both diagnostic and therapeutic aspects (i.e., "neuro-optometry"). While the present paper will only focus on the former aspect, the related clinical ramifications of the latter are obvious and manifold.[1]

The conventional, optometric, diagnostic armamentarium for the medical condition of mTBI/concussion is ever growing, as new techniques and tests are being introduced (e.g., the Tannen test[2]), and older ones are being better understood and hence incorporated more frequently into patient care (e.g., binasal occlusion, yoked prisms).[1] This evolution is positive for the field of neuro-optometry.

There have been several basic clinical and laboratory diagnostic protocols proposed over the years.[3-5] These developments and other factors (e.g., the sports concussion crisis) have lead to tremendous growth in this area of brain injury within the neuro-optometric domain.[1]

One area of diagnostic, clinical vision testing that is still evolving and gradually being used more frequently is what may be considered "advanced" testing in mTBI/concussion. It is growing as technology advances, and as the procedures become automated, such as the case with hand-held, objective dynamic pupillometry.[6] Advanced diagnostic testing can be extremely beneficial, especially to the more experienced neuro-optometrist, and others, to provide better diagnostic capability, hence in turn leading to more targeted and efficacious therapeutic interventions[1]. While such "advanced" testing has been used for years in the non-TBI population, it still remains relatively infrequently used in those with mTBI/TBI.

Thus, the purpose of the present narrative review is to briefly discuss the area of vision problems in mTBI/concussion, and furthermore to propose a set of "advanced" diagnostic tests and procedures of a sensory and motor nature that can be employed by the neuro-optometrist and others. Incorporating these tests and protocols will broaden the diagnostic spectrum and improve clinical care for the visually-symptomatic patient with mTBI/concussion. This paper reflects the views and perspectives of the authors based on their years of clinical and research experience in the area.

Table 1: Advanced Diagnostic Sensory Tests

- electro-retinography
- optical coherence tomography
- b-scan ultrasound
- visual-evoked potential
- dark adaptation
- glare sensitivity
- intuitive colorimetry
- perceptual testing

There are several "advanced" diagnostic, sensory tests that may be beneficial in the mTBI/concussion population. The first four are objective in nature and assess processing in the early visual system pathways. In contrast, the other tests are of a subjective, psychophysical nature and assess the visual pathways over a range of relatively early and late processing levels.

The *electro-retinogram (ERG)* is an objective, quantitative technique that examines dynamic responsivity of the retinal elements.[7] Using the non-pattern "flash" ERG, the initial a-wave response reflects global photoreceptor activity, whereas the subsequent b-wave response reflects global bipolar and Mueller cell activity, with critical parameters being their amplitude and latency. In contrast, when using the "pattern" ERG, the response primarily reflects global ganglion cell activity. The pattern ERG is sensitive to retinal defocus effects, as well as age, in both cases reducing response amplitude. Thus, in the latter case with a patterned target, careful pre-testing refraction is mandated for the presence of clear retinal imagery. Fortunately, over the normal range of pupil diameters across all ages, there is no effect on the response. Since many with mTBI manifest retinal/optic nerve diseases in much greater proportion than found in the normal population,[8] such as glaucoma and optic nerve damage, the pattern ERG is probably the more important of the two approaches. Furthermore, the newer multifocal pattern ERG technology allows the clinician to assess small, "local" regions of the retina. For example, over 100 different areas throughout the central 50 degrees of the retina can be evaluated quantitatively and simultaneously following a single test presentation.[7] Only one study[9] used electro-retinography to assess retinal function in patients with mTBI (n=50). No abnormalities were uncovered. However, this may be due to using the flash versus pattern ERG. Further studies are thus warranted using conventional and multi-focal pattern ERGs in this population, especially where combined ocular injury and head trauma have been documented.

Optical coherence tomography (OCT) is an objective, non-invasive, rapid, direct, simple, and quantitative high resolution imaging technique to view the internal ocular structures, especially of the retina.[10] It uses the principle of low-coherence interferometry. The

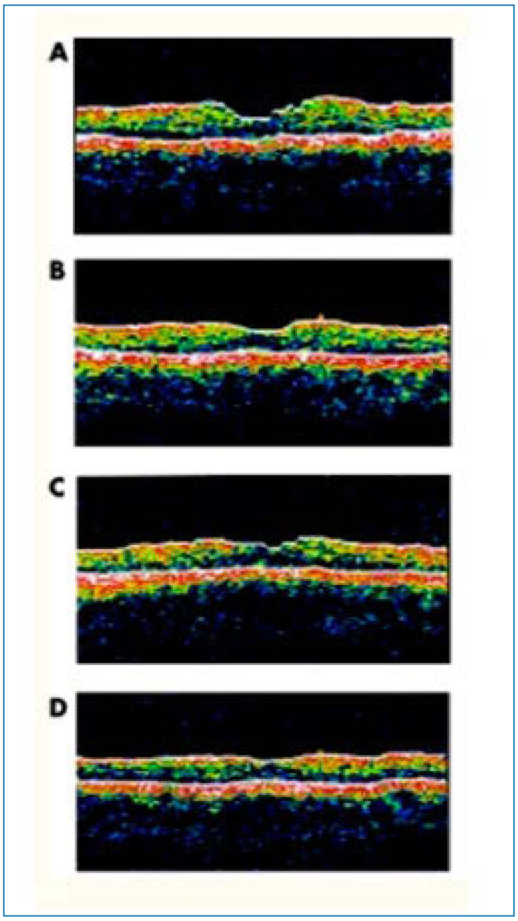

Figure 1: Optical coherence tomography scans on day 7 (A), 28 (B), 49 (C), and 77 (D) after injury. There is progressive thinning of the macular region.

technique provides a two-dimensional, cross-section of the globe (Figure 1). It has been helpful diagnostically in a variety of ocular conditions, such as glaucoma, macular edema, and rod and cone disturbances.[11] Individuals with mTBI/TBI have a high frequency of occurrence of such ocular problems,[8] as mentioned earlier, and thus the inclusion of OCT would likely prove beneficial in many cases. For example, it has been used to follow the progression of retrograde degeneration of the nerve fiber layer in blunt eye trauma,[12] which frequently occurs in conjunction with head trauma, to assess retinal dysfunction and the effect of its physical disruption.[13] Lastly, the OCT was proposed by us years ago as one of the key, "targeted", objective techniques to use in the diagnosis of ocular-based, vision problems in mTBI.[4]

B-scan ultrasonography is a non-invasive, rapid, and simple technique to visualize and examine the internal structures of the entire eye.[14] It provides a two-dimensional, cross-section of the globe. This is especially critical when such information is not available by other procedures/techniques, such as with the presence of a dense and large corneal or lenticular opacity. This technique employs high-frequency, ultrasound waves (e.g., 10 Mhz) that reflect, or "echo", off the internal structures of the eye (e.g., lens, retina). This information is then used to reconstruct a two-dimensional, ocular image of relatively high resolution. This technique is of particular relevance to the present paper for detection of vitreal (e.g., posterior vitreal detachment, vitreal hemorrhage), retinal (e.g., retinal tear, retinal detachment), and optic nerve (e.g., papilledema) problems, which are common in the general mTBI population,[8] and in fact occur with a much greater frequency than in the general population (5-10x greater), especially in our warfighters.[1] In fact, B-scan ultrasonography has been advocated for use in civilian survivors of improvised explosive devices (IEDs), where ocular (and head) injury is prevalent due to the extreme and rapid shockwave forces, as well as to the presence of flying debris.[15]

The visual-evoked potential (VEP) is an objective, quantitative technique that assesses globally the dynamic responsivity of the visual cortex over the central visual field.[16] Only the "pattern" VEP will be discussed, as it is most relevant to the mTBI/concussion population. Furthermore, it exhibits much less variability than the non-pattern, "flash" VEP, and hence is more useful in the clinic. Similar to the earlier pattern ERG discussion, careful refraction is mandated prior to testing to maximize responsivity, especially as regards to its amplitude. The pattern VEP has two main aspects to its waveform that are important clinically. The initial N1/P75 wave reflects general visual cortical responsivity, whereas the subsequent P1/P100 wave reflects activity of the dorsal striate visual cortex of the

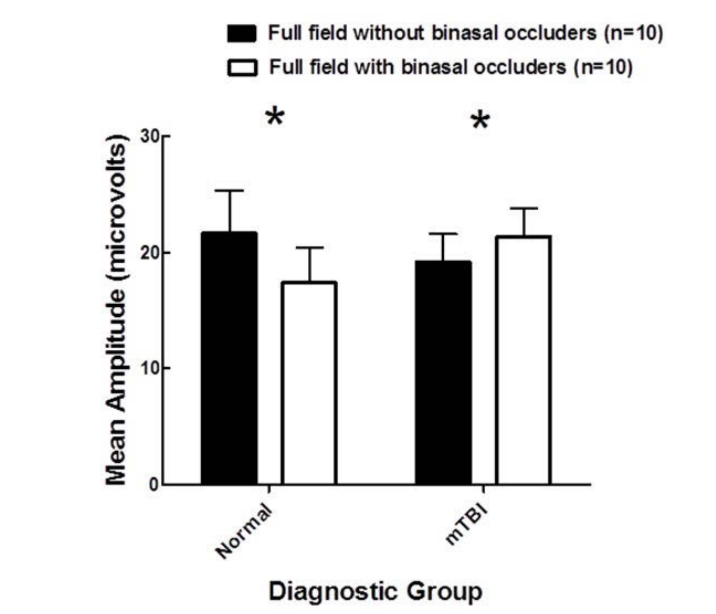

Figure 2: Group mean VEP amplitude as a function of test condition (with or without BNO) in normals and in those with mTBI and VMS.

middle occipital gyrus. The pattern-reversal VEP has been used in several recent studies in the mTBI population. First, an optimal stimulus and test protocol was developed.[17] It was found that the mean VEP amplitude of the mTBI population was smaller than found in the normal cohort. Then, two important, objectively-based, cortical, vision biomarkers were discovered. First, with marked reduction in mean test field luminance (~0.75 cd/m^2), the average latency in those with mTBI was consistently and significantly more delayed than found in the normal cohort.[18] Second, in those having mTBI and visual motion sensitivity (VMS),[19] the addition of binasal occluders (BNO) to the patient's spectacles produced a significant and consistent enhancement in amplitude as compared to the baseline VEP[19] (Figure 2). In an early study using the pattern VEP, abnormal and variable waveforms were found in approximately 75% of the mTBI clinical population.[9] Thus, the pattern VEP could prove invaluable to the neuro-optometrist, and others (e.g., the neuro-ophthalmologist), to document objectively the presence of mTBI/concussion with VMS, especially in those cases where the history and symptoms leading up to the referral are vague, unclear, and/or incomplete, for example as may be the case in a young child. Lastly, use of the newer multifocal VEP approach allows one to assess small, "local" regions of the patient's visual field and correlated visual cortex.[16] Thus, the combined use of a multifocal pattern ERG and VEP provides a detailed, quantitative "roadmap" of functional abnormalities in the early visual system neural pathways.

Dark adaptation refers to the eye's ability to detect progressively lower intensities of light over time, following a full bleaching of the retinal photopigments.[20] It reflects both cone (initial photopic) and rod (later scotopic) responsivity, with the rods exhibiting overall greater influence over the 30 or so minute test period. The total response exhibits a range of sensitivity of 7 or more log units in the typical normal case. It also exhibits a cortical influence, at least in mTBI.[20] This technique has been used to study macular problems and retinitis pigmentosa, and other retinal dysfunctions.[21] Most interestingly, it has been consistently found that many with mTBI (50-100%)[20,21] exhibited **elevated** visual thresholds; that is, they needed more light to detect the test stimulus than was found in normals. At first glance, this may seem to be paradoxical, since most of this population (50% or more) also exhibit photosensitivity.[22] It has been hypothesized that in this subset of photosensitive mTBI patients, a cortical adaptive gain mechanism is active, which effectively functions to attenuate all levels of light to, in turn, reduce the sensation of photosensitivity at *photopic* levels. Thus, an overall elevated threshold is present.[20] Such testing may help the clinician better understand light and dark adaptation/basic visual perception in this population. Furthermore, the results are consistent with the finding that approximately 50% of patients with mTBI and photosensitivity later exhibit some degree of neuro-perceptual gain adaptation, and thus report reduced photosensitivity over time (e.g., one year or more).[22] A hand-held device to measure dark adaptation exists for the clinician.[20]

Glare sensitivity refers to the adverse effect of scattered light on a visual task (e.g., visual acuity),[23] for example as found in some patients with cataracts but otherwise being normal. Light scatter reduces retinal-image contrast, thus resulting in a "washed-out" perceptual effect. There are two categories of glare:[23] (1) the "discomfort" variety in which a visual task is made slower, more difficult, or "taxing", but is not reduced in visual performance level (e.g., visual acuity remains constant), with addition of a glare source; and, (2) the "disability" variety in which addition of a glare source reduces visual performance (e.g., visual acuity decreases with glare). Unfortunately, the terms "glare" and "glare sensitivity" are frequently, and we and others believe incorrectly, used interchangeably with the common phenomenon of "photosensitivity/light sensitivity" in the mTBI population, and elsewhere.[24] So, is glare sensitivity *per se* really a problem in this subset of mTBI patients? Upon consultation with several experts and literature sources in the field, the answer is likely "not", or at least it is not very common, as a separate and distinct entity, assuming absence of cataracts or other media light scattering problems. However, both careful clinical testing and laboratory studies should be performed for clarification and insight. Clinically, testing is simple and direct.[23] Essentially, a standardized visual task, such as Snellen visual acuity, is assessed with and without a controlled glare source. Any substantial worsening of visual performance with the presence of glare would confirm the diagnosis of disability glare. A hand-held device is available for clinical testing (www.marco.com). Neurologically, discomfort glare in normals has recently been found to be associated with the cortical phenomenon of response "hyperexcitability" in three brain regions:[23] the cunei, lingual gyri, and superior parietal lobes. Interestingly, this increased hyper-type of brain response has also been documented in other possibly-related neurological conditions (e.g., migraine).[23] Further brain imaging studies are needed to disentangle this complex situation in both the normal and mTBI populations.

Colorimetry refers to a subjective, psychophysical approach used to quantify the influence of "color", using specific chromatic filters, on visual performance (e.g., reading) and visual comfort (e.g., reduction of photosensitivity).[24] It is believed that specific chromatic filters "balance" the magnocellular and parvocellular visual streams[24] and/or reduce the "hyperexcitability" of specific regions of the brain,[24] in many diagnostic groups (e.g., migrainers). It is well established that achromatic, neutral "gray" filters produce

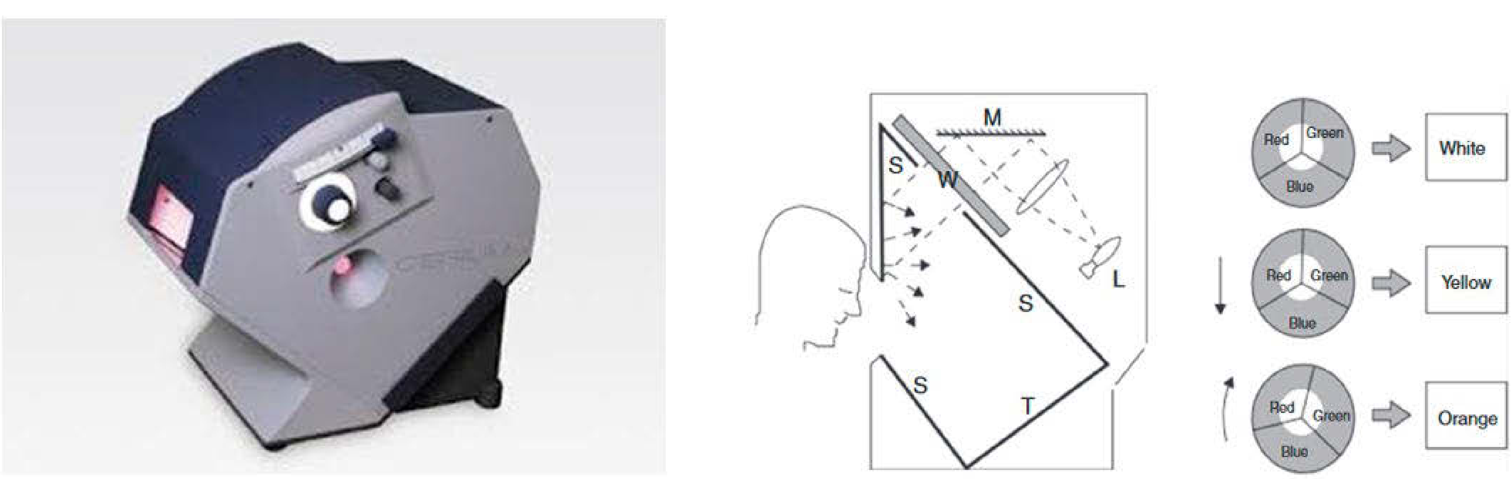

Figure 3: Intuitive Colorimeter. External view (left), internal view (middle), and schematic of some chromatic variations (right).

relief from photosensitivity in visually-normal individuals.[24] These same filters can also be beneficial in those with mTBI/concussion **and** photosensitivity, but specific chromatic filters may have even more dramatic relief[21,24,25] such as Omega-3 (purplish-red) and NL-41 (rose). While there are a range of diagnostic tests to assess for the presence of photosensitivity and to quantify its magnitude,[24] an intriguing development has been the Intuitive Colorimeter.[26] This device allows for a very precise, optimal chromatic tint to be found using independently-controlled variations in light hue, saturation, and brightness, while viewing and reading standardized texts (Figure 3). Use of the Intuitive Colorimeter and its prescribed tints has been found to decrease visual discomfort and enhance reading ability in some patients with mTBI/concussion.[24-26] Further detailed testing (e.g., a clinical trial) is warranted to demonstrate the instrument's diagnostic robustness in the mTBI/concussion population.

Perceptual testing refers to the assessment of the higher-level, neuro-sensory, visuo-perceptual aspects of the visual system.[27] It includes such areas as: visual discrimination, visual memory, spatial relations, form constancy, sequential memory, visual figure ground, and visual closure.[27-28] These are common areas of perceptual dysfunction in the mTBI population.[27] For example, an individual with a "figure-ground" deficit would have difficulty finding an object that is well above their detection visual threshold (i.e., visual acuity level) embedded in an array of objects. This might include locating a milk carton in the refrigerator or a pencil on a crowded desktop. A common test used by the neuro-optometrist, and others, is the Test of Visual Perceptual Skills (TVPS).[28] This is a topic deserving more attention in both the clinic and research laboratory. The underlying neurology is beyond the scope of the present paper.

There are several "advanced" diagnostic motor tests that may be beneficial in the mTBI/concussion population. All but one are objective in nature. These motor tests assess the visual pathways at several different processing levels.

Table 2: Advanced Diagnostic Motor Tests

- dynamic eye movements, accommodation, and pupil
- reading eye movements
- eye-hand/eye-foot reaction time
- dynamic posturography

Oculomotor and related systems refer to the two primary subcomponents of the global, eye movement neural network, namely the "near triad" and "version."[29] *First,* the near triad includes vergence, accommodation, and the pupil, which act in a synkinetic manner, and hence are grouped together here. For example, when bifixating from far-to-near, there occurs increased vergence to fuse, increased accommodation to focus, and decreased pupil diameter to assist focusing and enhance visual clarity. Thus, in effect, these three systems track, respond, and assist each other in this integrated, binocular, oculomotor task. Interestingly, their respective systems' responses in mTBI/concussion behave in a similar **abnormal** manner. That is, they are frequently smaller, slower, delayed, and more variable,[1] as compared to a normal cohort. For example, their respective response peak velocities are all reduced, at times by 50% or more, which is a very consistent finding (100% of the cases tested in our laboratory). Thus, the peak velocity parameter, and others, appear to serve as reliable, objective, vision-based biomarkers for the diagnosis of mTBI/concussion.[30] These three systems have been tested extensively, and the abnormalities well-documented, using objective measures in the laboratory over the past decade or so.[1] However, for the clinician, a hand-held, dynamic pupillometer exists.[6] It provides a simple, rapid (5 seconds), automated, quantitative analysis of the key diagnostic parameters crucial for mTBI/concussion[6] (Figure 4). *Second,* the versional (i.e., conjugate) component of the

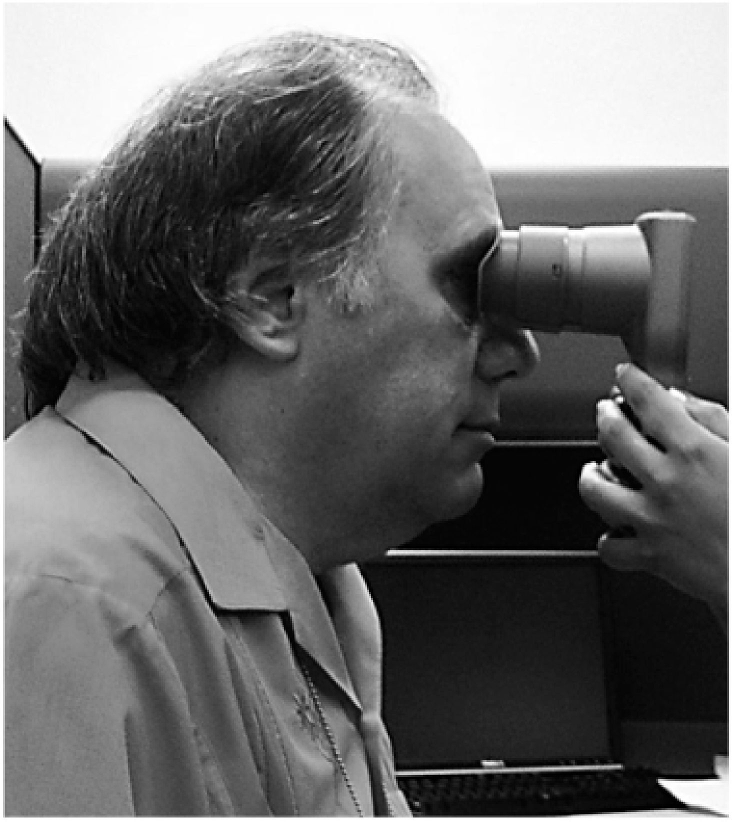

Figure 4: Subject (the first author) being tested with Neuroptics monocular pupillometer.

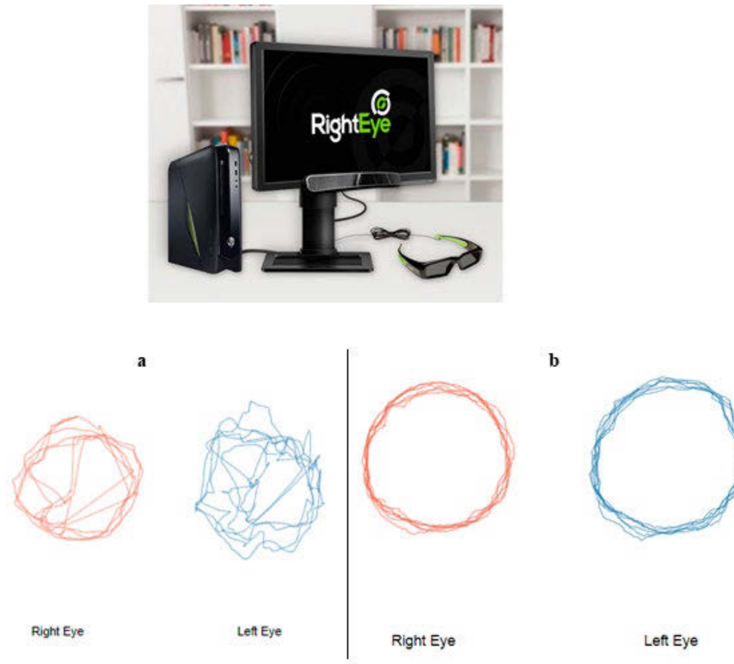

Figure 5: Circular pursuit eye movements recorded with the Right Eye two-dimensional video eye tracking system. (a) recording of circular pursuit after mTBI showing poor tracking quality; (b) recording of normal circular pursuit showing good tracking quality.

global oculomotor complex encompasses the fixational, saccadic, pursuit, vestibulo-ocular reflex (VOR), and optokinetic systems.[29] Only the first three are most relevant to the clinician in the present context. The fixational system allows for gaze maintenance; the saccadic system allows for rapid gaze changes such as occur during visual search and reading; and the pursuit system allows for smooth tracking of objects, with all three systems working in concert for optimal eye movement control and related visual information processing. In mTBI/concussion, versional oculomotor deficits are very common, perhaps occurring in 90% of the visually-symptomatic population.[31] Fixation is more variable by up to 200%, saccadic accuracy is reduced by 20% but with normal peak velocities, and pursuit accuracy is reduced by 20%, all as compared with normals. However, in contrast to the near triad dynamic parameters, none of the above, or other, abnormal versional parameters are specific for the mTBI/concussion population, and hence cannot serve as objective biomarkers for this diagnosis. These, and other, dynamic versional parameters have been studied extensively in the laboratory.[1] However, they can also be investigated and quantified by the clinician using a recent relatively easy, objective, automated binocular eye movement system[32] (Figure 5). The neurology of the near-triad and versional system is beyond the scope of the present paper.

Reading eye movements refer to the sequence, and dynamics, of the oculomotor system as one reads across a line of text.[29] Two primary eye movements are involved: (1) saccades rapidly (30-40 msec) alter gaze to the next word, while the fixational system pauses (250 msec total) to allow for text processing (75 msec), and subsequent saccadic positional processing (175 msec) to determine the next fixational position. In addition, there occurs very brief intrasaccadic divergence. It is of interest, and importance, that one of the most common visual symptoms in the mTBI/concussion population is "reading difficulty", typically of an oculomotor origin.[33,34] This does not seem unreasonable given the

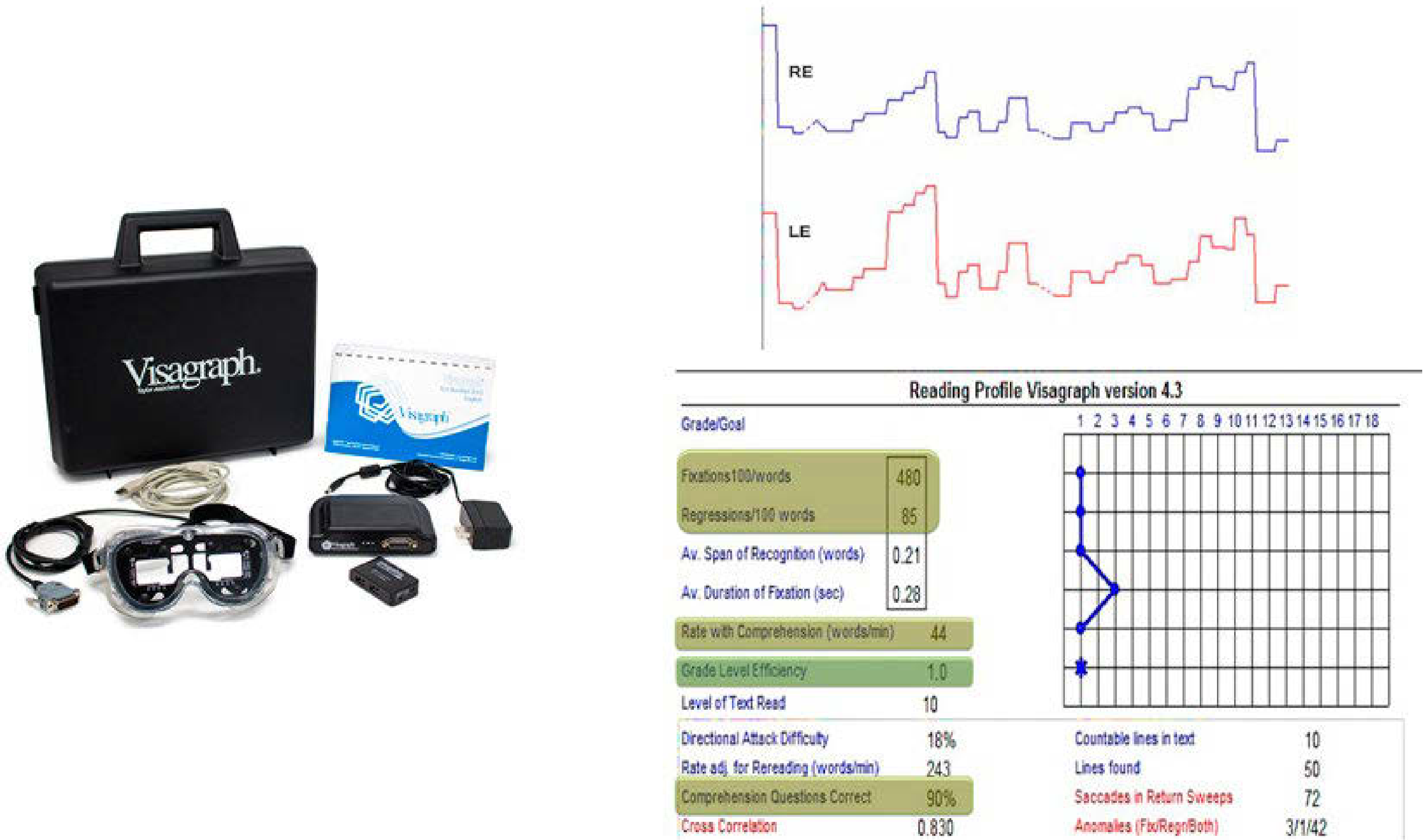

Figure 6: Visagraph reading eye movement system (left). Reading eye movements in an adult mTBI patient showing slow, poor quality eye tracking (upper right); plot of reading eye movement parameter values, with oculomotor control being at the first-grade level (lower right).

complex nature of the reading act, especially in the presence of abnormal eye movement control, accommodative deficits, impaired attention, cognitive difficulties, and more, all leading to "cognitive fatigue", frustration, and poor comprehension.[33] In the laboratory, these patients manifest a reduced reading rate, an increased frequency of saccadic eye movements, and a reduced grade-level reading performance.[34] Fortunately, for the clinician, a simple, rapid, binocular, automated, and quantitative reading eye movement system has been available for years (bernell.com) to assess reading ability objectively at different levels of graded text (Figure 6), as well as under different "task loads", such as with inclusion of external noises, visual distractions, time constraints, etc. We believe that such testing in this population is of great diagnostic importance, especially as related to academic success and job performance. The underlying neurology of reading is complex, including basic vision, language, attention, and cognitive processing, and more.[29]

Eye-hand/eye-foot reaction time refers to the overall, integrated, sensorimotor minimum response time to a randomly-presented sensory stimulus, such as to the onset of a simple light target.[35-37] The pre-motor (i.e., sensory) processing component is approximately twice as long as the subsequent motor component (e.g., 167 versus 77 msec, respectively), for eye-hand reaction time in normals,[35] with the combination being the overall reaction time. The eye-hand reaction time is approximately 40 msec shorter than the eye-foot reaction time,[37] likely being mechanical in nature, in normals (i.e., 280 versus 320 msec, respectively). Both reaction times are slightly longer in the mTBI population[37] by approximately 10 msec

Figure 7: Subject being tested using dynamic posturography.

on average; however, it can be up to 50 msec longer, with these delays occurring at the pre-motor level. This 10 msec delay likely causes no adverse vocational, sports, or driving effects. However, of interest, these delays can be up to 100-150 msec in the **moderate** TBI population,[37] which may bear adverse consequences. These reaction times have been assessed in the laboratory.[35-37] However, a system designed for the physical therapist is available to the optometrist, and others, that can be used with some practice.[36,37] The underlying neurology is beyond the scope of this paper.

Dynamic posturography is an objective, automated, quantitative, and relatively rapid approach to assess one's ability to maintain stable stance under a range of controlled conditions available to the clinician (e.g., www.biodex.com)[38] (Figure 7). The various test conditions quantify the influence of vision, vestibular, and/or proprioception on the patient's overall balance/body sway. For example, with some systems, the effect of imposed Gibsonian "optic flow" simulating

Figure 8: Depiction of Gibsonian optic flow while moving down a supermarket aisle.

natural visual motion, for example, on a highway or in the supermarket aisle (i.e., "supermarket syndrome")[39] (Figure 8), can be assessed. This is especially important in those with mTBI reporting symptoms (e.g, instability, disequilibrium) of visual motion sensitivity (VMS) (~40%)[1] in their normal environment. Moreover, this technique can be used to quantify the effect of binasal occluders (BNO) on balance and ambulation in these same patients, thus functioning as an additional diagnostic test in concert with the aforementioned VEP.[19] Lastly, this approach may also be beneficial in those mTBI patients reporting general vestibular problems (~80%),[1] especially in the absence of VMS per se. However, since such balance deficits are not unique to mTBI/concussion, this approach cannot provide objective biomarkers for this specific diagnosis. Systems for more sophisticated gait analysis are available to the clinician (e.g., tekscan.com). The underlying neurology is beyond the scope of the present paper, although the analysis of optic flow per se is believed to be performed by newly-discovered cortical areas V6/6a.[40]

Table 3: Additional Possible Diagnostic Sensory and Motor Tests

- rod and frame spatial orientation
- anti-saccade test

Rod-and-frame test assesses the visual perception of spatial orientation verticality in an orientation-biased visual environment.[41] In essence, the goal is to determine if an individual is "field-dependent" or "field-independent". The subject sits partially within an enclosure that can be rotated either clockwise or counterclockwise with respect to true, or objective, vertical. In addition, a rotatable rod is present in the visual field (Figure 9). The goal is to ascertain the influence, if any, of the orientation of the surround visual field (i.e., the enclosure) on the subject's setting of the perceived vertical orientation of the rod. If the surround frame exerts an influence, the person is categorized as being "field dependent", and vice versa. Many patients with mTBI report "spatial disorientation" and related symptoms (e.g., "balance" problems, postural instability).[1,39,40] This test might prove beneficial in the diagnosis of one's "susceptibilty" to the surround visual field, such as when the head is tilted or when many non-vertical contours are present in the visual field. It may also be predictive of one's sensitivity to visual motion in the field (i.e., VMS). While the conventional rod-and-frame test per se has not been used much in the brain injury population, a virtual reality rod-and-frame type test room has been employed to assess the effect of its orientation on objective balance scores in concussion patients in their acute phase.[42,43] Their ability to remain stable was impaired when compared to normals. A clinical test system could be developed within an Oculus Virtual Reality System. The neurology underlying the rod-and-frame test is complex. It incorporates the basic vision, vestibular, and proprioceptive systems, as well as higher-level visual perceptual aspects (e.g., spatial orientation), cognitive style, and sensory/motor cue integration, and more.[41]

Anti-saccade test refers to assessment of the cognitive branch of the saccadic system employing a Stroop-like approach.[44] The goal is to determine the individual's ability to saccade in the direction *opposite* to the target displacement. That is, if the target rapidly shifts to the right, the **initial** saccade must be executed to the left without much additional delay. This is a difficult task, as one must first inhibit/suppress the initial reflexive saccadic motor program, and then reprogram the saccade's direction, which occurs at a high-level of brain execution. Patients with mTBI exhibit an increased response latency and/or more initial directional errors than found in the normal population. This could be tested by the clinician using a three-target hand-held system (i.e., left, center, and right). This oculomotor deficit is believed to involve the prefrontal cortex.[44]

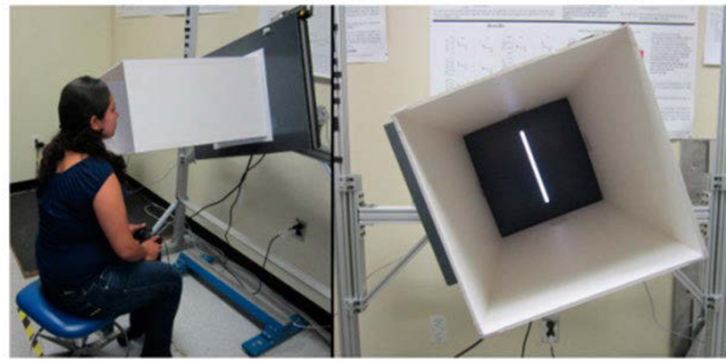

Figure 9: Rod-and-frame device. Subject being tested (left); device in rotated position showing internal aspects of the test enclosure and adjustable test rod (right).

CONCLUSIONS

A broad range of advanced level, sensory and motor, diagnostic tests has been proposed for the patient with mTBI/concussion. It is believed that incorporation of some, or all, of these tests will assist the neuro-optometrist and others in their final and more comprehensive diagnosis, with positive therapeutic ramifications and visual benefit. And, if the present "advanced" level tests are used in combination with an earlier proposed set of more "basic" level diagnostic tests,[45] then the neuro-optometrist would have accessible a wide armamentarium to help the visually-symptomatic patient with mTBI/concussion attain their vocational and avocational goals, and thus improve their quality of life.

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Kenneth J. Ciuffreda received his B.S in biology from Seton Hall University in 1969, his O.D. from the Massachusetts College of Optometry in 1973, and his Ph.D. degree in physiological optics from the University of California/School Optometry at Berkeley in 1977. He has been a faculty member at the SUNY/State College of Optometry in New York City since 1979, where he is presently a Distinguished Teaching Professor. He has also had adjunct appointments for many years at Rutgers/The State University of New Jersey, as well as at the New Jersey Institute of Technology, both in the department of biomedical engineering. He also helped establish a school of optometry in Harbin, China. He has conducted research in many areas: amblyopia, strabismus, reading, myopia, eye movements, accommodation, bioengineering applications to optometry, and more recently with an emphasis in the area of acquired brain injury, both the diagnostic and therapeutic aspects. His goal has been the use of objective recording techniques in the diagnosis and treatment of neurological and ocular conditions. He holds two patents, and has received many awards and honors from the AAO, AOA, NORA, COVD, and various state optometric associations and colleges. He has authored over 400 research papers/chapters, and 10 books. His hobbies are playing jazz guitar and enjoying the visual aspects of art.

ARTICLE

An Investigation of the Druid® Smartphone/Tablet App as a Rapid Screening Assessment for Cognitive and Psychomotor Impairment Associated with Alcohol Intoxication

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ABSTRACT

Background

Neuropsychological tests have been used for years to determine impairments in cognitive and motor functions. There have been increases in impairment related to the abuse of alcohol and/or drugs related to driving. Recently, there has been an increased use of the Smartphone/Tablet applications for neurocognitive impairment testing. The DRUID® test is intended to identify and measure impairment from alcohol and various drugs by measuring changes in divided attention, decision making, reaction time, motor tracking, and balance movements control.

We investigated the application of The DRUID® test as a potential rapid screening for cognitive and psychomotor impairment as a function of specific levels of alcohol that are known to have an effect on driving and job performance.

Methods

There were 48 volunteer drinkers, (Mean age 30[5.36])19 females -29 males who were administered a two minute DRUID® test pre and post drinking alcohol in a controlled dosage setting. Breath testing for alcohol was performed confirming absence of alcohol (Pre DRUDI®) and the when dosing exceeded the legal intoxication level for alcohol in Massachusetts (Blood Alcohol Content BAC 0.08%).

Results

DRUID® post drinking scores were significantly higher (worse) than DRUID® pre drinking. Higher scores on the BAC and DRUID® correspond to higher intoxication and associated impairment. There were no significant differences by gender for any of the central variables. A repeated measures t-test comparing DRUID® pre and post alcohol BAC scores revealed a highly significant ($t_{(47)} = 34.5$, $p < .0001$), difference in pre- and post DRUID® scores ($t_{(47)} = 8.68$, $p < .0001$).

Conclusions

The DRUID® test is a compelling and useful Smartphone/Tablet based candidate as a rapid screening test for identifying cognitive and psychomotor impairment associated with the intoxication level of alcohol and effects on driving.

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Keywords: alcohol impairment, driving skills, psychomotor impairment, smartphone apps, traffic safety

INTRODUCTION:

There are millions of people in the United States who will become impaired and/or disabled, annually either partially or permanently, from multiple causes. The effects may be mild to severe and range widely in nature across all ages. Such causes often include impairment from accidental/unintentional injuries, cognitive/mental changes, and from neurological and cardiovascular events.[1] In the quest to identify, diagnose and plan treatment for such impairments there is a continual need for appropriate assessment tools. In many of these cases, there is a need for neurologic and cognitive functioning testing. The aim of neurological and cognitive performance testing is detection of possible impairment in many areas of cortical functioning.[2]

This testing has a primary task to determine a decreased ability to perform basic screening skills as well as complex neurological and psychomotor tasks.

Two fundamental areas that have seen increases in neurological and cognitive impairment are the abuse of alcohol and/or drugs related to driving[3-5] and traumatic brain injuries.[6-10]

A range of neuropsychological tests have been used for years to measure and determine impairments in cognitive and motor functions. Often, specific neuropsychological and cognitive functions are known to be linked to a particular cortical structure or pathway related to the observed impairment.

Traditionally, neuropsychological assessment relied on time consuming paper and pencil based tests to assess cognitive abilities, and studies conducted with these tests have generated thousands of scholarly articles promoting their strengths and debating their weaknesses.

In the past several decades, neuropsychological assessment has undergone substantial growth and improvement in the evaluation in the abuse of alcohol and/or drugs related to driving and traumatic brain injury.[11]

These clinically helpful evaluations often are quite time consuming, costly, and may lead in delays for treatment in many situations. Lack of early identification of possible neurologic and/ or cognitive impairments can appreciably delay diagnosis and appropriate treatment and can affect the individual's quality of life.[11]

More recently, increasing numbers of researchers and clinicians have started to apply various technologies to improve the efficiency, reliability, and cost-effectiveness of neuropsychological assessment. Rapid advances in technology, including improved computer programming, have allowed many assessment measures to even be administered, scored, or interpreted without the direct interaction of a clinician.[12]

There remain numerous questions and challenges to better support measurement tools and convert these findings into meaningful recommendations and treatments. Computerized neurocognitive tests have several advantages since they can be administered relatively quickly and do not require a clinician's presence or time. They can be adapted to a specific clinical issue, e.g., traumatic brain injury, concussion, mild cognitive impairment, drug abuse impairment, and are often self-scoring and produce a report briefly after the test is finished. Another benefit is the use of the computerized test results for in quicker or more efficient decision making as the data can be stored and easily accessible for ongoing comparison of previous results. With the advent of smartphones and tablet based applications, there is an increased growth of more rapid, diverse, and accurate assessment of neuro–cognitive impairment.

With this technology change, there has been an increase in use of the smartphone and Tablet applications for neurocognitive impairment in numerous conditions e.g., hearing and vision loss, addiction, neurological diseases, mental illness, brain injury /concussion, and alcohol and drug impairment.[13-18] It allows people to use some of the newer Internet-based tests at home, using a tablet or a smartphone, for screening for impairment and monitoring treatment.

Abuse and adverse effects of alcohol and its impact on driving continues to be a national concern causing multiple injuries and impairment. The role of alcohol in affecting neurological and cognitive functions and a person's the ability to safely operate a motor vehicle has been fully documented and acknowledged.[20]

Over the years, there have been numerous studies related to alcohol impairment. These have ranged from the examination of simple sensory, perceptual, and motor behaviors to more complex measures of cognitive functioning, such as divided attention and mental workload.[19]

Computer based tests of neurocognitive performance were used to test subjects under the influence of alcohol and a battery of mental tests and standardized roadside field sobriety tests. The abilities evaluated and included were divided attention, focused selective attention, reaction time, balance, critical visual tracking, and visual motor control. These are identified as sensitive functional biomarkers i.e., a characteristic of a physiological and/or psychological ability that is objectively measured and evaluated as an indicator of pharmacological responses. Numerous studies[21,24-26] demonstrated that these select cognitive abilities were very good predictors of impaired performance relative to changes in alcohol concentration.

Impaired driving deterrence from alcohol abuse remains a major priority of law enforcement and industry fitness for work programs nationwide.[27-29]

Unfortunately, the recognized cognitive and psychomotor tests used in clinic or laboratory settings to assess alcohol impairment are not readily applicable for use by of law enforcement and industry in the field.

At present, the most widespread suitable and reliable field test method used by law enforcement to determine if a driver exhibits brief behavioral and physical signs of alcohol impairment is the Standardized Field Sobriety Test (SFST).[30] During these SFST procedures, the officers require a subject to listen and follow instructions while performing simple physical movements. Impaired persons have difficulty with tasks requiring their attention be divided between simple mental and physical tasks.

In the United States, Blood Alcohol Concentration (BAC) refers to the percent of alcohol (ethyl alcohol or ethanol) in a person's blood stream. Legal impairment of driving under the influence of alcohol is applicable when a BAC level of 0.08% or higher is determined to be present . Officers trained to conduct SFSTs, were able to correctly identify alcohol-impaired drivers over 90% of the time who had BAC levels above the legal limit of 0.08%. However, in plenty of these cases, the BAC is often discovered to be well above the 0.08% level allowing for more obvious identification of impairment on the SFST.[30-31] The SFST may not be sufficiently sensitive to observe impairment behavior to lower BAC levels or causes other than alcohol, e.g., cannabis.[32]

Other studies have reported impairment from alcohol not be uniform across different areas of cognitive processing and that both the size of the alcohol effect and the extent of effect change across different dose levels, Low and moderate doses of alcohol may not compromise cognitive ability in non-problem drinkers under certain task conditions nor yet be evident in SFST results.[33-34]

Though the use of computer based tests of cognitive and psychomotor functions to measure impairment related to alcohol is quite valid and possibly more sensitive to impairment, it is unfortunately not practical for use in the field at this time. Conceivably, the potential use of Smartphones and/or tablet based applications, e.g., iPads, for detecting impairment from alcohol intoxication, as well as other drugs, may offer be a supplemental, practical, accurate, and efficient method to measure cognitive and psychomotor impairment.

In this study, we investigated the application of a rapid Smartphone/Tablet based test protocol ability to identify cognitive and psychomotor impairment as a function of specific levels of alcohol that are known to have an effect on driving and job performance. The DRUID® app[16] is such a new Smartphone/Tablet application. The DRUID® test is designed to identify and measure impairment from alcohol and various drugs by measuring changes in divided attention, decision making, reaction time, motor tracking, and balance movements control. Using this method, we sought to determine if subjects differed in their performance in DRUID® scores from a baseline sober condition with an intoxicated condition where the alcohol level was considered to be legally above the level for safe driving. Further examination would be carried out to determine if there was a significant difference and correlation between pre and post alcohol levels and the DRUID® app scores.

METHODS

Alcohol Impairment Workshops

In order to obtain alcohol drinking subjects for this study, we obtained permission to use data acquired in testing alcohol workshop subjects as part of the training of police recruits during the Standardized Field Sobriety Test (SFST) 3-day program established by the International Association of Chiefs of Police and the National Highway traffic and Safety Administration.[30] These alcohol workshops were located at two police academies in Massachusetts operated under the administration of the Municipal Police Training Committee (MPTC).[35] The MPTC is responsible for establishing training standards for and delivering police training in Massachusetts. They follow and incorporate the national protocols established by the International Association of Chiefs of Police and the National Highway traffic and Safety Administration.[30] These sessions recruit and use volunteers to drink measured doses of alcoholic beverages under controlled conditions usually for about 4 hours. Blood alcohol concentration (BAC), also known as blood alcohol level, is measured on a breath testing device. BAC is commonly reported as a percentage of alcohol weight per volume of blood. Each subject is dosed with alcohol at established intervals and their blood alcohol content (BAC) is carefully monitored throughout the workshop by certified Massachusetts Municipal Police Training Committee instructors. Certified Standardized Field Sobriety instructors performed measurements using the Drager Alcotest 6510 instrument, a breath-based alcohol testing device. The Draeger 6510 is a Breathalyzer used widely by the Police around the world to measure Breath Alcohol Content (BAC) at an accuracy of ± 0.005%BAC at 0.100%BAC (Figure 1).[36]

Figure 1. Drager Alcotest 6510 Portable Breath Tester

Baseline breath alcohol test evaluations confirming the absence of alcohol were performed at the beginning of the workshop, before the subject's first drink using a calibrated Drager Alcotest 6510 Portable Breath tester. When dosing reached or exceeded the legal impairment level of alcohol as defined by the legal limit or Massachusetts (BAC 0.08%), drinking was suspended and a final BAC level was recorded.

Subjects

Forty-eight volunteer drinkers, 19 females and 29 males, participated in the study. Subjects were recruited from police academy resources. Each subject signed an informed consent form[a] explaining the purpose of this workshop to assist in training police officers to recognize persons impaired by alcohol or drugs.

They were encouraged to ask any questions and could refuse at any time to participate. Subjects were recruited solely on the basis of their availability, and not on their age, gender, weight, or ethnicity. All subjects were of legal drinking age. None of the subjects reported fatigue, presence of any health conditions, or use of any medications that excluded participation in the study.[30] Subject demographic data are summarized in Table 1.

Table 1. Characteristics of Subjects[a]

Participants N=48	
Mean Age (yrs)	30.00 (5.36)
Age Range (yrs)	21-40
Male, N, (%)	(n=29) 60%
Female N, (%)	(n=19) 40%

DRUID® Tasks and Testing Procedures

DRUID® is an application designed to capture measures of cognitive and motor impairment in divided attention, decision making, reaction time, motor tracking, and balance movements, following the intake of drugs such as alcohol or cannabis.[16] DRUID® testing consist of four tasks to measure cognitive and psychomotor performance. The tasks were consistent with those identified in research on the effects of alcohol and driving impairment.[19,21,37]

Specifically, the DRUID® tasks are:

Task 1—Reaction Time/Decision Making

Shapes flash on the screen for ½ second, either a square or a circle, one shape being the Target-shape and the other being the Control-shape. The user is instructed to touch the screen where the Target shape appeared, and to touch the oval shape at the top of the screen when the Control-shape appears. Users must first make a decision about what type of shape appeared (square or circle) and perform a different action (where to touch the screen) depending on that decision. DRUID® measures reaction time in touching the screen, and errors in choosing the correct action based on each stimulus shape. DRUID® Task 1 is shown in Figure 2.

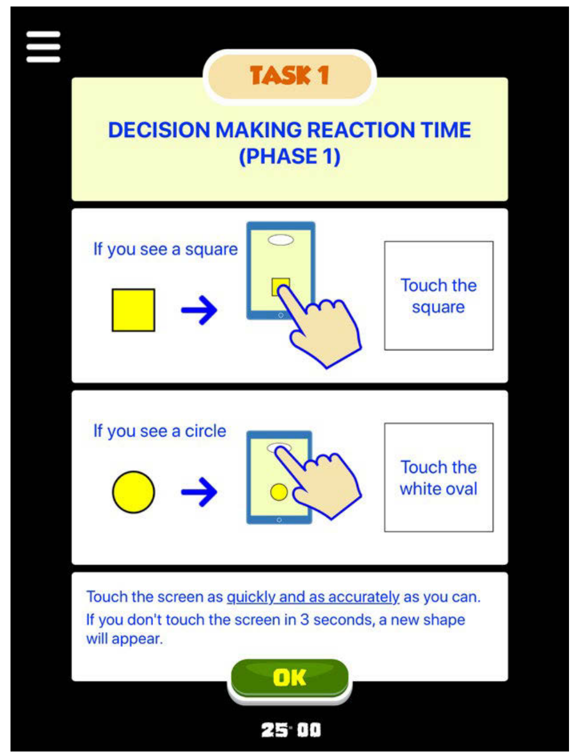

Figure 2. Task 1—Decision Making Reaction Time

Task 2—Reaction Time

This task requires users to press a "START" button to begin internally counting for a minute and to press a "STOP" button when they estimate 30 seconds has passed. In addition, circles are flashed on the screen for ½ second, and the user is required to touch the screen where they appeared. Users thus need to count time passing as well as reacting to stimuli on the screen, a Divided Attention Test (DAT). DRUID® Task 2 is shown in Figure 3.

a The standard informed consent form for alcohol workshops approved by the Massachusetts Municipal Police Training Committee is available upon request.

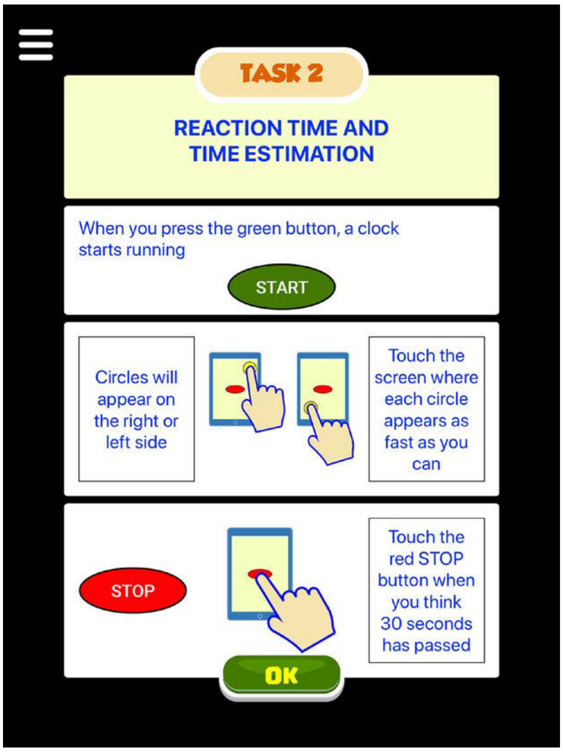

Figure 3. Task 2 – Reaction Time

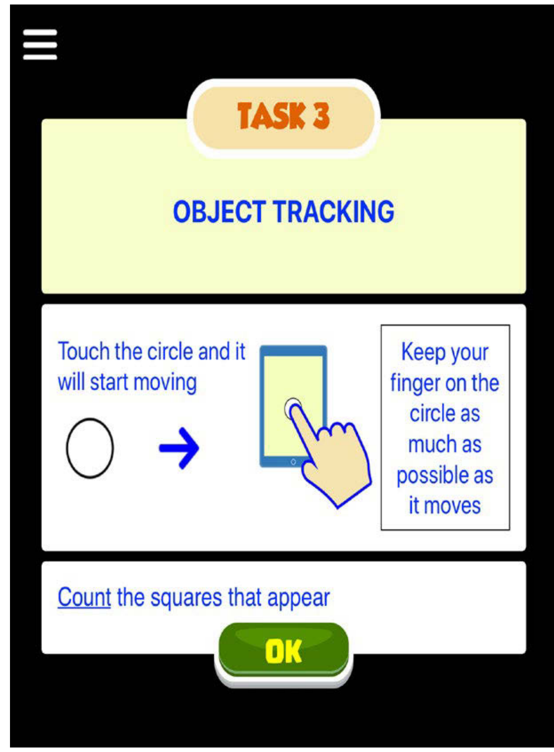

Figure 4. Task 3 – Motor Tracking

Task 3 — Motor Tracking

This task presents a circle that moves around the screen, sometimes jumping a distance, and the user is required to keep their finger on the circle as much as they can. In addition to keeping track of the moving circle, users are required to count the number of squares that flash on the screen for ½ second, incorporating a DAT. DRUID® Task 3 Object Motor Tracking Directions screen is shown in Figure 4.

Task 4 — Balance

DRUID® uses the accelerometer to test stability and balance performance. Users are instructed to stand on their right leg for 15 seconds, holding the device in their opposite hand, trying to keep the device as still as possible, then to switch the device to the opposite hand and stand on the left leg for 15 seconds. DRUID® Task 4 Balance Directions screen is shown in Figure 5.

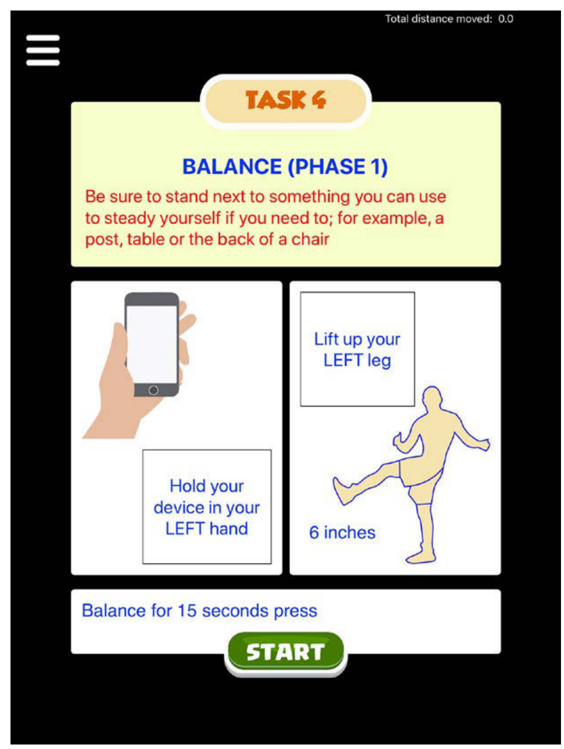

Figure 5. Task 4 – Balance

DRUID® Test Protocol and Output

The DRUID® tasks requires approximately two minutes to complete following the instructional phase. The testing was performed on iPad Tablets with the DRUID® Research application installed and administered by independent examiners from the DRUIDapp, Inc. Each subject is assigned an identification number to protect identity. All the data from the testing is transmitted for analysis via Wi-Fi using the algorithm by the DRUID® designer. There is a pre-test practice trial period for each of the four tasks to ensure the subject understands the test and becomes familiar with the iPad tablet.

The DRUID® Baseline evaluations were performed after the initial breath testing and before the subject's first drink. Once drinking commenced and the blood alcohol levels (BAC) increased to be above a 0.08% BAC, the DRUID® procedures were administered again.

DRUID® Output

For each of the four tasks, subject response data was collected. The specific measures were each DRUID® were as follow:

- Task 1, Reaction Time/Decision Making, there are three measures of the data output. These are Average Reaction Time, Average Error Distance (in inches), and Percentage of wrong shapes selected.
- Task 2, Reaction Time, there are four measures of the data output. These are average Error Distance (inches), number of errors counted, average reaction time (seconds), and difference in time from 30 seconds.
- Task 3, the Motor Tracking, there are two measures. These are the percentage of time the finger is not on the moving circle target and error count in counting squares.
- Task 4 Balance, there are two measures. These are in inches of sway for movement while standing on left leg and inches of sway for movement while standing on right leg.

Each of the tasks will have an output to a screen of the responses following each assessment. At the conclusion of the testing, the DRUID® app integrates hundreds of data points into a smaller set of variables which is transmitted for analysis via Wi-Fi to the DRUID® designer. An algorithm then integrates these variables into an overall measure score of impairment, using a formula based on analyses of all the data collected. Impairment scores range from 0-100, and generally range between 30-70. The pre and post alcohol drinking scores were then made available to the investigators for analysis.

RESULTS

A statistical analysis was performed using the SPSS v19 statistics package on the data from the study. Characteristics of the subjects for the study sample (n = 48) were displayed in Table 1.

Summary statistics for the major variables in the study (pre/post Blood Alcohol Content (BAC) and pre/post DRUID® scores are presented in Table 2.

Higher (more errors) scores on the BAC and DRUID® represent higher intoxication and associated impairment. There were no

Table 2. BAC and DRUID® Total Impairment Scores

	All Participants (n=47)	Males (n=28)	Females (n=19)
BAC, pre-alcohol % Mean [SD]/Median	0.00[0]/0.00	0.00[0]/0.00	0.00[0]/0.00
BAC, post-alcohol % Mean[SD]/ Median $t_{(47)}$ = .82, *n.s.*	0.113[.023]/0.111	0.111 [.025]/.107	0.117[.020]/0.111
BAC post-alcohol BAC % range	(0.08 - 0.17)	(0.08 - 0.16)	(0.09 - (0.17)
DRUID® Pre-alcohol Mean [SD]/Median $t_{(47)}$ = 1.30, *n.s.*	44.3[4.9]/43.6	45[5.3]/43.0	43.2[4.0]/43. 7
DRUID® Pre-alcohol (range)	(36.0 - 60.0)	(37 .0 - 60.0)	(36.0 - 51.2)
DRUID® Post-alcohol Mean [SD]/ Median $t_{(47)}$ = .14, *n.s.*	57.1 [11.3]/54.4	56.9[9.65]/55	57.4[9.57]/53
DRUID® Post-alcohol (range)	(42.5 - 99.0)	(44.0 - 80.0)	(42.5 - 99.0)

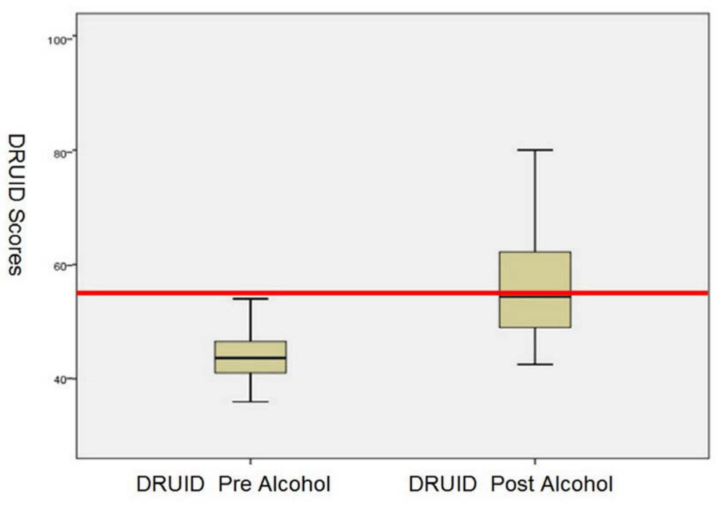

Figure 6. Boxplot of the medians for the DRUID® Baseline scores vs. DRUID® intoxicated scores beyond BAC 0.08%

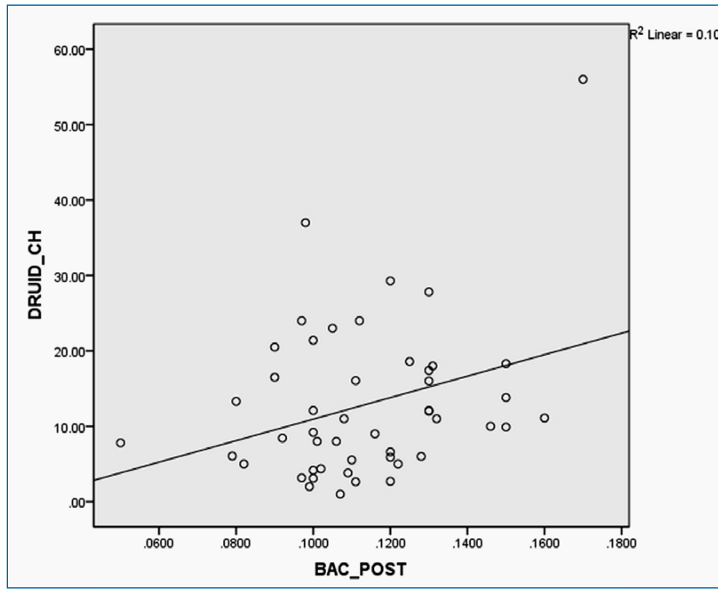

Figure 7. Scatterplot of change in BAC vs DRUID scores. The higher the BAC, the greater was the increase in their impairment score.

significant differences by gender for any of the pre and post alcohol level and DRUID® scores.

As displayed in Table 2, each mean/ median pair is very close in value, therefore the median values were computed since the median is inclined to be more robust to both skewness as well as outliers to measure central tendency than the mean. There was no significant difference between genders in their Post-BAC scores and the Pre and Post DRUID scores.

A repeated measures t-test comparing pre- and post-alcohol BAC scores was highly significant ($t_{(47)}$ = 34.5, p < .0001), as was the difference in or change between the pre- and post-DRUID® scores ($t_{(47)}$ = 8.68, p < .0001). The distributions of the Pre- and Post-DRUID® scores as a function of the pre- and post-alcohol consumption is shown in a box plot. (Figure 6) This displays a boxplot around the medians for the DRUID® Baseline (non-intoxicated) scores and the same individuals' DRUID® scores when they were alcohol-impaired beyond the legal limit of BAC > 0.08%.

Since the box plot of the full sample identified an isolated high outlier (score of 99) in the post-DRUID® scores that could affect the test of means, the paired sample t-test was rerun, excluding the high outlier. The resulting test statistic was larger than with the outlier ($t_{(46)}$ = 10.1, p < .0001), indicating that the outlier had increased the variability in the denominator of the t-test, producing no bias.

No subjects' DRUID® scores decreased between the sober vs. intoxicated measurements. Using the mean of the intoxicated participants' DRUID® scores as a limit identifying intoxication (solid horizontal red line in Figure 6), there were no false positives identified by DRUID® in the participants before they started drinking alcohol.

Increases in the subjects' DRUID® scores from their baseline scores following alcohol consumption are strongly correlated to their increased BAC (r= 0.430, p<0.003). DRUID® impairment scores were calculated subtracting each subject's pre-alcohol DRUID® score from their post-alcohol DRUID® score. A regression analysis of BAC predicting DRUID® change scores was statistically significant (β = .32, $t_{(47)}$ = 2.26, p = .029), showing that the higher the individual's BAC, the greater was the increase in their DRUID® score. This is shown in a scatterplot in Figure 7.

A further analysis of the difference between the pre alcohol vs. post alcohol DRUID® score was performed. The mean difference or change in the pre alcohol vs. post alcohol DRUID® scores was 11.95 [SD 8.15]. This large value for the standard deviation indicates that the

DRUID® values are spread over a large range. The range of changes in DRUID® scores was from a minimum of 1.00 to a high of 37.00. The higher the score became, the greater was the impairment from the alcohol on the testing.

DISCUSSION

Alcohol abuse has clearly been demonstrated to have an effect on driving and job performance.[19,21,37] In this study, our goal was to investigate the use of a convenient and efficient application of a quick Smartphone/Tablet based protocol's ability to identify cognitive and psychomotor impairment as a function of specific levels of alcohol. Higher scores on the BAC and DRUID® represent higher intoxication and associated impairment. The results indicate there is a positive relationship between elevated Blood Alcohol Content (BAC) levels and increased impairment on the The DRUID® test scores. There were no significant differences by gender for any of the central variables.

For years, computer based applications tests of neurocognitive performance have been applied in the assessment of in neurological and cognitive impairment. As technology improved, the personal computer features would merge with cell phone capabilities into the smartphones. The smartphone and tablet became available and in widespread use less than 12 years ago.[38,39]

It was only a matter of time to see similar assessment protocols applied to newer technologies to measure impairment related to alcohol and drug abuse and traumatic brain injuries. Today, few people worldwide can imagine life without their smartphones and tablets for a myriad of daily applications. Currently, there are many tests that can be administered at home, on the playing field, in the workplace, and in the clinical setting using a tablet or a smartphone, for screening for impairment and monitoring treatment. Unfortunately, the recognized cognitive and psychomotor tests used in clinic or laboratory settings to assess alcohol impairment are not readily applicable for use by of law enforcement and industry in the field. This study was an endeavor to assess the applicability of the use of the DRUID® app for measuring changes in divided attention, focused selective attention, reaction time, balance , critical tracking tasks, and visual motor control as it applies to alcohol induced impairment.

Our findings and the use of the DRUID® protocol are similar to other smartphone applications associated with concussion and mild traumatic brain injury assessment tools. For example, HitCheck®[15] is a smartphone based cognitive assessment application that can take baseline measurements of normal performance and then be applied to screen for changes from a possible brain injury . HitCheck® assesses cognitive and psychomotor changes in performance in nine areas associated with brain injuries, e.g., balance, reaction time, coordination, short-term memory, long-term memory, color recognition, impulse control, pattern recognition and problem solving. The HitCheck® test takes approximately 7-10 minutes to complete, which is a fraction of the time of established computer based programs.

Specific to alcohol impairment and driving, the design and use of the DRUID® set of four tasks is supported by similar though more extensive neurocognitive test batteries of cognitive and psychomotor testing of alcohol and driving. Computer based tests measuring skills related to test driving and alcohol are often more complex yet are similar in construct to the DRUID® app's use of divided attention, psychomotor vigilance test, and a balance test. These areas of testing were reported to be most sensitive to the impairing effects of alcohol and being considerably valid in assessing potential driving impairment.[25,40]

There are some limitations and observations regarding the DRUID® test battery as used in this study. For it to be used effectively over time and to be administered by different testers, the interrater and test-retest reliability of its outcomes measures should be investigated. Presently, the test is used as a pre and post screening tool that will often reflect variations in the subject's skill and experience. This was observed in the results in the study. The mean change or difference between the pre and post drinking alcohol in the DRUID® score was 11.95 [SD=8.15]. A high standard deviation is a indication that the values are spread over a large range of values. The range of changes in scores was from a minimum of 1.00 to a high of 37.00. The higher the change, the greater was the impairment from the alcohol on the DRUID® testing. Though the post alcohol overall DRUID® scores demonstrated impairment in pre and post drinking, there was a robust amount of variation in the pre and post DRUID® scores. This may have been due to numerous factors, e.g., variation in alcohol levels, tolerance to alcohol, and how the subject was influence in their cognitive and psychomotor skills by the alcohol.[41,42]

Another factor to be considered in the current study is that DRUID® impairment measurements were for increasing BACs only. There may be different responses on the DRUID® if measurements were taken on the decreasing or downside phase,of the blood alcohol level, i.e., after they have stopped drinking,[24,25,43] An important aspect of evaluating a potential smartphone/tablet based screening test, such as DRUID,® is the relationship of scores with an established battery of tests that measure similar cognitive testing and impaired driving ability.

While the appearance of alcohol impairment is best captured by more extensive cognitive and psychomotor testing batteries, the DRIUD® has significant potential value as a valid and reliable quick screening tool that captures many aspects of divided attention, balance, reaction time, and coordination.

As mobile technologies become an everyday part of our lives, it is important that the public feels confident that the content of the apps represents the best information available in safeguarding public safety.[44]

With further research and development of the DRUID® app, the future use of this type of smartphone/tablet type applications for alcohol and potentially drug testing will be undoubtedly more valid and reliable. It may prove to be more sensitive to lower BAC levels below the thresholds on the SFST tests. It may as well be sensitive to types of drug impairment and serve as a valuable impairment screening tool for alcohol and drug abuse for the workplace and clinical settings.

The DRUID® test is a compelling and useful smartphone/tablet based candidate as a rapid screening test for identifying cognitive and psychomotor impairment associated with the intoxication level of alcohol and effects on driving.

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Disclosure

Dr. Jack Richman and Lt. Stephen May report no personal or financial interest and no present or past employment or activity which would be incompatible with participation in any activity related to this study. This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

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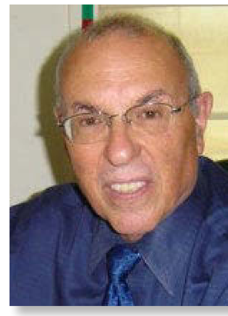

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Dr. Richman is Professor Emeritus from the New England College of Optometry and has lectured widely, both in this country and internationally.

For more than 50 years, he has practiced clinically and academically as a full professor and chief of the Pediatric Optometry and Binocular Vision service at the Pennsylvania College of Optometry, The Michigan College of Optometry at Ferris State University, and the New England Eye Institute in Boston.

His primary areas of lecture and clinical research have included binocular vision dysfunctions, pharmacology, eye movements, visual attention dysfunction, and the effects of drugs on the visual system. He has approximately sixty published articles and book chapters

Presently, he is retired from full time practice and teaching. He is a part time adjunct professor at the Massachusetts College of Pharmacy and Health Sciences – School of Optometry where he lectures and conducts research on vision and driving. Clinically, Dr. Richman continues to serve on the consulting staff at Spaulding Rehabilitation Boston and Spaulding Rehabilitation Hospital Cape Cod.

Dr. Richman has been active in law enforcement for over 26 years. He is a certified Standardized Field Sobriety instructor, a Drug Recognition Expert, and a Drug Recognition Expert instructor. He was the medical consultant to the National Highway Safety Committee's Technical Advisory Panel of the International Association of Chiefs of Police for more than sixteen years. He continues as a consultant to the committee. Presently, he is the police physician and a Drug Recognition Expert instructor for the Hingham Police Department in Massachusetts. He is active in training police officers in Massachusetts and throughout New England states on a regular basis.

ARTICLE

Exploring the Role of Telemedicine in Low Vision Rehabilitation in Patients with Heredomacular Degeneration – A Novel Concept

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Keywords: biofeedback, heredomacular degeneration, low vision rehabilitation, telerehabilitation, Teleophthalmology, video game training

ABSTRACT

Background

Teleophthalmology is widely used for screening and diagnosis of many eye disorders. But its role in low vision rehabilitation is unexplored. The purpose of this study was to explore the feasibility of teleophthalmology for visual rehabilitation.

Methods

We prospectively enrolled 15 patients (age range 12-30 years, mean 16±3.2 years) with heredomacular degeneration with reduced central vision but healthy paracentral retina. We used visual stimulation and biofeedback with video game play. After the baseline investigations, the patients were given a compact disc with the video game and were trained to play the game. Subsequently, they did 40 hours of the visual training at home which was monitored using teleophthalmology by us at our tertiary institute. We used video chat and screen sharing software to guide the patients and monitor compliance. The primary outcome was feasibility of monitoring visual training remotely and secondary outcome was improvement in visual function.

Results

Seven patients returned for follow up after completing the training. The visual acuity improved from 0.74±0.29 to 0.66±0.32 logMAR ($p=0.043$). There was significant improvement in contrast sensitivity ($p=0.023$) and fixation stability ($p=0.018$). The vision related quality of life questionnaire showed improved scores. The ease of communication, patient comfort were high. The office visits were limited to two.

Conclusions

Our study showed preliminary evidence of benefit of teleophthalmology in visual rehabilitation and monitoring. The reduced visits would likely promote compliance and reduce economic burden of the rehabilitatory training.

INTRODUCTION

Teleophthalmology, by definition, is the integrated system of eye care delivery through digital medical equipment and telecommunications technology.[1] In the last 2 decades or so, there has been a rapid rise in e-health and remote health services.[2] The diagnosis in Ophthalmology being mainly a visual or image based diagnosis, it has lent itself very well to the concept of telemedicine. As a result, teleophthalmology has evolved as a major branch of telemedicine.[2] Also, the digital revolution and the tremendous advances in the visualization systems such as the fundus cameras has greatly helped in the evolution of teleophthalmology branch. The ease of capturing retinal and external eye images, portability of the instruments has made it easy to transport these visualization systems to remote areas. Thus, it has made medical care accessible to increasing number of patients.[3]

Teleophthalmology has till date focused on screening and monitoring of diseases. Several studies involving telemedicine based screening of diabetic retinopathy have documented increased number of patients being screened and identified with diabetic retinopathy changes, leading to decreasing visual impairment.[3-7] Another area where teleophthalmology has been successful, is for screening and diagnosis of retinopathy of prematurity (ROP). Several studies have shown successful use of teleophthalmology for screening for ROP in remote neonatal intensive care units.[2,8] This has led to reduction in the childhood blindness.[8]

However, the use of teleophthalmology for treatment or visual rehabilitation has not been explored. Pratibha et al[6] and Murthy et al[9] have hinted at the possibility of using teleophthalmology for low vision rehabilitation. Recently, Kozak et al[10] have published a case report where teleophthalmology guided laser treatment has been done remotely. In a case report by Hall et al[11] removal of corneal foreign bodies was remotely supervised with teleophthalmology help. We propose the concept of telerehabilitation for low vision training in young patients with Stargardt disease.

The Concept:

Stargardt disease is the most common form of heredomacular degeneration (HMD) affecting young individuals in the first or second decade of life.[12] It can lead to severe visual impairment due to central visual loss. So far there is no treatment for this disease. Various optical, non-optical and/or assistive devices help the persons in recognizing faces, watch TV, see the black board, read fine prints, perform computer or mobile phone tasks.

As they lose the central vision, many of these young people use points that are located outside the central area of degeneration to fixate. This point is referred to as preferred retinal locus (PRL). The PRL may be at a considerable distance from the atrophic area resulting in eccentric fixation that is often unstable.[13] Poor fixation stability is correlated with poor visual acuity and poor reading speed.[14] One of the methods used to improve the fixation stability in such situations, is the bio-feedback training using the MP1 microperimeter (Nidek instruments Inc, Padova, Italy). It increases attention modulation and helps the brain to memorize the fixation location thereby providing an efficient PRL for visual tasks.[15,16] Similar stimulation can be done with aggressive video game play. Action videogames have been shown to be effective in improving vision in adult patients with amblyopia.[17,18] The hypothesis is that with visual stimulation and the biofeedback provided by the game when the target is correctly hit, induces the neurons located outside the area of degeneration to send stimuli to the cortical region in the brain. Plasticity of the brain allows this to function as new fixation. Gradually these connections are reinforced leading to a stable system, better fixation and resultant improved vision.[19-21] We did a pilot study which showed possibility of vision improvement in Stargardt disease with video game stimulation (manuscript under review). This visual rehabilitation can be monitored remotely with the help of teleophthalmology.

MATERIALS AND METHODS

We prospectively enrolled 15 patients in this study. The study conformed to the tenets of the Declaration of Helsinki and was approved by the institutional review board and ethics committee. Written informed consent was obtained from all the participants and also from their guardians in case of minors.

Patients with Stargardt disease and no other health issues were recruited for this study. The diagnosis of Stargardt disease was clinical and was confirmed by fundus photo, autofluorescence, optical coherence tomography (OCT) and full field electroretinography (ERG). The fundus showed a well demarcated area of degeneration at the macula with beaten bronze appearance and hypoautofluorescence. The surrounding retina was normal or had a few flecks. The optic nerve head was normal. OCT revealed thinning of the retina with atrophy of the photoreceptors at the fovea. The ERG showed normal photopic and scotopic responses in all the patients.

The patients underwent baseline tests which included logMAR visual acuity recording for distance and near, visual evoked potentials (VEP), stereopsis (assessed by Randot Stereo test, Stereo Optical Co., Inc., Chicago, Illinois), contrast sensitivity measurements (assessed by Pelli-Robson test). The retinal sensitivity and fixation were analyzed with microperimetry on scanning laser ophthalmoscopy optical coherence tomography (SLO/OCT) (Optos PLC, Washington DC).

All patients were advised to play action videogame (Call of Duty 4 Modern Warfare, developed by Infinity Ward and published by Activision) for 1 hour daily in each eye with alternate patching. The participants played the game at a distance between 33 and 40 cms from the screen. A participant with minimum visual acuity of better than or equal to 1.0 LogMAR can play comfortably at 33 cms. The video game had 3 levels of magnification and resolutions viz. video mode 720x576, 1024x768 and 1920x1080 pixels. In case of difficulty, the resolution and magnification could be increased. The playing distance was kept constant as far as possible. They were given 2 training sessions of 15 minutes at the baseline office visit. The availability of internet enabled device for video chat was confirmed from the patient and attendant. Patients were advised to download a screen sharing software and a video chat software. A day and time was fixed for video chat each week. Patients were given the timetable for the training and telecommunication. Patients were asked to maintain a log book recording the sessions of training, duration and difficulties faced. Patients were then sent home.

During the teleconsultation, a link was established between the patient who was at his residence and the authors at the teleophthalmology department of their institute using the broadband satellite connection. After greeting, the patients were asked a set of questions each time to confirm the number of sessions completed, the duration of training completed as well as any difficulties faced during the training and any improvements noted. The level of the game currently being played was noted down. A screen sharing software (V see or Skype) was turned on and patients were asked to play the game live for about 10-15 mins. The screen sharing software showed the game being played on the patient's screen and an external device with another video chat software operated by the patient's attendant showed the patient in action. Thus, it was possible to monitor the way the training was undergoing. The compliance was monitored weekly.

At the end of 40 hours, (20 hours each eye), all patients were reassessed in the office and all the tests were repeated. All patients were administered a previously validated low vision questionnaire before and at the

Table 1: Parameters checked before and after 40 hours of training with video game.

	Case 1		Case 2		Case 3		Case 4		Case 5		Case 6		Case 7	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
VA (LogMAR)														
RE	0.5	0.34	0.24	0.18	0.54	0.44	1	1	0.9	0.86	1	.92	1	1
LE	0.92	0.6	0.3	0.12	0.5	0.44	1	.94	0.92	0.84	1	0.9	0.94	0.96
BE	0.42	0.34	0.2	0.12	0.38	0.34	0.98	0.94	0.9	0.8	1	0.9	0.94	0.94
Contrast Sensitivity														
RE	1.65	1.65	1.5	1.65	1.5	1.65	1.05	1.35	1.05	1.35	1.05	1.2	1.35	1.5
LE	1.5	1.65	1.5	1.65	1.6	1.85	1.35	1.65	1.2	1.35	1.2	1.35	1.65	1.5
Stereopsis (arc sec)	Not measurable	70	80	50	70	70	>500	>500	>500	200	>500	200	>500	400
Worth Four dot test														
Distance	LE-sup	Uncrossed	Fusion	Fusion	Varying	Varying	LE-sup	LE-sup	RE-sup	RE-sup	Fusion	Fusion	RE-sup	RE-sup
Near	LE-sup	Fusion	Fusion	Fusion	Fusion	Fusion	LE-sup	LE-sup	RE-sup	RE-sup	Fusion	Fusion	Fusion	Fusion
Reintal sensitivity (dB)														
RE	8	9.12	15.23	16	18.46	19.04	14.96	17.46	13.2	NA	19.1	15.27	17.46	18.12
LE	8.04	9.05	15.88	16.27	18.49	19.31	16.15	17.46	17.3	NA	15.08	16.3	16.45	17.12
Visual Evoked potential														
RE(1-degree checker size)														
Latency (ms)	109.37	93.75	95.48	95.48	95.48	97.22	86.14	104.16	114.5	105.9	76.38	71.1	104.6	125
Amplitude (mv)	2.84	3.3	2.75	3.18	4.69	4.69	3.12	3.65	2.09	4.14	1.53	3.78	3.12	1.54
RE(15-degree checker size)														
Latency (ms)	91.59	85.54	85.06	85.06	111.11	88.54	105.9	111.11	100.69	109.37	107.6	90.27	112.1	98.96
Amplitude (mv)	2.21	3.62	5.44	5.44	6.81	7.65	3.46	1.89	2.45	1.79	3.61	3.93	1.89	4.56
LE (1-degree checker size)														
Latency (ms)	112.84	86.8	90.27	90.27	95.48	99.22	83.33	107.63	79.86	72.91	71.18	92.01	107.8	88.33
Amplitude (mv)	2.21	3.62	5.44	5.44	6.81	7.65	3.46	1.89	2/45	1/79	3.61	3.93	1.89	4.56
LE (15-degree checker size)														
Latency (ms)	104.16	71.18	79.56	81.59	92.01	104.16	88.54	90.27	NA	116.3	94.75	118.05	100.9	102.43
Amplitude (mv)	1.55	4.05	2.12	2.12	3.71	4.23	2.24	4.93	NA	1.6	3.85	1.98	4.93	5.31
RE-LogBCEA	7.34	5.25	6.44	4.56	6.39	5.83	6.5	5.89	5.68	5.3	7	6.05	7	6.95
LE-LogBCEA	7.93	6.11	3.34	3.04	6.29	6.04	7.12	7.3	6.72	5.5	8.5	7.12	7.3	7.11
VRQoL score	60	65	59	67	62	65	55	63	45	49	55	55	55	61

VA=visual acuity, RE=right eye, LE=left eye, sup-suppression, BCEA=bivariate contour ellipse area, VRQoL=vision related quality of life.

end of the training, which specifically tests visually impaired young adults on their level of impairment based on the difficulty in doing daily vision based tasks. (Appendix)

Statistical Analysis

The data were processed in Microsoft Excel 2013 (Microsoft Corp., Redmond, Washington, USA), and statistical analyses were carried out using the statistical software IBM SPSS Statistics for Windows (IBM Corp., Released 2013. Version 21.0. Armonk, New York, USA). Mean and standard deviation were calculated for continuous variables. Students' paired t test was used for comparison and p value of < 0.05 was considered to be significant.

RESULTS

The study was conducted between September 2016 and September 2017. Fifteen patients in the age range of 13-30 years (mean 18.5±3.2 years, median 16 years) were included. There were 7 patients who were fully compliant and came back for follow up tests. These were included in the final analysis. These included 5 males and 2 females. All the patients were diagnosed clinically to have Stargardt disease. Healthy paracentral and peripheral retina was confirmed on fundus examination, autofluorescence and electroretinography. The visual acuity was tested with the corrected refractive error. For all the participants, the difference between present glasses (if any) and current refraction was within 0.50 DS (Spherical equivalent). There was no change in the visual acuity with present glasses in use and current refraction.

The pre-training mean distance visual acuity was 0.74±0.29 logMAR (range 0.20 to 1.0 logMAR). After training, it improved to 0.66±0.32 logMAR (p=0.043). There was significant improvement in contrast sensitivity (1.30±0.25 to 1.47±0.18, p=0.023) and in fixation stability measured by the log of bivariate contour ellipse area (6.6±0.54 to 5.69±0.75, p=0.018) The retinal sensitivity improved by 1.7±3.39dB (p=0.86). There was improvement in stereopsis. The 1 degree checker size pattern visual evoked potentials showed mild improvement in amplitudes as well as latencies (p=0.17, p=0.75). Similarly, the 15 degree checker size also showed improvement but was not statistically significant (p=0.34, p=0.07). Near visual acuity before the training, ranged from 0.32 to 0.6 logMAR (mean 0.44). And after the training, it improved to 0.35 logMAR (range 0.20 to 0.50 log MAR) (p= 0.60), but did not reach statistical significance. The details are given in table 1.

Subjectively, patients noted some improvement in daily tasks with improvement in questionnaire scores. Almost, all the patients reported improvement in distance vision tasks. They all reported improvement in identifying persons and improved scores on the task of walking alone along a corridor without bumping into objects or persons. All of them also reported better scores in locating dropped objects, reading bus numbers and other details such as bus destination. Cases 4 and 5 also reported improvement in reading textbook at an arm's distance and identifying colors.

All the patients were comfortable with using the technology for communication. They could successfully connect and communicate with us regularly during the training. The rehabilitation could be successfully monitored in all the patients with telecommunication.

DISCUSSION

This was a feasibility study undertaken to test the possibility of using teleophthalmology for visual rehabilitation. We successfully demonstrated the application of real time teleophthalmology in visual training and monitoring. Traditionally, teleophthalmology involves acquisition of images which are stored and then transferred to a remotely placed specialist. This is followed by further interaction with the patient and formation of a referral plan for appropriate treatment. In another modification of this system, automated imaging systems with built in pattern recognition algorithms or machine learning software are used to screen large sections of population.[22]

Although, the main application of teleophthalmology has been in diagnosis of diseases, recently a few reports have evaluated the feasibility of using teleophthalmology for therapeutic purposes. Teleophthalmology guided retinal photocoagulation has been reported wherein images of the patients retina were transferred from the base hospital to the specialist situated in another hospital in another country, a plan for retinal photocoagulation was made and transferred to base hospital where the laser photocoagulation was performed for 10 patients with results comparable to conventional methods.[10] Scan images, surgical plans and 3D models have been transferred previously using telemedicine in other specialties.[23] In another report, removal of a corneal foreign body was remotely supervised by teleophthalmology means.[11]

This is probably the first report of application of teleophthalmology for visual rehabilitation. Previously, Pratibha et al[6] and Murthy et al[9] have hinted at the possibility of low vision rehabilitation using teleophthalmology, mainly for patients with diabetic retinopathy. The main advantages of this telerehabilitation were reduced visits to the hospital. Only 2 visits were needed in this study whereas the number of visits would have been nearly 20 for each session of video game training. Also, the rehabilitation and training could be done in the more natural environment of patient's familiar surroundings. This would help in correctly assessing the visual needs of the patient and directly addressing them in a more customized manner. We selected patients with Stargardt disease for this study for 3 reasons. First, they have a healthy retina surrounding the area of atrophy at the macula which is amenable to stimulation and can lead to better fixation stability and visual improvement. Secondly, these young patients have more brain plasticity and would show better results. Thirdly, the young patients are more technology savvy. They would be more interested in playing a video game. They would also be more at home using newer technologies of telecommunications such as video chat or screen sharing.

In conclusion, we have explored the novel concept of visual rehabilitation using teleophthalmology. The concept of visual stimulation using video game for patients with heredomacular degeneration is also a new concept. To the best of our knowledge, this is the first study using teleophthalmology for visual rehabilitation. A pubmed search did not reveal any articles pertaining to this subject. The study demonstrates that it is feasible to use teleophthalmology for visual rehabilitation.

Appendix

The L V Prasad low vision questionnaire validated and published by Gothwal, et al.[24]

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Dr. Ratra is an accomplished vitreoretinal surgeon. She also practices medical retina and treats many patients with macular degenerative conditions. She has a special interest in developing newer and simpler methods for visual rehabilitation of young patients with heredomacular degeneration.

BOOK REVIEW

Outsmarting Autism

by Patricia Lemer

Paperback: 624 pages

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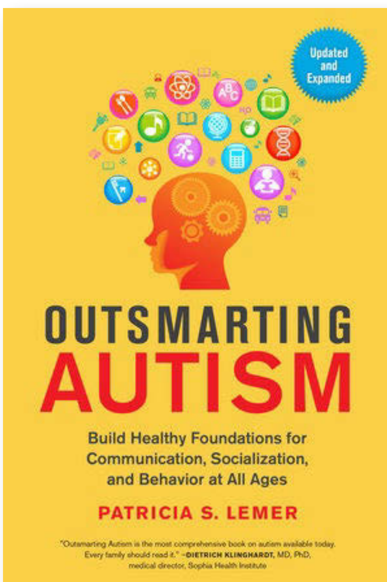
Reviewed by:
Randy Schulman, MS, OD, FCOVD



Outsmarting Autism by Patricia Lemer is one of the most comprehensive compendiums on a topic you will find, and it is covers one of the most complicated, potentially controversial and emotional subjects one may come across. An updated and expanded version of the original 2014 version, it covers everything from the diagnosis of autism, stress factors involved, beginning treatments, foundational issues, expanded treatments including sensory motor integration, communication, academic and later life considerations.

With 1 in 68 children diagnosed with autism in 2016 and 1 in 37 boys diagnosed now, we are looking at an epidemic that has dire consequences for our society. We are guaranteed to come in contact with someone on the spectrum and this book gives detailed and cutting edge ways to address factors associated with the exponential rise in autism rates and concrete treatment methods. It behooves the optometrist to familiarize him or herself with the many factors associated with this condition.

The book is divided into sections and reads as a "How To" manual for handling "autism." Lemer begins with an overview of the autism epidemic and Total Load theory outlining the various toxins, conditions and genetic and environmental factors contributing to developmental delays. Step One of the book is dedicated to "taking away the bad stuff and adding back the good stuff". In this first part, various stressors including biochemical, environmental, physical, social, educational and emotional challenges are discussed. Great detail regarding the importance of digestive health and the connection to immune, hormonal and detoxification systems in the body is covered. Specific lifestyle recommendations with the goals of essential nutrition, strengthening the immune system, balancing hormones and detoxifying the body are addressed in depth. She includes theory, treatment and efficacy of numerous treatment methods including various diets, supplements, herbs and medical interventions. Lemer covers an exhaustive list of modalities from more traditional to the latest treatments using energy medicine.

Step Two of the book addresses correcting the foundational issues including structural, chiropractic, body kinesthiology, reflex integration, and dental considerations. Lemer's chapters on brain integration including primitive reflex integration are the some of the most user friendly, clear and easy to understand descriptions and treatment considerations on such complex topics.

Step Three involves sensory motor integration processing and includes a chapter on the various therapies dedicated to sensory processing and a chapter on vision. Her chapter on sensory processing is comprehensive, complete with the various interventions for integrating sensory motor systems. Her chapter on vision is an incredibly well crafted synthesis of the model of vision used by behavioral optometrists today and pioneered by such greats as Getman, Gesell, Skeffington, Piaget and Wachs and the work on autism and vision by Kaplan. Lemer weaves through this chapter concepts such as the importance of vision development to the entire system, focal and ambient systems, vestibular, visual auditory, visual motor processing, and movement patterns including primitive reflexes. Accurate examples of what is expected in a vision examination and the various visual interventions available are discussed including lenses, prisms, vision therapy and tints. She clearly shares about the power of lenses and prisms and their immediate and profound effects on the total system and their contribution towards integrating the individual for whom they are appropriately prescribed.

Her accurate and eloquent description of vision therapy, its importance, description and follow up is worthy of incorporating in patient education literature.

Step Four of the book is dedicated to the various therapies and educational interventions primarily involved in communication, socialization, behavior and cognition. There are many techniques and tools for learning presented from those more well established to the latest options including an informative discussion on assistive technologies, neurofeedback and programs for enhancing academics.

Finally, Step Five addresses the future, planning for transition out of the educational system and into the community and beyond. The very last chapter focuses on prevention and planning for pregnancy and birth.

Outsmarting Autism covers nearly every theory and therapy for those on the spectrum offered today. Lemer reviews both older treatment methods as well as the most cutting edge and even controversial interventions. She discusses the history behind treatments as well as countless stories of individual breakthroughs and practitioners passionate about their work and bettering the lives of their patients. Every chapter is exceptionally well resourced averaging 50 plus references with additional book, website and newsletter links. Lemer's style is easy to read despite the complicated and nuanced etiologies, expressions and treatment modalities. She gives great examples and engages the reader with her wit and wisdom. This book allows the reader to understand the best ways to handle autism in a step by step fashion with copious resources and directions to turn for every aspect of this complex condition, including both the "Do It Yourself" options and when to seek professional help. In summary, this is a must read resource for any eye care practitioner treating these complex patients.

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Dr. Schulman graduated cum laude from the University of Pennsylvania where she received her Bachelor of Arts degree in Psychology. She graduated with her Doctorate in Optometry and Masters in Vision Science degrees from the State University of New York, College of Optometry. Dr. Schulman received her Fellowship in the College of Optometrists for Vision Development and is an Associate member of the Optometric Extension Program, in addition to being an Adjunct Professor at the State University of New York College of Optometry.

Dr. Schulman has lectured extensively on behavioral optometry topics such as vision in the classroom, vision and aging, visual difficulties in the developmentally delayed, and lectured and published on vision and autism. She specializes in behavioral optometry and vision therapy, pediatrics, learning disabilities and preventative, integrative and alternative vision care for all ages.
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49th Annual Meeting Poster Preview

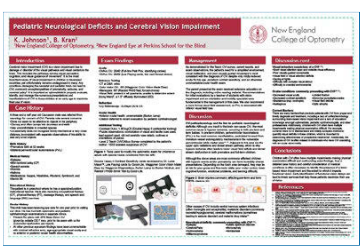
(Full-size Poster can be accessed by clicking on the poster image.)

Prevalence of Visual Dysfunction Among Division 1 (D1) Baseball Student Athletes
Kara Heying, OD, FCOVD & Sheri Roggy, OD
Contact Author:

Using the Z-Bell^{SM} Technique to Prescribe Spatial Neuromodulating Spectacles for a mTBI Collegiate Athlete
Doug Major, OD, FAAO, FCOVD, ABO, ZBell Cert; Nancy J. Major, MS, COVT, ZBell Cert
Contact Author:

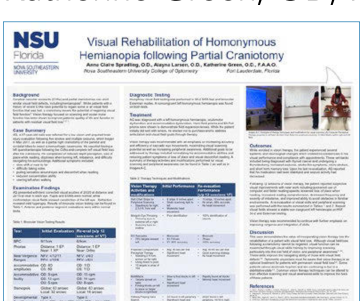
Regaining Control of a Divergence Excess Exotropia
Alexandria R. Wiss, OD
Contact Author:

Pediatric Neurological Deficits and Cerebral Vision Impairment
Kirsten Johnson, OD; Barry Kran, OD, FAAO



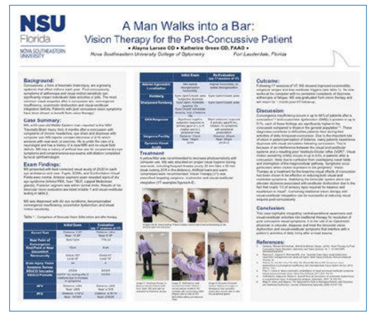
Contact Author:

Visual Rehabilitation of Homonymous Hemianopia Following Partial Craniotomy
Anna Claire Spradling, OD; Katherine Green, OD, FAAO



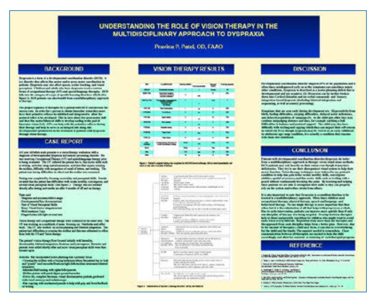
Contact Author:

Pediatric Neurological Deficits and Cerebral Vision Impairment
Alayna Larsen, OD; Katherine Green OD, FAAO



Contact Author:

Understanding the Role of Vision Therapy for Patients with Dyspraxia
Pravina P. Patel, OD, FAAO



Contact Author:

Case Examples of Interprofessional Collaboration in Children with Specific Learning Disorder
Heidi Patterson, BSc, OD; Angela Peddle, OD, FCOVD; Lisa W Christian, OD, FCOVD, FAAO

Contact Author:

49th Annual Meeting Poster Preview

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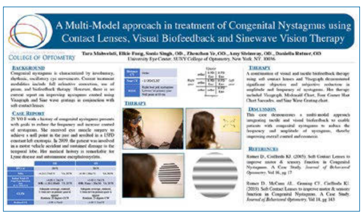
A Multi-Model Approach in Treatment of Congenital Nystagmus Using Contact Lenses, Visual Biofeedback and Sinewave Vision Therapy

Tara Mahvelati; Elkie Fung; Sonia Singh, OD; Zhenzhen Ye, OD; Amy Steinway, OD; Daniella Rutner, OD



Contact Author:

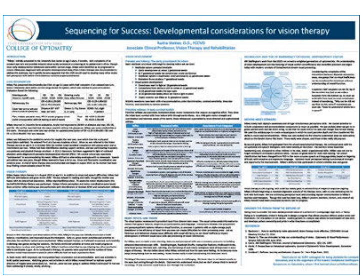
Systematic Approach to Treatment of Binocular Dysfunction Using Virtual Reality

Benjamin T. Backus, PhD, FCOVD-A, Assoc. Prof. Emeritas SUNY College of Optometry; Tuan A. Tran, OD; Brian D. Dornbos, OD, FAAO; James J. Blaha, Chief Executive Officer; Manish Z. Gupta, Chief Technology Officer

Contact Author:

Sequencing for Success: Developmental consideration for vision therapy

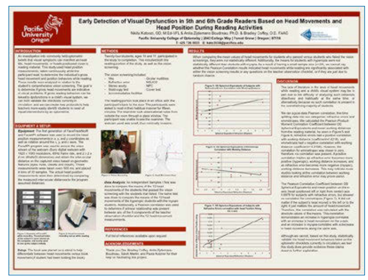
Audra Steiner, OD, FCOVD



Contact Author:

Early Detection of Visual Dysfunction in 5th and 6th Grade Readers Based on Head Movements and Head Position During Reading Activities

Nikita Katoozi, OD, MEd-VFL; Bradley Coffey, OD, FAAO



Contact Author:

Recovering from My Concussion – A Case for Optometry in the Recovery Team

Amanda Nanasy, OD

Contact Author:

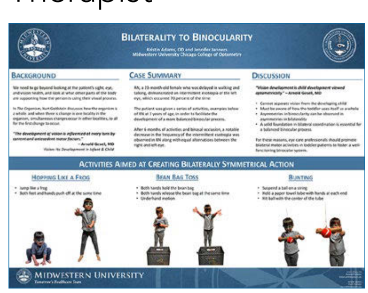
"Out for Recess" Successive Treatments of Pediatric Post-Surgical Intermittent Exotropia

Katharine Funari, OD; Jo Ann Bailey, OD, FAAO; Erin C. Jenewein, OD, MS, FAAO

Contact Author:

Bilaterality to Binocularity

Kristin Adams, OD; Jennifer Janners, Vision Therapist



Contact Author:

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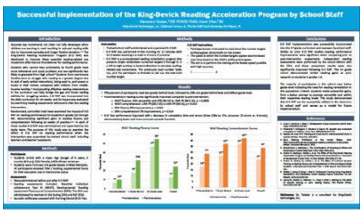
Successful Implementation of the King-Devick Reading Acceleration Program by School Staff

Alexandra Talaber OD, FCOVD, FAAO;
Kiomi Villar, PhD Candidate



Contact Author: ✉

Near Vergence Facility Response in Pre-Presbyopes, with Open-Loop Accommodation

Ronald Gall, OD, MSc, FAAO, FCOVD, Diplomate BVPPO; Bruce Wick OD, PhD, FAAO, Diplomate BVPPO

Contact Author: ✉

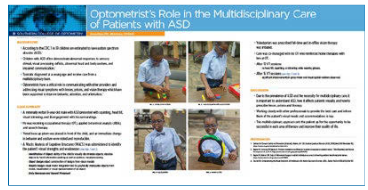
Special Considerations When Performing Vision Therapy for Field Loss on Children with Acquired Brain Injury

Alexandria Tilley, OD; Ilana Gelfond, OD, FCOVD; Rebecca Marinoff OD, FAAO;
M.H. Esther Han OD, FCOVD, FAAO

Contact Author: ✉

Optometrist's Role in the Multidisciplinary Care of Patients with ASD

Emma Pope, OD; Alicia Groce, OD FAAO



Contact Author: ✉

The Pediatric/Vision Therapy Residency at Salus University

Ruth Y. Shoge, OD, FAAO; Erin Jenewein, OD, FAAO, Dipl; Stan Hatch, OD, FAAO, Dipl

Contact Author: ✉

Development and Validation of a Mobile Application for the Screening of Visual Dysfunction Following Concussion

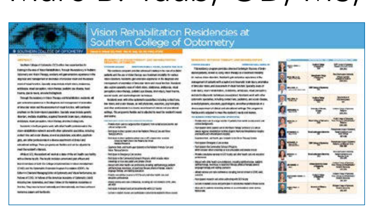
Diane Tucker, OD, FAAO, FCOVD; Susan Linder, DP, DPT, NCS; Karen Guzi, CNS;
Jay Alberts, PhD

COI statement: Jay Alberts and Susan Linder have filed intellectual property protecting the visual modules used in this study.

Contact Author: ✉

Vision Rehabilitation Residencies at Southern College of Optometry

Pamela H. Schnell, OD, FAAO;
Marc B. Taub, OD, MS, FAAO, FCOVD, FNAP



Contact Author: ✉

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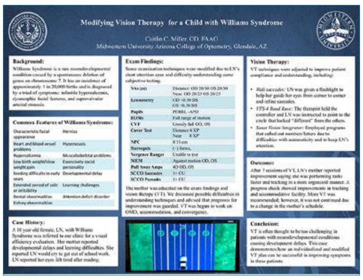
Modifying Vision Therapy for a Child with Williams Syndrome

Caitlin Miller, OD



Contact Author:

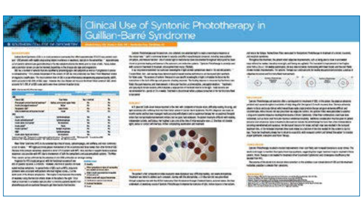
Role of Complicating Medical Conditions in the Management of Accommodative and Vergence Dysfunctions in Patient with Epilepsy

Kelsey Starman, OD; Dan Fortenbacher, OD, FCOVD; Alyssa Bartolini, O.D.

Contact Author:

Clinical Use of Syntonic Phototherapy in Guillian-Barre Syndrome

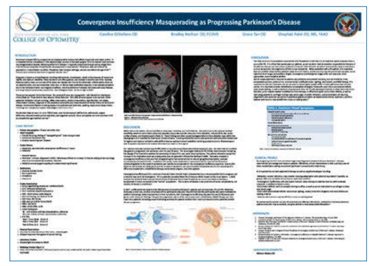
Elizabeth Nace, OD; Moshe Roth, OD



Contact Author:

Convergence Insufficiency Masquerading as Progressing Parkinson's Disease

Candice DiStefano; Bradley Meltzer, OD, FCOVD; Grace Tan, OD; Shephali Patel, OD, MS, FAAO



Contact Author:

Strabismus, Chorioretinal Scarring, and Unexpected Prism: A Case Report

Daniel McIntosh, OD

Contact Author:

Results from the 2016 and 2017 National Survey of Children's Health (NSCH) on Vision Services for Children with Diagnosed Learning Disabilities, Behavior Problems, ADHD, and Autism

Sandra Block OD, MEd, MPH, FAAO, FCOVD, Professor Illinois College of Optometry

Contact Author:

Role of Electrophysiologic Testing in the Special Needs Population

Brandon Harnos, Doctor of Optometry Candidate; Erica Schulman, OD, FCOVD; Tamara Petrosyan, OD

Contact Author:

49th Annual Meeting Poster Preview

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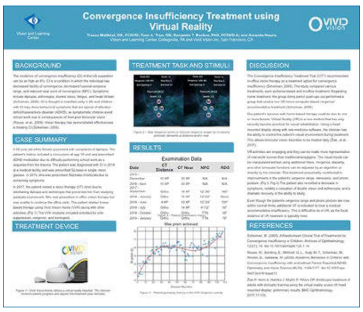
Convergence Insufficiency Treatment using Virtual Reality

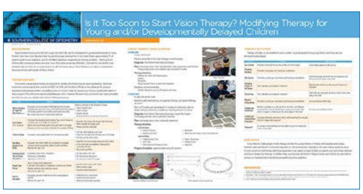
Tressa Malikkal, OD; Tuan Tran, OD; Ben Backus, PhD; Amanda Hauns



Contact Author:

Is It Too Soon to Start Vision Therapy? Modifying Therapy for Young and/or Developmentally Delayed Children

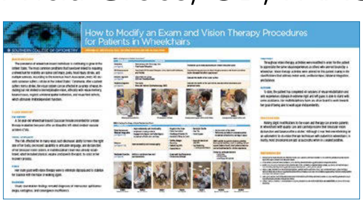
Katlyn Martin, OD



Contact Author:

How to Modify an Exam and Vision Therapy Procedures for Patients in Wheelchairs

Amber Delly, OD; Pam Schnell, OD, FAAO; Marc Taub, OD, MS, FAAO, FCOVD; Alicia Groce, OD, FAAO



Contact Author:

Adding Low Power Vertical Yoked Prism to the Spectacle Prescription in the Management of Exotropia

Jesse Willingham, OD; Ciara McCaffrey, OD

Contact Author:

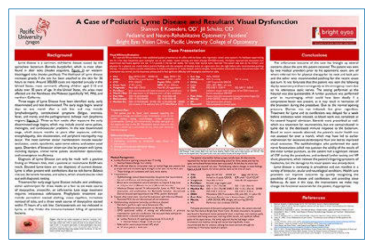
Spectacle Correction and its Effect on Sensory Fusion: Two Case Studies

Jesse Willingham, OD; Sonia Singh, OD

Contact Author:

A Case of Pediatric Lyme Disease and Resultant Visual Dysfunction

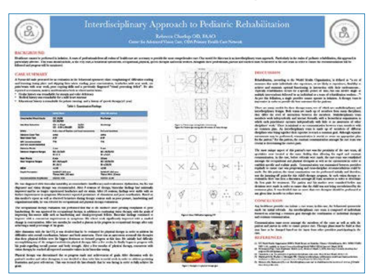
Shannon Koenders, OD; Jill K. Schultz, OD, FCOVD



Contact Author:

Interdisciplinary Approach to Pediatric Rehabilitation

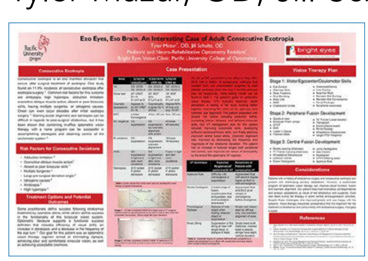
Rebecca Charlop, OD, FAAO



Contact Author:

Exo Eyes, Eso Brain. An Interesting Case of Adult Consecutive Exotropia

Tyler Mazur, OD; Jill Schultz, OD



Contact Author:

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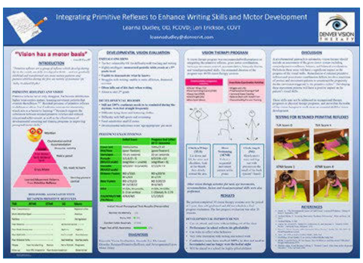
Double Trouble. The Importance of Optometric care in a Rehabilitation Facility

Laura Aelvoet, OD

Contact Author:

Integrating Primitive Reflexes to Enhance Writing Skills and Motor Development

Leanna Dudley, OD, FCOVD;
Lori Erickson, COVT



Contact Author:

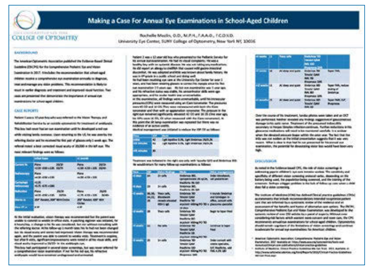
Validity of Wide-range Assessment of Vision-related Essential Skills (WAVES) in Japanese Children with Learning Problems

Tomohito Okumura, MSOptom, MEd, FAAO, FCOVD; Tomoko Miura; Makoto Nakanishi; Miho Fukui, MD, PhD; Mari Toshikawa, MD, PhD; Shuichi Shimakawa, MD, PhD; Eiji Wakamiya, MD, PhD; Hiroshi Tamai, MD, PhD

Contact Author:

Making a Case for Annual Eye Examinations in School-Aged Children

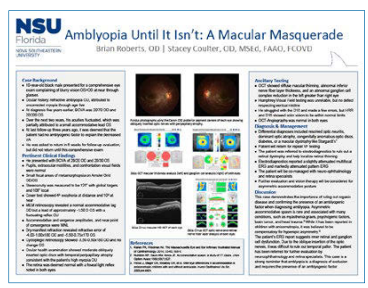
Rochelle Mozlin, OD, MPH, FCOVD, FAAO



Contact Author:

Amblyopia Until It Isn't – A Macular Masquerade

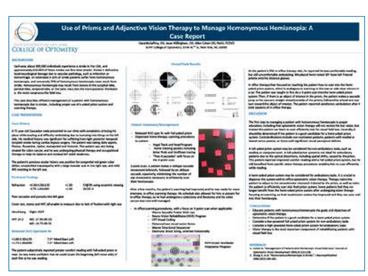
Brian Roberts, OD;
Rachel "Stacey" Coulter, OD, FCOVD, FAAO



Contact Author:

Use of Prisms and Adjunctive Vision Therapy to Manage Homonymous Hemianopia: A Case Report

Ciara McCaffrey, OD; Jesse Willingham; Allen Cohen



Contact Author:

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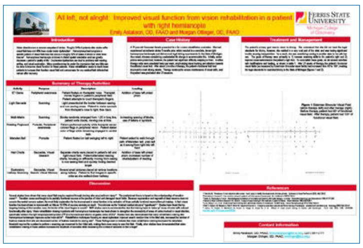
All left, not alright: Improved visual function from vision rehabilitation in a patient with right hemianopsia

Emily Aslakson, OD, FAAO;
Morgan Ollinger, OD, FAAO



Contact Author:

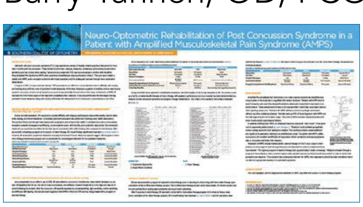
Maximizing Multiple Rehabilitative Therapies Through Co-Management, Identification and Rehabilitation of Visual Dysfunction in a mTBI Patient

Samantha Del Campo, OD;
Guillermo Del Campo, OD

Contact Author:

Neuro-Optometric Rehabilitation in a Patient with Post-Concussion Syndrome with Amplified Musculoskeletal Pain Syndrome

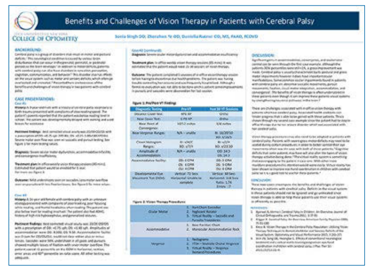
Sneha Bagavandoss, OD;
Barry Tannen, OD, FCOVD, FAAO



Contact Author:

Benefits and Challenges of Vision Therapy in Patients with Cerebral Palsy

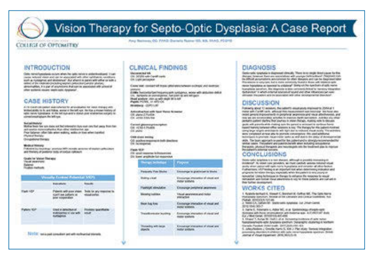
Sonia Singh, OD; Zhenzhen Ye, OD;
Daniella Rutner, OD, MS, FAAO, FCOVD



Contact Author:

Vision Therapy for Septo-Optic Dysplasia: A Case Report

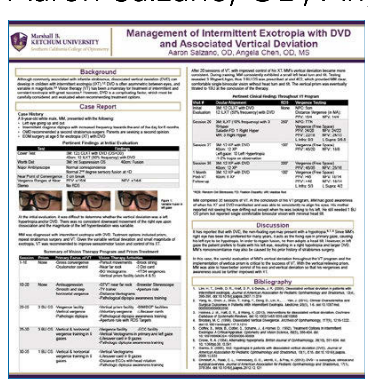
Amy Steinway OD, FAAO;
Daniella Rutner OD, MS, FAAO, FCOVD



Contact Author:

Management of Intermittent Exotropia with DVD and Associated Vertical Deviation

Aaron Salzano, OD; Angela Chen, OD, MS



Contact Author:

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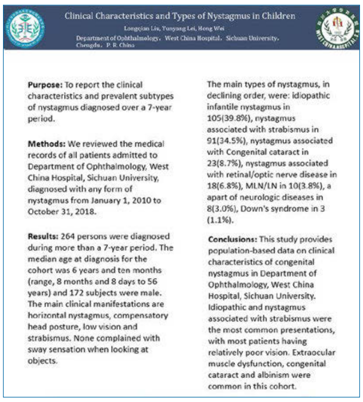
Clinical Characteristics and Types of Nystagmus in Children

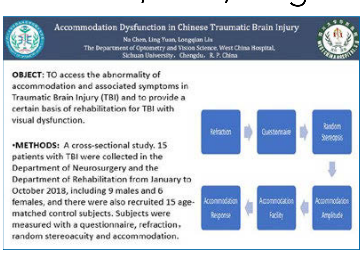
Longqian Liu, MD, FCOVD-A;
Yunyang Lei, MD; Hong Wei, PhD



Contact Author: ✉

Accommodation Dysfunction in Chinese Traumatic Brain Injury

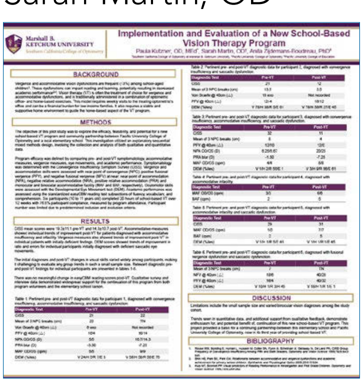
Na Chen, PhD; Ling Yuan; Longqian Liu, PhD



Contact Author: ✉

Implementation and Evaluation of a New School-Based Vision Therapy Program

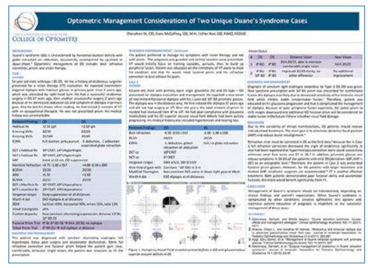
Paula Kutzner, OD, ME;
Anita Zijdemans-Boudreau, PhD;
Sarah Martin, OD



Contact Author: ✉

Optometric Management Considerations of Two Unique Duane's Syndrome Cases

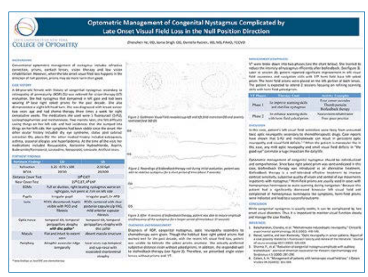
Zhenzhen Ye, OD; Ciara McCaffrey, OD;
Esther M. H. Han, OD, FAAO, FCOVD



Contact Author: ✉

Optometric Management of Congenital Nystagmus Complicated by Late Onset Visual Field Loss in the Null Position Direction

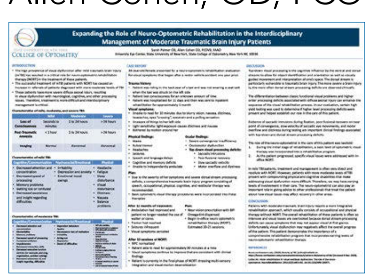
Zhenzhen Ye, OD; Sonia Singh, OD;
Daniella Rutner, OD, MS, FAAO, FCOVD



Contact Author: ✉

Expanding the Role of Neuro-Optometric Rehabilitation Therapy in the Interdisciplinary Management of Moderate Traumatic Brain Injury Patients

Sarah Palmer, OD;
Allen Cohen, OD, FCOVD, FAAO



Contact Author: ✉

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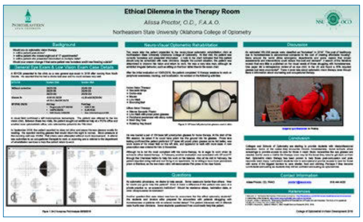
Ethical Dilemma in the Therapy Room

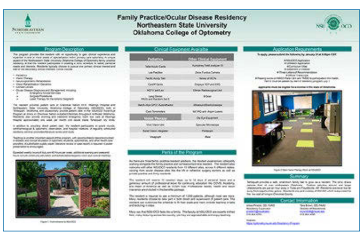
Alissa Proctor, OD, FAAO



Contact Author:

Family Practice and Ocular Disease Residency

Alissa Proctor, OD, FAAO



Contact Author:

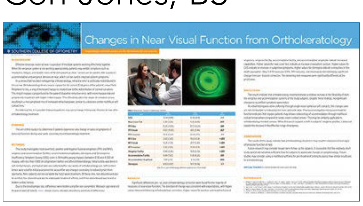
Multi-modality Optometric Treatment of Deep Amblyopia Secondary to Micro-esotropia and Anisometropia

Judy Cao, OD, FAAO, FCOVD; Derek Tong, OD, FAAO, FCOVD, FNORA; Jana Giebel, OD

Contact Author:

Changes in Near Visual Function from Orthokeratology

Morgan Ollinger, OD, FAAO; Jessica Lam, OD, FAAO; Sari Schwartz, OD, FAAO; Cori Jones, BS



Contact Author:

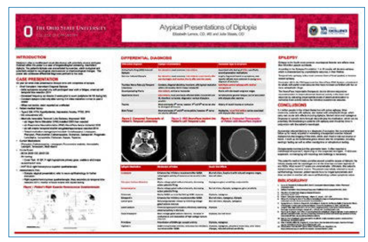
Treating Eccentric Fixation in the Presence of Refractive Amblyopia

Allan McCleary, OD

Contact Author:

A Marathon Runner with Diplopia

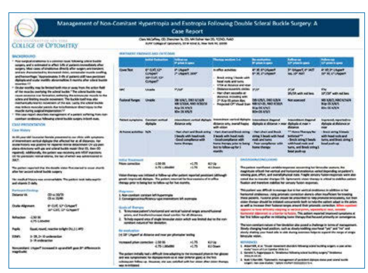
Elizabeth Lemos, OD, MS



Contact Author:

Management of Non-Comitant Hypertropia and Exotropia Following Double Scleral Buckle Surgery: A Case Report

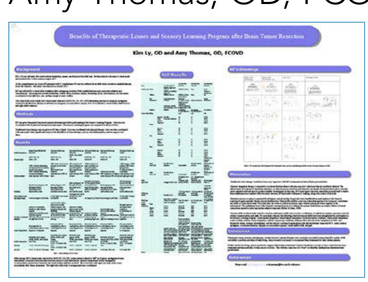
Ciara McCaffrey, OD; Zhenzhen Ye; Esther M.H. Han



Contact Author:

Benefits of Therapeutic Lenses and Sensory Learning Program after Brain Tumor Resection

Amy Thomas, OD, FCOVD & Kim Ly, OD



Contact Author:

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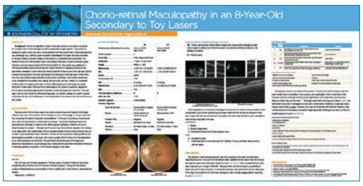
Chorioretinal Maculopathy in an 8-Year-Old Secondary to Toy Lasers

Janette Dumas, OD; Morgan McClintic, BS



Contact Author:

PUCO Pediatric/Rehabilitation Residencies

Curtis Baxstrom, OD, FCOVD, FAAO, FNORA; Pacific University College of Optometry residencies

Contact Author:

The Effects of Font Style on the Gardner Reversal Frequency Test

Jennifer Dryden; Breanna Barnes; June Morikawa; Colleen Tejchma; Christina Esposito, OD, FCOVD, FAAO; Kelly Varney, OD, FAAO

Contact Author:

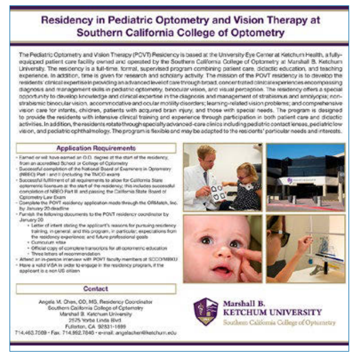
Multiple Orbital Fractures with Inferior Rectus Entrapment Following Blunt Force Trauma

Aaron Heltunen, OD;
Steven Klein, Residency Supervisor

Contact Author:

Residency in Pediatric Optometry and Vision Therapy at the Southern California College of Optometry at Marshall B. Ketchum University

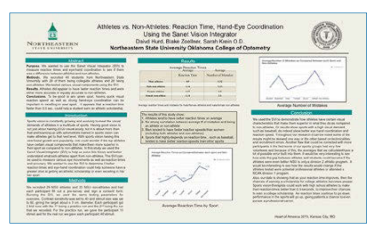
Angela Chen, OD, MS



Contact Author:

Athletes vs. Non-Athletes: Reaction Time, Hand-Eye Coordination Using the SVI

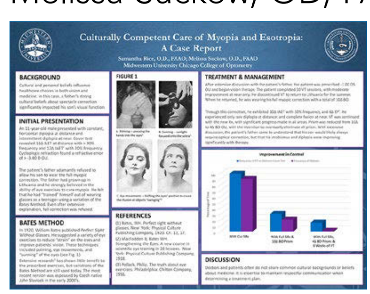
David Hurd; Blake Zoellner; Dr. Sarah Krein OD



Contact Author:

Culturally Competent Care of Myopia and Esotropia

Samantha Rice, OD, FAAO;
Melissa Suckow, OD, FAAO



Contact Author:

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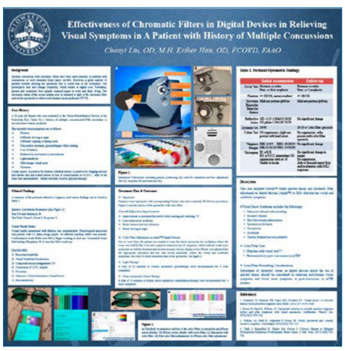
Effectivity Study of At-Home Sports Vision Training Compared to In-Office Training

Brittany Wolthuizen; Kelsey Buford

Contact Author:

Effectiveness of Chromatic Filters in Digital Devices in Relieving Visual Symptoms in a Patient with History of Multiple Concunssions

Chenyi Liu, OD; Dr. Myoung Hee E. Han



Contact Author:

Neuro Optometric Rehabilitation in Patient with Acquired Right Hemianopia

Angela C. Howell, OD, FCOVD

Contact Author:

Visual Evaluation of a Non-verbal Patient Who Uses a Picture Device

Angela C. Howell, OD, FCOVD; Christy Lemmons, Speech Language Pathologist

Contact Author:

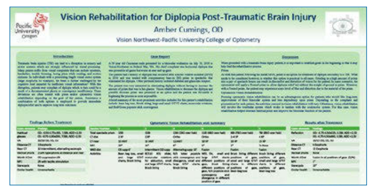
Vision and the MTHFR Gene Mutation

Joseph N. Trachtman, OD, PhD, FCOVD-A

Contact Author:

Vision Rehabilitation for Diplopia Post-Traumatic Brain Injury

Amber Cumings, OD



Contact Author:

Reliability and Normative Data of Computerized Dynamic Visual Acuity Tests

Melissa Hunfalvay, PhD, Chief Science Officer; Nicholas Murray, PhD, Associate Professor, Department of Kinesiology, East Carolina; Claire-Marie Roberts, Senior Lecturer, Department of Psychology, University of the West of England, Bristol; Belinda Lange, Associate Professor, Flinders University, Adelaide, South Australia

Contact Author:

The Reliability, Validity, and Normative Data of Interpupillary Distance and Pupil Diameter Using EyeTracking Technology

Melissa Hunfalvay, PhD, Chief Science Officer; Nicholas Murray, PhD, Associate Professor, Department of Kinesiology, East Carolina; Takumi Bolte, RightEye, LLC, Computer Scientist

Contact Author:

49th Annual Meeting Poster Preview

(Full-size Poster can be accessed by clicking on the poster image.)

Developmental Changes in Oculomotor Behavior Across the Lifespan

Melissa Hunfalvay, PhD, Chief Science Officer; Nicholas Murray, PhD, Associate Professor, Department of Kinesiology, East Carolina; Karla Kubitz, PhD, Associate Professor, Department of Kinesiology, Towson University; Claire-Marie Roberts, Senior Lecturer, Department of Psychology, University of the West of England, Bristol; Takumi Bolte, RightEye, LLC, Computer Scientist; Ankur Tyagi, RightEye, LLC, Data Analyst
Contact Author:

Effect of Monocular Blur on Basketball Free Throw Performance

Kennedy Simmons; Jenny Rider; Dr. PM Cisarik
Contact Author:

Treatment for a Case of Accommodation Spasm

Fuhao Zheng; Yuwen Wang; Yipao Li; Pingping Huang; Hao Chen
Contact Author:

Non-strabismic Binocular Vision Anomalies in Subjects with and without Asthenopia

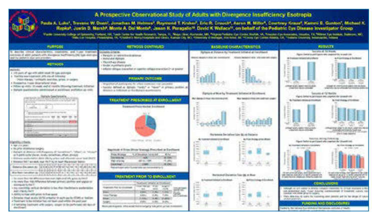
Hira Nath Dahal; Ritu Bhandari, M. Optom; Mohammad Nooruz Zaman, M. Optom
Contact Author:

Evaluation of Primitive Reflexes in Children with Special Education

Ethelvina Gallegos, OD/Student MRV Universidad Autónoma de Aguascalientes, México; Elizabeth Casillas, OD/MCO
Contact Author:

A Prospective Observational Study of Adult Divergence Insufficiency Esotropia

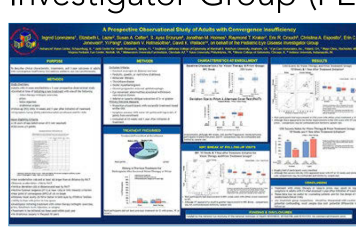
Paula A. Luke, OD; Trevano W. Dean, MPH; Jonathan M. Holmes MD; Raymond T. Kraker, MSPH; Eric R. Crouch MD; Aaron M. Miller MD; Courtney Kraus MD; Kammi B. Gunton MD; Michael X. Repka MD; Justin D. Marsh MD; Monte A. Del Monte MD; Jason H. Peragallo MD; David K. Wallace, MD, MPH; on behalf of the Pediatric Eye Disease Investigator Group (PEDIG)



Contact Author:

A Prospective Observational Study of Adult Convergence Insufficiency

Ingryd Lorenzana, OD; Elizabeth L. Lazar MSPH; Susan A. Cotter, OD, MS; S. Ayse Erzurum, MD; Jonathan M. Holmes, MD; Raymond T. Kraker, MSPH; Eric R. Crouch, MD; Christina A. Esposito, OD; Erin C. Jenewein, OD, MS; Yi Pang, OD, PhD; Dashaini V. Retnasothie, OD, MS; David K. Wallace, MD, MPH; on behalf of the Pediatric Eye Disease Investigator Group (PEDIG)



Contact Author:

49th Annual Meeting Poster Preview

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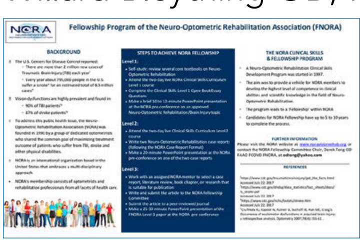
Pediatric Optometry & Vision Therapy/ Neuro-Optometry Residency Program at the Center for Vision Development Optometry Inc.

Derek Tong, OD, FAAO, FCOVD, FNORA

Contact Author:

Fellowship Program of the Neuro-Optometric Rehabilitation Association (FNORA)

Derek Tong, OD, FAAO, FCOVD, FNORA; Curtis Baxstrom, OD, FAAO, FCOVD, FNOR; Willard Bleything OD, MS, FAAO, FCOVD



Contact Author:

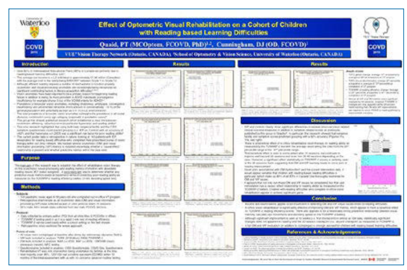
Prevalance of Non-Strabismic Binocular Vision Dysfunction Among Optometry Students in Bangalore, India

Manish Dahal; Bikash Khatri

Contact Author:

Effect of Optometric Visual Rehabilitation on a Cohort of Children with Reading-based Learning Difficulties

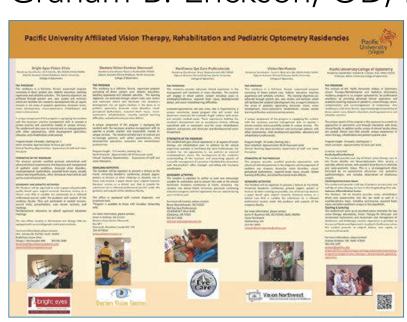
Patrick Quaid, MCOptom, FCOVD, PhD; Daniel Cunningham OD, FCOVD



Contact Author:

Pacific University Affiliated Vision Therapy, Rehabilitation and Pediatric Optometry Residencies: Pacific University Oregon

Jill K. Schultz, OD, FCOVD, FAAO, FNORA; Dawn A. Dunford OD, FCOVD; Bruce Wojciechowski, OD, FCOVD; Curtis R. Baxstrom, OD, FCOVD, FAAO, FNORA; Graham B. Erickson, OD, FAAO, FCOVD

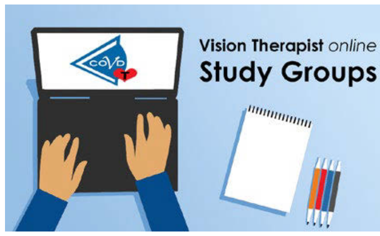


Contact Author:

CALENDAR OF EVENTS

MARCH 2019

March 30, 2019
ONLINE! **Taking the Oral Interview Communicating Comfortably and Confidently What You Already Know**



APRIL 2019

April 9-13, 2019
Kansas City, Missouri
COVD 49th Annual Meeting
Save the Date!

April 25-28, 2019
Cedarville, Ohio – Thursday & Friday
Beavercreek, Ohio – Saturday & Sunday
Optometric Vision Therapy: Improve Outcomes, Part I
Speaker: Brenda Heinke Montecalvo, OD, FCOVD, FAAO, FCSO

MAY 2019

May 25-26, 2019
Ottawa, Ontario, Canada
Vision Therapy 101
Presented by Dawn Dunford, OD, FCOVD

JUNE 2019

June 6-9, 2019
Cedarville, Ohio – Thursday & Friday
Beavercreek, Ohio – Saturday & Sunday
Optometric Vision Therapy: Improve Outcomes, Part II
Speaker: Brenda Heinke Montecalvo, OD, FCOVD, FAAO, FCSO

JUNE 2019

June 22-23, 2019
Surrey, British Columbia, Canada
Diagnosis and Managements for Acquired Brain Injury and Concussion: Primary Concepts for Primary Care and Vision Therapy Optometrists
Presented by Barry Tannen, OD, FCOVD

JULY 2019

July 18-21, 2019
Cedarville, Ohio – Thursday & Friday
Beavercreek, Ohio – Saturday & Sunday
Optometric Vision Therapy: Improve Outcomes, Part III
Speaker: Brenda Heinke Montecalvo, OD, FCOVD, FAAO, FCSO

OCTOBER 2019

October 5-6, 2019
College of Optometry at Western University of Health Sciences, Pomona, California
ENVISION CONFERENCE WEST
A Multidisciplinary Low-vision Rehabilitation Research Conference

October 11-13, 2019
YMCA of the Rockies, Estes Park, Colorado
50th Colorado Vision Training Conference
Speaker: Bob Sanet, OD, FCOVD
Topic: Innovations in Strabismus and Amblyopia Treatment

Join us for this special 50th anniversary conference!

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