Decoding Binocular Vision

Clinical studies on the Neurolens impact to patients and practices

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Factors contributing to the inaccuracy and lack of repeatability with the traditional subjective heterophoria measurements.

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Background

Clear and single binocular vision is critical for normal visual behavior. Our eyes focus (accommodation) and align (vergence) to the object of interest in the real world thereby maintaining clear and single binocular vision. Any inaccuracies in the alignment would lead to eye deviations which can be broadly classified into three types: heterophoria, fixation disparity and heterotropia (strabismus). Heterophoria is the relative misalignment of the eyes in the absence of fusion. In other words, it is the eye misalignment measured under dissociated conditions. It can be horizontal, vertical, cyclo deviated or any combination of the above and is typically compensated by the eye's fusional vergence in the presence of fusion. An inability to compensate this eye misalignment would lead to a manifest deviation called heterotropia or strabismus. Fixation disparity, on the other hand, is the relative misalignment of the eyes in the presence of fusion. This deviation is typically less than the Panum's fusional area therefore objects in space do not appear double. Conditions related to phoria or fixation disparity are clinically referred to as non-strabismic binocular vision disorders.

Traditionally, a diagnostic vision testing routine involves determination of uncorrected refractive errors which are corrected using lenses that provide the best possible vision. However, comprehensive vision care cannot just be limited to the best monocular and binocular visual acuity that can be provided. In the natural world, our eyes work together to focus and align objects to achieve a clear and single binocular vision. Therefore, to provide the best vision care, it is important to also evaluate how well our patients' eyes work together. This is especially critical in this modern day and age where we see an increasing trend in our near vision demand associated with viewing digital devices including phones, tablets and computers. This increasing near visual demand increases the load on the accommodation and vergence mechanisms to constantly focus and align objects at closer distances. Recent reports show that, on average, American children and adults spend about 7.5 to 9.7 hours/day on digital platforms with about 40-80% of them reporting one or more Digital Vision Syndrome (DVS) symptoms such as tired eyes, eye strain and discomfort or dry eyes (Rosenfield, 2016). Therefore, it is important to evaluate the binocular vision mechanism in these patients and treat them accordingly.

To evaluate the binocular vision mechanism, clinicians measure the magnitude and the direction of the phoria at distance (6m) and near (40cms). Tests such as cover-uncover, Von Graefe or modified Thorington are typically used to measure phoria. A comprehensive way to measure binocular vision would include testing the limits (NPA/NPC), amplitudes (NFV/PFV, NRA/PRA), accuracy (phoria/fixation disparity, lag/lead of accommodation) and the dynamics (vergence and accommodation facility) of both accommodation and vergence. Prism bars, flippers, RAF rulers, Maddox rods, retinoscopes and phoropters are employed to obtain this information about these two motor mechanisms. Given the unique cross-coupled behavior of the accommodation and vergence mechanism, another important measure would be to determine the strength of the cross-links between the two systems typically quantified as accommodative vergence response (AC/A ratio) and vergence accommodation response (CA/C ratio). CA/C is not commonly measured in a clinical setting. Individual clinical practices typically measure only phoria and limits (NPA/NPC). If the patient with phoria is symptomatic, treatment options aimed at reducing the phoria are traditionally recommended. Currently, several treatment options including lenses, prisms and vision therapy are available and often prescribed based on the information obtained from the above-mentioned tests (Scheiman & Wick, 2014). Given how important it is to evaluate binocular vision in this digital world, it is crucial that we test this mechanism both comprehensively and accurately; however, the current testing routine involved for phoria estimations is not ideal and has several sources that could potentially cause errors in estimating the binocular function. These sources include the subjective nature of testing, inter-examiner repeatability and the variability and complexity involved in the tests and procedures.

Sources of Error

Subjective nature of the tests

Most clinical testing routines for evaluating binocular vision are subjective, depending on either the patient's attentive response or the clinician's level of expertise. This subjectivity could cause inaccurate estimates of the phoric posture with poor repeatability. Furthermore, given the subjective nature of testing, these tests will not be suitable for testing young children or individuals that are differently abled where it is difficult to obtain an accurate verbal response.

Inter-examiner repeatability

Most clinical tests, given their subjective nature, are dependent on the clinicians' ability to perform the test accurately. Although several studies have reported that the level of expertise does not lead to clinically significant differences in phoria estimations, these studies do show that the variability in the estimation is larger with novice examiners (Hrynchak et al., 2010). Another potential source for inter-examiner repeatability would be the difference in the neutralization criterion employed by the clinician. For example, when performing subjective prism cover test, some examiners choose the prism value which neutralizes the eye movement as their end point while others choose the prism which creates an opposite movement of the eye or the point of reversal. Given the steps of prism changes seen in a prism bar, this could potentially lead to a variability of about 2-4PD. A study with a small sample also reported that the smallest phoria value that can be detected by clinicians with varying levels of expertise is about 2-3PD (Fogt et al., 2000). This would mean that any misalignments less than this value would not be detected and may potentially lead to inaccuracies. Finally, while performing tests that depend on the placement of prisms, such as prism cover test or fusional vergence testing, the distance between the prism and eye can impact prism effectivity and can lead to spurious or less reliable estimations.

Tests and procedures

Another crucial aspect to consider is what measurements should be used to calculate the prismatic correction that could be prescribed to your patient. Should you decide the prism value based on dissociated phoria, fixation disparity or both? Is one more effective than the other? Although most clinicians in North America typically prescribe prisms based on the dissociated phoria, there is evidence that fixation disparity could be a better predictor and should be employed for estimating the prism value. These studies argue that fixation disparity tests provide a more natural viewing condition with both eyes viewing similar content which could be fused (Yekta et al., 1989). Others have pointed out that neither of these alignment tests really provide any natural cues with measurements since the subjects view targets in an artificial or abnormal viewing conditions. Previous studies suggested that the practitioners could recommend prisms that make their patients feel most comfortable while viewing objects in real world (Otto et al., 2008). There is also disagreement on effectivity of prism corrections estimated based on either dissociated or associated phoria values (reviewed in Otto et al., 2008).

As mentioned before, several tests including Thorington, cover test and Von Graefe are used to measure phoria. Several studies have reported a significant difference in measured estimates between the tests with a standard deviation of about 4-5PD. One would reasonably expect to see differences between the tests given the difference in the testing procedure, stimuli used, influence of proximal convergence, ability to control accommodation and the nature of subjectivity involved in the test. For example, does the subjective test involve a patient's response compared to a clinician's judgement of the deviation? A study looking at the inter-examiner repeatability of different tests reported that only tests such as the Thorington have high inter-examiner repeatability while commonly employed tests such as the Von Graefe have a very low repeatability with differences as large as 3-5PD (Rainey et al., 1998; reviewed in Goss et al., 2010).

Another important difference that could lead to the lack of repeatability and inaccuracies in the estimate is the amount of the time used to dissociate the eyes before taking a measurement. Previous research had reported a dissociation time as long as 5-25 min would be necessary to minimize the influence of vergence adaptation so a more accurate estimate of heterophoria could be obtained (Rosenfield et al., 1997). Unfortunately, this is not possible in a clinical setting and, given the limited ability of an unaided eye to identify and track very small and slow eye motion, it is difficult to say if measurements are indeed obtained after the eye stabilizes in a certain phoric posture under dissociated conditions. This, again, would potentially cause errors in the estimation. Finally, a major complexity associated with binocular vision testing is that the clinician must typically perform a battery of tests to decide on type and magnitude of the corrective option. This is especially challenging in busy individual practices to invest a significant amount of time into performing a battery of tests to estimate an accurate prism correction that can effectively relieve symptoms.

Neurolens Measurement Device, Gen 2 (NMD2)

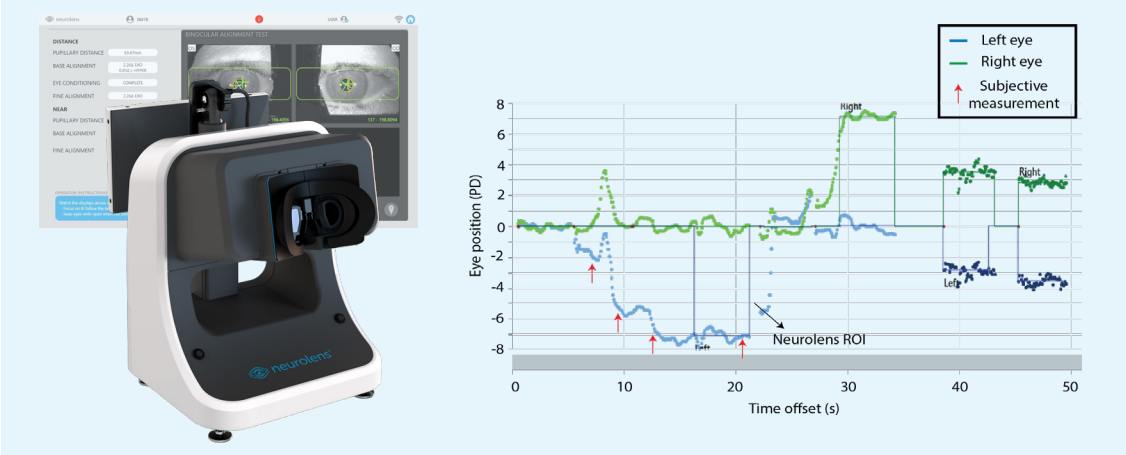

***Figure 1**: An illustration of the Neurolens Measurement Device, Gen 2. An example data trace of a subject's left eye (blue) under dissociated conditions. Eye position, in prism diopters (PD), is plotted as a function f time offset. After dissociation, the left eye slowly drifts towards the phoric position. Neurolens measurement algorithm measures the phoria position once the dissociated eye stabilizes, defined as the Neurolens region of interest (ROI). However, when a clinician subjectively measures phoria or even when a patient subjectively responds, depending on the time of measurement, indicated approximately with red arrows, the amount of phoria value can vary anywhere from 2-7 PD. That is approximately a 5PD variability that can be induced depending on the time of the measurement. This could be one of the potential causes of variability with the traditional clinical methods that measure eye alignment.*

The Neurolens Measurement Device, Gen 2 (NMD2) is a diagnostic tool that measures binocular vision. It is an objective, efficient, patient-friendly, accurate, precise and simple way to measure eye alignment along with the inter-pupillary distance and AC/A measurements. The NMD2 does not rely on subjective responses, therefore eliminating both clinician and patients' biases or variabilities. The objective measuring aspect of the NMD2 is achieved by employing an eye tracking system which robustly tracks patients' eyes in a continuous fashion while the eyes are dissociated. This allows the system to measure the phoria once the eye stabilizes under dissociated conditions leading to an accurate and repeatable estimate of the phoria (Figure 1). The system can identify phoria smaller than 1PD and can detect changes as small as 0.01PD. An internal clinical study done using three different systems on 15 subjects with and without non-strabismic disorders found that the repeatability of the NMD2 was 0.53PD for distance and 0.86PD for near phoria measurements which is significantly lower than 2.5-5PD reported with the traditional methods such as Von Graefe and Thorington. Furthermore, the examiner's level of expertise or the patient's responsiveness do not affect the NMD2 measurements. The NMD2 continuously monitors the eye movement and measures both dissociated phoria and fixation disparity at distance and near. To ensure accurate estimates were obtained and the eye movement data was not corrupted with large eye/head movements, the NMD2 also provides a measurement quality index (MQI) which informs the examiner about the quality of measurement obtained (MQI > 0.7 is considered a good measurement with the eye movement having been neutralized within 0.25PD).

The NMD2 is simple in the sense that it employs an iterative procedure which takes the misalignment measurements into account and provides a final Neurolens prism correction (Neurolens value), in units of PD, which the clinicians can readily use to treat their patients. Unlike prescribing guidelines like Sheard's Criterion, Percival's Rule or the 1:1 rule, the Neurolens value utilizes a proprietary algorithm that was developed based on patient outcomes across hundreds of thousands of measurements and outcomes. The NMD2 is efficient in that it finishes the basic binocular vision testing, including phoria/fixation disparity and AC/A, and provides a Neurolens correction value within 180 seconds; and, it can be performed by a clinical technician. Finally, it also provides a visual representation of the patient's misalignment which can be used to explain the problem causing the symptoms along with the solution being recommended to the patient.

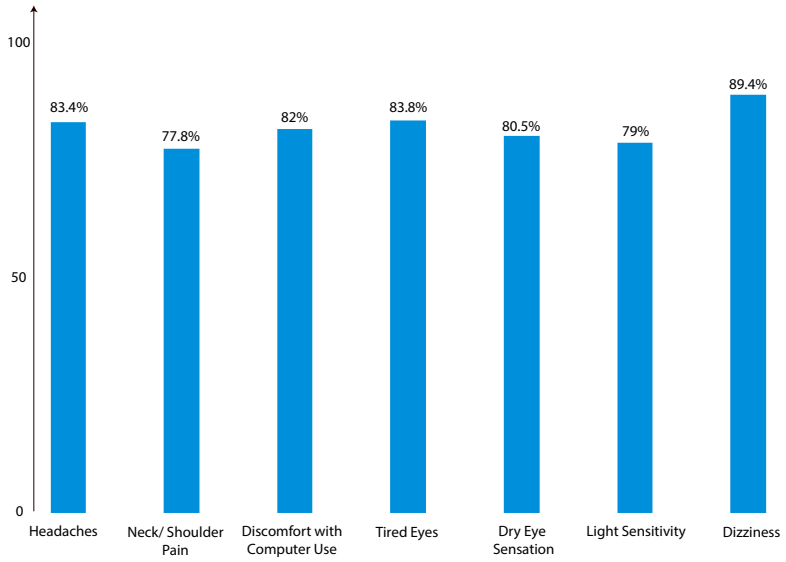

***Figure 2**: Proportion of individuals that reported symptom relief after wearing Neurolens correction for 60 days.*

As shown in figure 2, Neurolens correction prescribed based on the Neurolens prism value has proven very successful delivering a very high level of symptom relief for patients with various DVS related symptoms such as headaches, neck pain, discomfort with computer use, etc. Unlike a regular prism, Neurolenses incorporate a contoured prism design which allows clinicians to provide different amounts of prism at distance and near. Overall, approximately 83% of Neurolens wearers reported improvement in the typically reported DVS symptoms including discomfort with computer use (82%), tired eyes (83.8%) and headaches (83.4%). After a 60-day wear of Neurolenses, prescribed based on the neurolens prism value reported by the NMD2, approximately 80% of the symptomatic patients reported that they are willing to recommend Neurolens to their friends and family.

Conclusion

An average American spends about 7-10 hours/day on digital devices of which approximately 40-80% individuals experience some sort of DVS related symptoms including headaches, neck pain and tired eyes. Furthermore, individuals with traumatic brain injury (TBI), post LASIK surgery or young adults with myopia have also been reported to be strongly associated with non-strabismic disorders. It is therefore critical that these individuals are provided with the best possible comprehensive vision care, including an accurate and efficient binocular vision evaluation. The Neurolens Measurement Device, Gen 2 (NMD2) is an accurate, efficient, precise, objective and simple way to diagnose these patients and provide a treatment option (Neurolenses with contoured prism) that can relieve their symptoms, ultimately helping them to lead a symptom-free digital life.

__Table 1__: Summary of the differences between the traditional subjective methods used to estimate eye misalignment and NMD2.

Source of Error		Traditional Methods	NMD2
Subjective nature		Clinicians' expertise or patient responsiveness	Objective and can be operated by a technician
Inter-examiner repeatability	Variability with clinical expertise	Yes	No
	Neutralization criterion	Yes. Does the examiner choose a prism neutralization that induces no eye movement or opposite eye movement (reversal)?	No. The algorithm measures deviation when the eyes stabilize
	Accuracy of the end point	Depending on the test (prism bar) employed, can vary between 2-4 PD	Measurement Quality Index (MQI) > 0.7 would indicate that the end point is within 0.25PD
	Smallest phoria that can be identified	~2-3PD	Misalignment less than 0.01PD would be detected
	Prism effectivity	Depending on where the prisms have been placed relative to the patient's eyes, prism effectivity can be different	Vertex distance is always kept constant
Tests and Procedures	Should you decide the prism value based on the dissociated phoria, fixation disparity or both?	Clinicians typically use dissociated phoria	NMD2 utilizes a proprietary algorithm which takes both dissociated and associated phoria into account
	Repeatability	Depending on the test employed, it can be anywhere between 3-5PD	0.53PD for distance and 0.86PD for near measures
	Dissociation time	Variable depending on the test and is limited by the unaided eye's ability to track very small and slow eye movements	Eye trackers can accurately track the eye during dissociation and association measures

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Neurolens: a comprehensive way to treat Digital (computer) Vision Syndrome

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Background

Using digital devices regularly for prolonged hours is a common theme in today's technologically advanced world, both for personal and professional purposes. This is especially true for young children (~10 hours/day) and adults (~8 hours/day). Most users experience eye strain or related symptoms after using digital devices, commonly referred to as Digital Vision Syndrome (DVS) or digital eye strain (Rosenfield, 2016). It is therefore of the utmost importance that these individuals are provided with an easy-to-use treatment option that alleviates eye strain related symptoms, protects their eyes from harmful radiation and helps them lead a comfortable digital life. One of the commonly reported causes of DVS are the non-strabismic binocular vision disorders (accommodation and vergence disorders). Non-strabismic disorders are traditionally corrected using near adds, special coating lenses (for example, blue light filter lenses), prisms and vision therapy. However, these treatment options have a few limitations. For instance, vision therapy, although effective, does not provide instant relief and is heavily reliant on patient compliance. Most patients with DVS symptoms exhibit different magnitudes of eye misalignment at different viewing distances (Maples et al., 2009). Unfortunately, standard prisms provide a constant correction at different viewing distances and therefore may not be beneficial. Blue light filter coatings, often marketed and prescribed as a treatment option, only protect the eyes from harmful high energy radiation and do not alleviate DVS symptoms (Palavets & Rosenfield, 2019). This is not surprising given that these coatings do not have any impact on the common causes of DVS related symptoms; for instance, eye misalignment. It is also important to remember that digital eye strain due to non-strabismic disorders cannot just be limited to the eyes and is much more complex, involving both binocular and extraocular aspects. Given the near-dominant world we live in, it is increasingly important that clinicians have a comprehensive understanding of the underlying physiology, awareness of the various DVS symptoms, and knowledge of the treatment options that could effectively relieve their patients' symptoms.

Digital Vision Syndrome: Pathophysiology

There is no unified hypothesis as to why uncorrected refractive errors or non-strabismic disorders, such as convergence insufficiency, cause asthenopia-related symptoms. Several theories have been proposed to explain this association. One widely accepted theory is that the strain on the extraocular muscles (EOM) due to eye misalignment overstimulates the trigeminal nerve causing DVS symptoms, clinically referred to as Trigeminal Dysphoria. In this theory, the pathophysiological pathway involved is similar to the one involved in migraines (Digre, 2018). The trigeminal nerve is the fifth cranial nerve which innervates several parts of the face. The nerve has three branches: ophthalmic, maxillary and mandibular. The first two branches are purely sensory, but the third branch is involved in both sensory and motor functions. It has been previously reported that the ophthalmic branch, which supplies the eye and orbit, also supplies a large portion of the dura. This sensory link between the eye and the central nervous system through the trigeminal nerve is thought to be the causal link. The pathophysiology includes an eye misalignment leading to an increased effort by the visual system to realign to avoid double vision and strabismus. This constant effort to realign causes an overstimulation of the trigeminal nerve, which ultimately leads to an irritated nerve. This irritation then results in a painful stimulation of several parts of the eye, head and neck, leading to symptoms such as headache, neck pain and eye strain. The trigeminal 'caudalis' nucleus which relays information between the eyes and the central nervous system extends into the cervical spine in the neck. If the entire trigeminal nucleus is irritated during trigeminal dysphoria, it might explain why problems in the eyes lead to a pain in the neck.

Given the unique cross-linkage between accommodation and vergence, eye misalignments could often be caused due to an altered accommodation behavior. The accommodation system is primarily innervated by the parasympathetic nervous system, particularly the ciliary muscle, which is responsible for accommodation. Previous studies have reported that a dual innervation - meaning both the sympathetic and parasympathetic innervation - is responsible for maintaining the tonic/resting state of accommodation, and any imbalance in this dual innervation leads to an altered accommodation response at near (Bullimore & Gilmartin, 1988; Chen et al., 2003).

This imbalance between the sympathetic and parasympathetic stimulation is another explanation for why disorders in the eyes cause DVS related symptoms such as headaches. Previous studies have reported that increased levels of stress, mental effort or attention lead to enhanced sympathetic and parasympathetic innervation causing an imbalance in the autonomic innervation to the eye. It has been theorized that the increased sympathetic innervation in response to stress or mental effort leads to an overall reduction in the accommodative response at near. This reduced accommodative response leads to a compensatory increase in the parasympathetic innervation to the ciliary muscle, ultimately increasing the accommodative effort. This increased accommodative effort then leads to an eye misalignment because of the increased accommodative-convergence (AC) input. As shown in figure 1, this eye misalignment overstimulates the trigeminal nerve, sending pain impulses to different parts of the face and causing symptoms such as headache, neck pain, etc. Previous studies have reported that an increased load on the ciliary muscle leads to the activation of the trapezius muscle, a large triangular shaped muscle extending over the back of neck and shoulders (Sanchez-Gonzales et al., 2018; Domkin et al., 2019). This activation could explain the association between accommodation disorders and neck/shoulder pain. Other studies have also pointed out that eye misalignments or accommodative (focus) response errors would also lead to postural imbalances that could cause neck and shoulder pain (Sanchez-Gonzales et al., 2019, Ritcher, 2008).

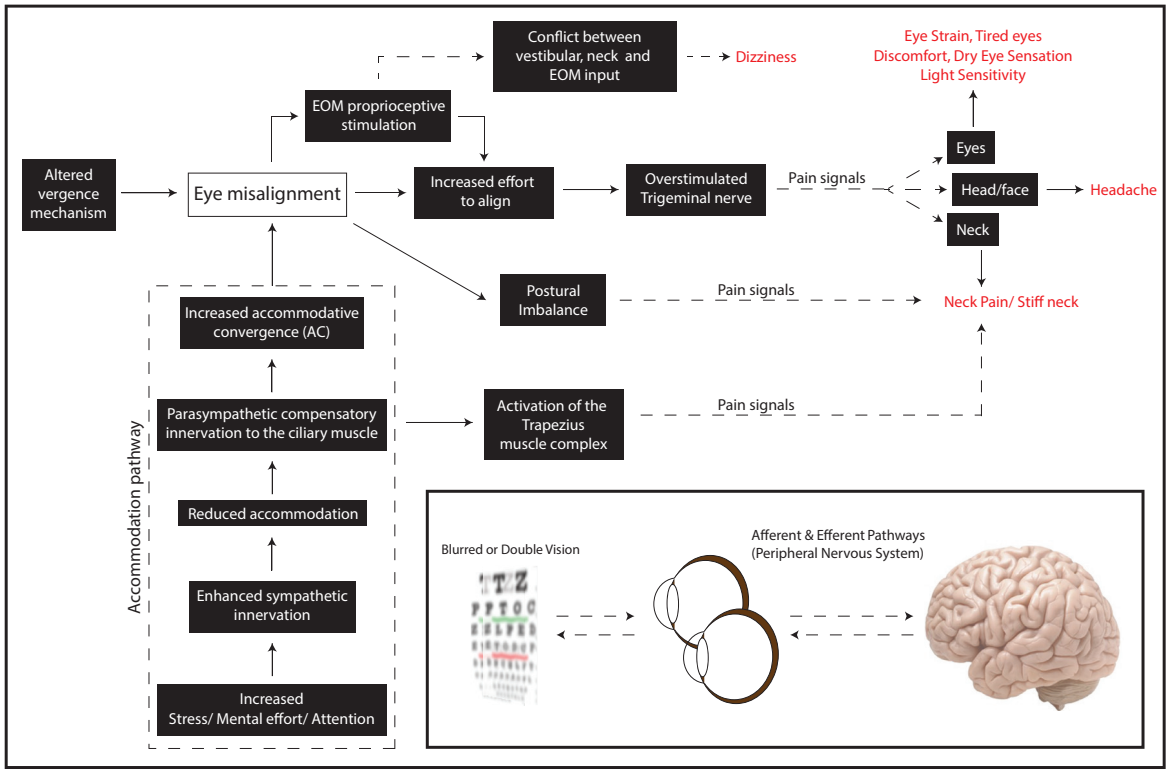

Figure 1: Hypothesized pathophysiological pathway of DVS symptomology related to vergence disorders.

Although the exact function is not totally understood, the sensory receptors of the EOMs provide proprioception (sense of awareness of the position or movement). This afferent proprioceptive signaling provides an extra-retinal signal on the position of the eyes to the visual system (Weir, 2006). As shown in figure 1, this afferent input could signal the visual system about the misalignment, leading to an increased effort to realign ultimately causing an overstimulated trigeminal nerve. When the eyes are misaligned either vertically or horizontally, it might lead to a conflict between the proprioceptive inputs from the vestibular system, neck muscles and the EOMs. This explains why an individual with eye misalignments often experiences symptoms such as nausea and dizziness. The pathophysiology of DVS related symptomology is likely not limited to the eyes and could be much more complex. Therefore, a comprehensive treatment for such a problem cannot be limited to the eyes.

Neurolens

Visible blue light and its impact on the eyes has made blue light protection a popular treatment offered by eye doctors in response to the increased prevalence of symptoms associated with computer and digital device use. Research shows that too much exposure to high energy short wavelength radiation can damage the eyes and skin, and can significantly affect sleep patterns. Increased use of digital devices emitting blue light is thought to increase the risk of blue light induced ocular damage. Accordingly, lenses with coatings that filter blue light have been designed for, and clinicians often prescribe them to, patients with DVS symptoms. As shown in figure 2 (data in blue), recent work shows that these coatings decrease harmful effects of blue light by 10-24% and reduce DVS related symptoms such as eye strain and discomfort in 20-30% of the patients (Leung, 2016).

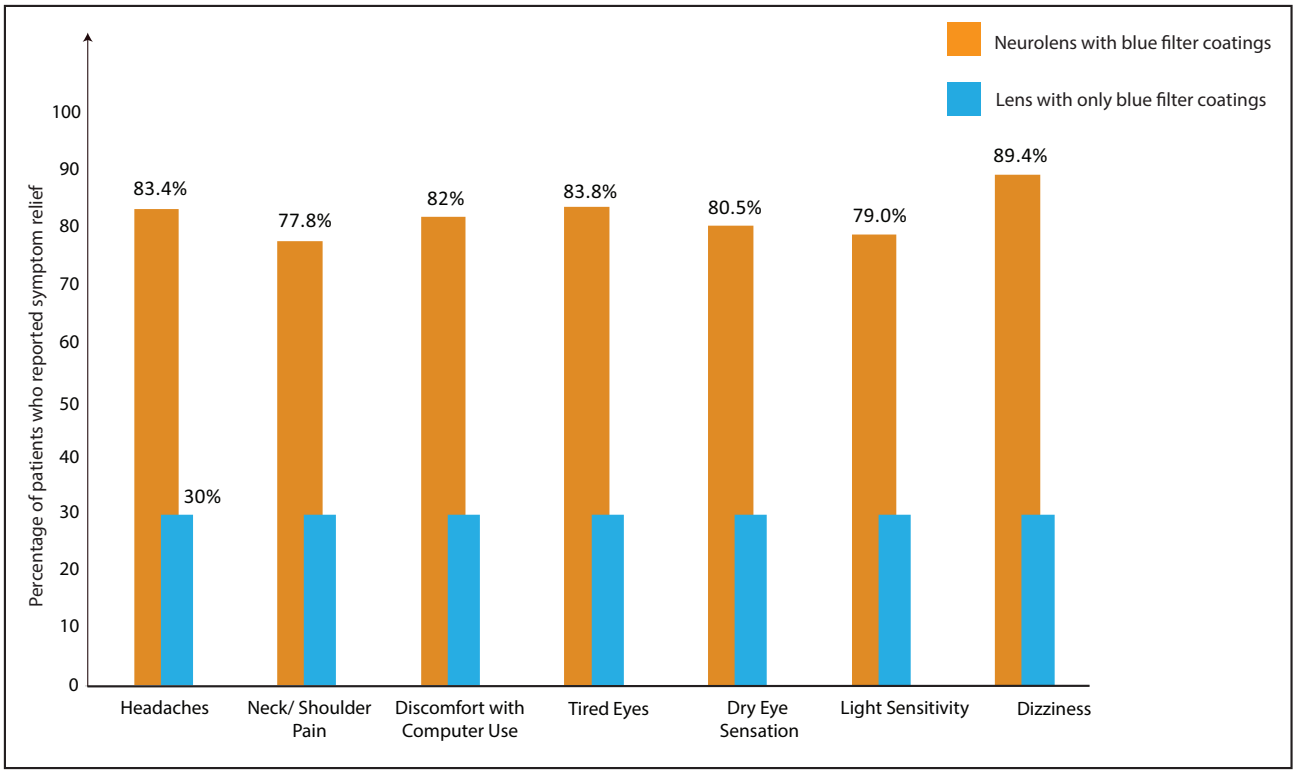

Figure 2: Proportion of patients who benefited post Neurolens wear compared to the symptom relief data on the efficacy of blue light filter coatings (Leung, 2016). Although, Leung's study did not report any symptom relief data on DVS symptoms such as dizziness or light sensitivity, we have taken their highest improvement score with blue lenses for DVS related symptoms such as visual comfort or eye strain and considered it as the baseline for the purpose of data comparison.

Neurolenses paired with blue light filter coating provide a comprehensive treatment in the sense that they not only provide protection from harmful blue light rays damaging the eyes, but also significantly alleviate DVS symptoms by correcting the eye misalignment using a customizable lens design that incorporates a contoured prism. Most patients with DVS symptoms exhibit different magnitudes of eye misalignment at different viewing distances. Unlike standard prisms, Neurolens employs a proprietary lens design that seamlessly varies the prismatic correction provided to the eyes at different distances. This allows clinicians to customize the lens correction for each individual patient depending on both patient needs and the clinical findings. As shown in figure 2 (data in orange), patient survey results post 60-day Neurolens wear collected from individual practitioners across the country show that Neurolenses with blue light filter coatings effectively relieve various DVS symptoms in more than 80% of Neurolens wearers. This is significantly more than what was reported in patients who wore standard lenses with blue light filters (~30%). About 83% of the symptomatic patients feel improvement in their headaches post Neurolens wear. About 78% of Neurolens wearers report improvements in neck pain, and 82-84% feel improvement in their eye tiredness or eye discomfort with computer use, which are commonly reported symptoms after prolonged near digital work. Importantly, 80% of symptomatic patients also reported that they would be willing to recommend Neurolenses to their friends and family.

Conclusion

Most individuals experience eye strain or related symptoms after using digital devices, commonly referred to as Digital Vision Syndrome or digital eye strain. A comprehensive treatment should involve both an option to correct the eye focusing and alignment errors along with an option to reduce the exposure to harmful high energy radiation from digital devices. Neurolenses, with customizable contoured prism and choice of blue light filter options, provide a comprehensive intervention to significantly reduce DVS symptoms associated with digital use. This symptom reduction allows individuals to comfortably navigate through their digital life, making ***digital well-being*** a real possibility.

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Can small prism corrections improve visual comfort? Yes! Here is why.

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Background

Digital Vision Syndrome (DVS) is an emerging public health concern where individuals experience a wide range of symptoms including headaches, eye strain, dry eye sensation and neck pain while navigating through their digital lives. Predictably, a growing trend in digital usage in the modern age has led to a steep acceleration of associated DVS symptomology (Rosenfield, 2016); therefore, it is critical to understand, measure and treat this problem appropriately. DVS could be caused by both ocular and extraocular anomalies. While ocular anomalies include uncorrected refractive errors, eye misalignments or dry eyes, extraocular anomalies include muscle strains due to compensating postural changes. Uncorrected refractive errors are typically corrected using prescription lenses, dry eyes are treated with therapeutics, and compensating postural habits are corrected by employing occupational therapy or better ergonomic habits.

An often-overlooked cause of DVS related symptomology is binocular vision disorders (BVD); for example, convergence insufficiency, where the patient typically presents with an eye misalignment (large exophoria at near compared to distance) coupled with other clinical signs such as reduction in near point of convergence (NPC). Typical treatment options for BVD involve prescription lenses, prisms or vision therapy (Scheiman et al., 2008). Lenses—especially plus lenses—are not commonly employed and are reserved for patients with heterophoria associated with a high AC/A. Prescription prism glasses, with horizontal and vertical relieving prisms, are offered to either patients with large phoria or in conjunction with vision therapy. The prism value prescribed is often based on fixation disparity analysis, Sheard's criterion or Percival's criterion. These glasses provide a constant prism correction to patients at all distances even though patients often present with varying amounts of misalignment at different distances.

Vision therapy is another commonly employed option for treating eye misalignment. The time course of the therapy and the treatment modality are decided based on the clinical (optometric) findings. The therapy, however, does not provide instant relief and is heavily reliant on the compliance of the patient over an extensive time course. Clinicians typically prescribe these treatment options only to symptomatic patients with large phoria. Clinicians tend to overlook patients with a smaller phoria and instead look for other causes for DVS.

There are several reasons why symptomatic patients with smaller phoria are not prescribed prisms or other corrective modalities to treat eye misalignments. One of the primary reasons is the inability to accurately measure smaller eye misalignments. As a result, only patients with a larger phoric posture are diagnosed and treated while individuals who could benefit from small prismatic corrections (less than 2PD) are overlooked. Clinicians have been testing phorias and fixation disparity subjectively for almost a century now, but it has been virtually impossible to accurately test prism in small increments of 0.10 PD for patients until the advent of the Neurolens Measurement Device (NMD) in 2018. There is a need to recognize the functionality and application of small prism correction. This paper will demonstrate how prescribing small amounts of horizontal prism (less than 2PD) can relieve symptoms commonly related to DVS. So, what do we know about the relationship between small eye misalignments and DVS symptoms?

Eye Misalignment and the Severity of Symptomology

One of the common misconceptions with binocular vision disorders is that symptomatic patients tend to exhibit large phoria or fixation disparity coupled with other clinical signs. The assumption is that these large eye misalignments reflect a breakdown of the binocular vision system, especially the accommodation (focusing) and vergence (aligning) mechanisms. However, several studies have consistently reported evidence contrary to this belief.

For example, data from the Convergence Insufficiency Treatment Trial (CITT) study of 221 subjects showed no correlation between the amount of exophoria and the severity of the symptoms of their patients (Bade et al., 2013). The Convergence Insufficiency Symptom Survey (CISS) score was also not correlated with the severity of the clinical signs such as near point of convergence (NPC) or positive fusional vergence limits (PFV). Simply put, the evidence suggests that the magnitude of clinical signs does not correlate with the severity of the symptomology. For instance, a patient with 1PD exophoria and a patient with 10PD exophoria with no other ocular or extraocular problems related to DVS might experience a similar magnitude of eye strain and need to be treated appropriately.

Diagnostic tools

Traditionally, eye alignment, i.e., phoria, tropia, or fixation disparity, is typically measured using clinical techniques that are subjective in nature. This results in poor repeatability, limiting a clinician's ability to measure small eye deviations accurately. Patient attentiveness or the clinician's level of expertise (Hrynchak et al., 2010) also affect the accuracy and repeatability of the test. For example, a previous study reported that the smallest phoria value that can be detected by clinicians with varying levels of expertise is about 2-3PD (Fogt et al., 2000). This would mean that any smaller misalignments may not be detected at all using traditional methods. The ability to track small and slow dissociated eye movements is also limited with the naked human eye. This introduces discrepancy in the dissociation time, ultimately affecting the accuracy of the misalignment estimation. Simply put, the subjective nature of the procedures limit clinician's ability to accurately measure small eye misalignments. This would explain why there is no concrete literature on the impact of small eye misalignments on subjective visual comfort and the benefit of correcting them.

Trigeminal dysphoria

DVS may not just be limited to the eye and could be much more complex. Although the exact mechanism is unclear, the hypothetical pathophysiology suggests that eye misalignment leads to increased effort by the visual system to realign to avoid double vision and strabismus. This constant effort to realign causes an overstimulation of the trigeminal nerve, which ultimately leads to an irritated nerve. This sensory irritation then results in painful stimulation of several parts of the eye, head and neck, leading to symptoms such as headache, neck pain and eye strain. Therefore, even small prismatic corrections of the misalignment could reduce the overstimulation of the trigeminal nerve and relieve patients' symptoms, ultimately improving their visual comfort.

Neurolens: A Better Way to Diagnose and Treat Eye Misalignment

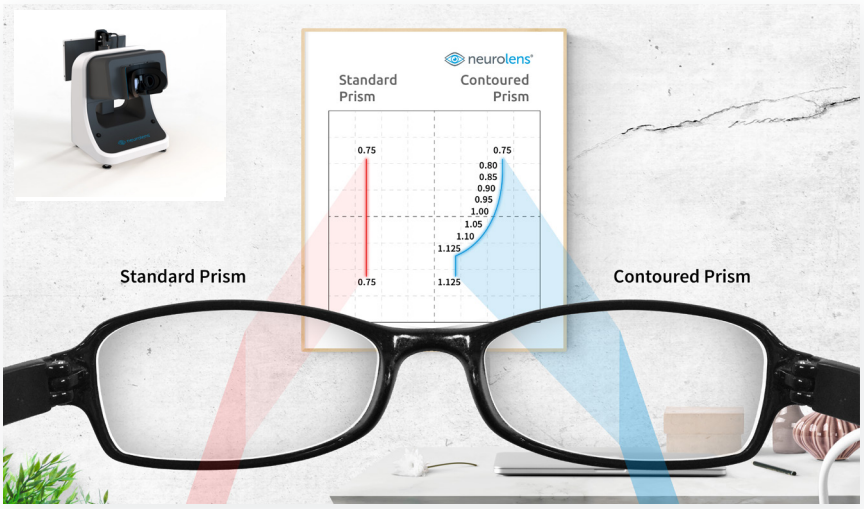

Figure 1: Contoured Neurolens design and the Neurolens Measurement Device, Gen 2 or NMD2 (inset).

Neurolens Measurement Device (NMD2)

The NMD2 is an objective, accurate, precise, simple and efficient way to measure eye alignment and calculate a patient's AC/A. The NMD2 does not rely on subjective responses, therefore eliminating both clinician and patients' biases or variabilities. The objective measuring aspect of the NMD2 is achieved by employing an eye tracking system that robustly tracks patients' eyes in a continuous fashion while the eyes are being dissociated and associated. The system can identify phoria smaller than 1PD and can detect changes as small as 0.01PD. The repeatability of the NMD2 is 0.53PD for distance and 0.86PD for near phoria measurements, which is significantly lower. This is better than 2.5-5PD reported with the traditional methods such as Von Graefe and modified Thorington (Goss et al., 2010). The NMD2 is simple in the sense that it employs an iterative procedure, which takes the misalignment measurements into account and provides a final Neurolens prism correction (Neurolens value). Unlike prescribing guidelines such as Sheard's Criterion, Percival's Rule or the 1:1 rule, the Neurolens value utilizes a proprietary algorithm that was developed based on patient outcomes across hundreds of thousands of measurements and outcomes.

Neurolenses

The Neurolens value obtained by the NMD2 is used to prescribe Neurolenses, which provide a proprietary contoured lens design, as shown in Figure 1. This technology seamlessly varies the prismatic correction provided to the eyes at different distances, allowing clinicians to customize the lens correction for each individual patient depending on both patient needs and their clinical findings. The NMD2 provides a Neurolens value at the end of the measurement which corresponds to the distance prism prescription of the patient. Clinicians can readily use this value as a guideline to treat their patients. Unlike a standard prism, the Neurolens contoured prism design allows clinicians to treat their patients with a distance prism correction and additional correction at near.

Do small Neurolens prism corrections provide any benefit?

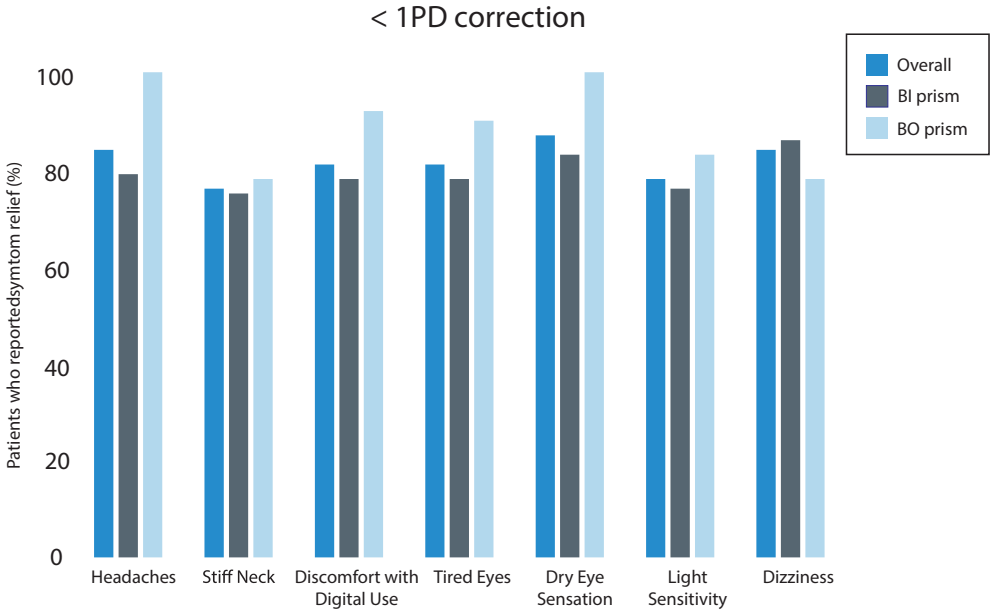

Figure 2: Proportion of patients who reported improvement in symptoms post wearing less than 1PD Neurolens correction.

Across multiple clinical practices, Neurolens prism corrections of 1PD and 2PD prescribed based on the Neurolens value have proven very successful in delivering a very high level of symptom relief for patients with various DVS related symptoms, such as headaches, neck pain or discomfort with computer use (Lifestyle Index Survey). Patient survey results post 60-day Neurolens wear were collected from individual practitioners across the country.

Overall, with a prism correction less than or equal to 1PD, 84% of the symptomatic patients reported improvement in their headaches post 60-day Neurolens wear. About 76% of Neurolens wearers reported improvements in neck pain, and 81% felt improvement in their eye tiredness or eye discomfort with computer use, commonly reported symptoms after prolonged near digital work. Similar symptom score improvements were found with both base in and base out corrections (Figure 2). Also observed were the symptom score improvements with a prism correction less than or equal to 2PD. With a 2PD Neurolens correction, 86% of the symptomatic patients reported improvement in their headaches post Neurolens wear. About 77% of Neurolens wearers reported improvement in neck pain, and 80% reported improvement in eye tiredness and 83% reported improvement in eye discomfort with computer use.

Conclusion

Eye misalignments are one of the most common causes of DVS related symptomology. There is a common misconception that only patients with large phorias or fixation disparity associated with other clinical signs suffer from visual discomfort. However, there is abundant evidence that there is no correlation between the magnitude of phoria and severity of the symptomology. Commercial data collected by Neurolens clearly shows that patients who received small amounts of prism correction reported significant improvements in their DVS symptoms such as headaches, eye strain or fatigue. The Neurolens Measurement Device, Gen 2 (NMD2) and Neurolenses, with customizable contoured prism design, provide a comprehensive way to accurately diagnose and treat Digital Vision Syndrome (DVS), allowing patients to lead a comfortable digital life.

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A New Treatment for Refractory Chronic Daily Headache

by

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Patients who experience headaches on a daily or almost daily basis and who have been unresponsive to the wide range of commonly prescribed headache treatments are said to suffer from Refractory Chronic Daily Headaches (CDH).

Common treatments today include the use of two or more "preventive medications" such as anti-seizure and anti-hypertensive medication, daily or near daily triptan medications (which increase serotonin release and block the release of neuropeptides in the trigeminal nerve), long-acting opioids, botulin toxin injections and nerve blocks (Robbins, 2014).

It is widely believed that chronic daily headaches originate in the brainstem through an interaction with the trigeminal nerve, the major pain pathway to the head and scalp (Mayo Clinic). In this paper we propose a previously undescribed pathophysiologic mechanism for CDH. Our hypothesis is that many patients who experience CDHs suffer from a form of visually induced trigeminal dysphoria and that the primary source of this dysphoria is untreated ocular misalignment.

We will discuss a treatment that utilizes spectacles with contoured prismatic correction and review data from a prospective pilot study that demonstrates the efficacy of this treatment in a subset of patients with CDH.

Methods

This study was conducted from September of 2012 to June of 2013 through the joint efforts of Neurology Associates, LLC and the offices of Dr. Jeff Krall in Sioux Falls, South Dakota. Candidates for this study were a highly selected group of individuals who suffered from refractory CDH. Interviews were conducted prior to testing. Individuals who gave a history of long-standing daily or almost daily headaches and who were resistant to other traditional therapeutic modalities underwent testing using a new proprietary testing device, called the Neurolens® Measurement Device.

A brief description of the Neurolens Measurement Device:
The Neurolens Measurement Device is a novel device, designed to measure binocular misalignment of the peripheral and central visual tracking systems. With this device, coordination of central binocular vision is tested first and measured without peripheral stimulation. Two independent central dots viewed at optical infinity are introduced on the measurement device viewing screen while the eyes are alternatingly occluded. If there is no imbalance of central fusion, the dot appears stationary during alternating ocular occlusion. If there is an imbalance of central fusion (a phoria), the central dot seems to dance as each eye moves to fix on the central dot following alternating occlusion. The Neurolens Measurement Device tracks the movement of each eye and automatically relocates the targets until no perceived movement of the central target or eye movement is detected. Horizontal misalignment of central fusional balance is then measured in pixels. Once neutralization is accomplished, the central dot is seen as stationary during alternating occlusion.

With the central dot visible and aligned with central fusion, several very compelling peripheral targets are then introduced independently to both the right and left eyes. These independent targets stimulate cortical fusion of one's peripheral field of vision due to their size and movement while allowing central vision to remain monocular. Any change in binocular alignment of the central vision is in response to fusion from peripheral binocular stimulation. If there is no disparity between the alignment of central vision and the peripheral alignment of the fused binocular images, the central dot remains stationary. If there is disparity between central fusion and the alignment of the peripheral tracking system, the dot begins to dance and vibrate.

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This imbalance is then tracked and the Neurolens Measurement Device automatically relocates the central target to align with the center of peripheral fusion. The deviation is measured in pixels on the monitor. This procedure is then repeated to measure the central and peripheral alignment of objects viewed at near.

Measurements taken from the Neurolens Measurement Device were then used to guide the manufacture of glasses with contoured prisms, designed to correct the measured imbalance. Patients found to have an imbalance based on evaluation with this instrument were entered into the study and were given spectacles with the calculated contoured prismatic correction. A unique proprietary manufacturing technique allows the power of the contoured prismatic correction to vary from distance to near vision.

The primary measure of efficacy in this study was the validated Headache Impact Test (HIT6) score (Yang, 2011). This questionnaire, which quantitates severity of headache symptoms, was performed before and after treatment. In addition, demographic information, including age, gender and duration of follow-up at the time of the post treatment testing, was collected.

Results

Data Analysis Overview

186 patients with severe headaches for which other treatments were ineffective were enrolled in this study. Patients received Neurolens spectacles with contoured prismatic correction, based on measurements from the Neurolens Measurement Device, for treatment of headache symptoms.

Of the 186 patients, 7 were lost to follow-up. Of 179 patients with follow-up data, the estimated mean decrease in HIT6 score was 7.64 units, with a 95% confidence interval of (6.46, 8.82). The two-sided p-value against the hypothesis of no-effect was highly statistically significant with a P-value < 0.0001. Multivariate regression models indicated an association of change in HIT6 score with initial HIT6 score. Self reported efficacy indicated that 146 of the 179 patients (81.6%) had a positive response to the treatment. In addition 69.66% of patients stated that they had reduced headache medications since wearing Neurolenses.

Characterization of study population

PATIENTS WITH FOLLOW-UP (N=179)
The average age of the study cohort was 39.7, where the youngest participant was 14 and the oldest 74. The study cohort was primarily female (n=144, 81.6%). 84.4% of the study cohort had an initial HIT6 score of 60 or higher, with a mean HIT6 score of 64.7 (SD 5.8). The mean days to follow-up were 88.2 (SD 91.4) and the median was 51. The minimum days to follow-up was 12, and the maximum was 411.

PATIENTS LOST TO FOLLOW-UP (N=7)
The average age of the cohort lost to follow-up was 37.9, where the age ranged from 20 to 50. 6 of the 7 patients were female (85.7%) and 6 of the 7 patients (85.7%) had an initial HIT6 score of 60 or higher, with a mean HIT6 score of 66.0 (SD 9.2). Overall, the patients lost to follow-up were very similar to the study cohort, indicating that there was likely no substantial bias introduced through loss of follow-up.

Review of Results

The following tables and plots demonstrate several facets of the data. **Figure 1** demonstrates patients' responses to the basic question: "Headaches are _____ after wearing lenses". This question was asked before and after treatment.

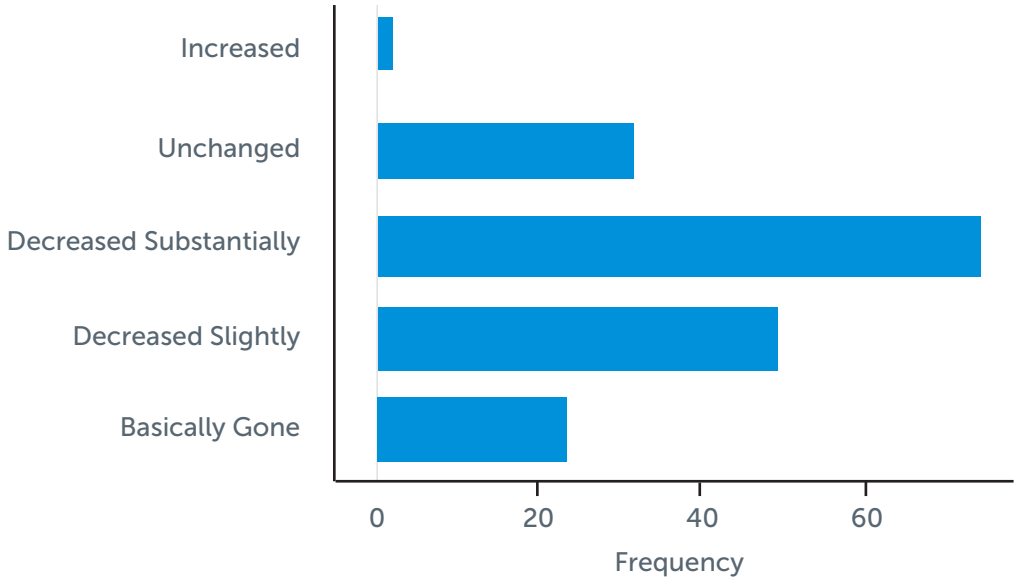

Figure 1: Relative Severity of Headaches Pre and Post-treatment

The results are also tabulated below:

Basically Gone	Decreased Substantially	Decreased Slightly	Unchanged	Increased
23 (12.8%)	74 (41.3%)	49 (27.4%)	31 (17.3%)	2 (1.1%)

Table 1. Relative Severity of Headaches Pre and Post-treatment

Of the 179 patients only 33 did not respond indicating a positive response rate to treatment. Positive responses regarding reduction of headaches were given in 81.6% of patients.

Figure 2 is a graphical depiction of the reallocation of patients to generally lower categories of symptoms following treatment.

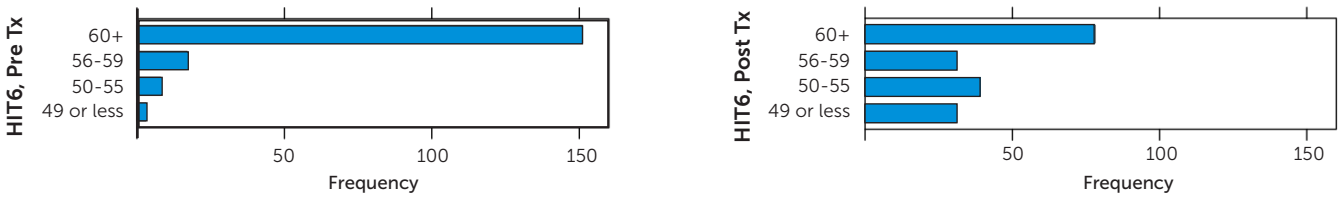

Figure 2: Reduction of Severity of Headaches Pre and Post Treatment

This is also illustrated in **Tables 2-4** below, which quantify the reallocation of patients to lower HIT6 score categories.

49 or less	50-55	56-59	60+
3 (1.7)	8 (4.5)	17 (9.5)	151 (84.4)

Table 2. Initial HIT6

49 or less	50-55	56-59	60+
31 (17.3)	39 (21.8)	31 (17.3)	78 (43.6)

Table 3. Final HIT6

	49 or less	50-55	56-59	60+
49 or less	2 (66.7)	0 (0)	1 (33.3)	0 (0)
50-55	2 (25)	4 (50)	1 (12.5)	1 (12.5)
56-59	8 (47.1)	2 (11.8)	3 (17.6)	4 (23.5)
60+	19 (12.6)	33 (21.9)	26 (17.2)	73 (48.3)
Total	31 (17.3)	39 (21.8)	31 (17.3)	78 (43.6)

Table 4. Initial HIT6 (Row) vs. Final HIT6 (Col)

Figures 3 and 4 illustrate the relationship of change in HIT6 score as a function of the initial HIT6 score.

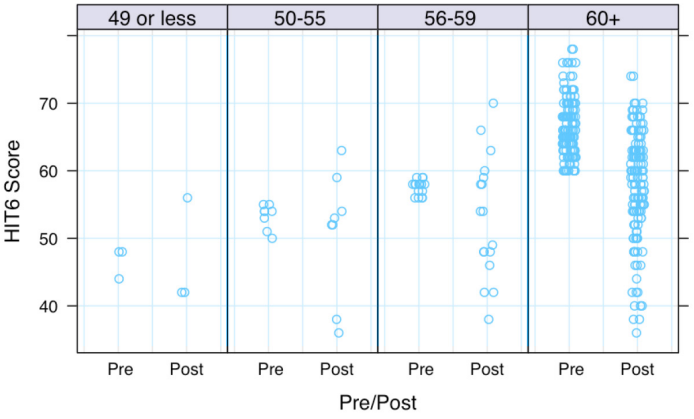

Figure 3: Change in HIT6 score as a function of the initial HIT6 score.

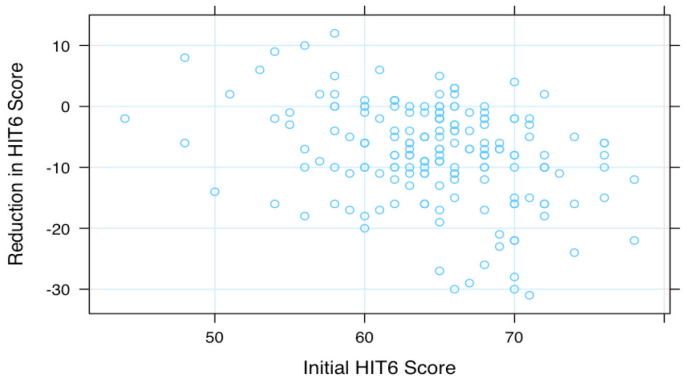

Figure 4: Scatter plot of HIT6 difference from pre to post treatment vs. Initial HIT6 Scores. These data indicate that the reduction is roughly linear with initial HIT6 score.

Figure 4 indicates that the reduction is roughly linear with initial HIT6 score.

Figure 5 indicates that the magnitude of change in HIT6 is similar between males and females. The overall mean difference in HIT6 by Pre/Post treatment was 7.64 with a 95% confidence interval of (6.46, 8.82). The two-sided P-Value against a null hypothesis of no effect was <0.0001

(Note that since this is a population for which other treatments were ineffective, the null hypothesis of no effect is the appropriate null hypothesis to test).

A multivariable linear regression was performed to assess the following: relationship of change in HIT6 by Initial HIT6 (continuous), gender, age (categorized by quartile) and follow-up days (categorized by quartile).

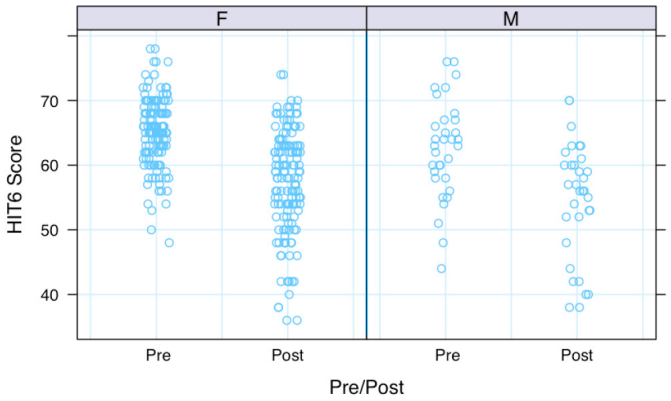

Figure 5: Pre and Post HIT6 scores separated by gender. These data suggest that the magnitude of change in HIT6 is similar between males and females.

Table 5 lists the ANOVA table describing the overall effect of these factors, with Age and Initial HIT6 score statistically significantly associated with change in HIT6. The significance of the age factor was driven largely by a smaller estimated difference in the 40-49 group. For initial HIT6 it was estimated that the HIT6 difference would be 4.92 units larger for an initial HIT6 score that was 10 units higher.

Factor	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Initial HIT6	1	1266.976	1266.976	23.18856	< 0.001
Gender	1	49.73542	49.73542	0.910272	0.341397
Follow-up Days	3	151.9422	50.64741	0.926963	0.429049
Age	3	762.0053	254.0018	4.648813	0.00377
Residual	170	9288.458	54.63799	NA	NA

Table 5. ANOVA table for multivariable model

Study Strengths and Limitations

Strengths

The strengths of the study include that it incorporated a large number of patients (n=186) with minimal loss to follow-up (n=7). Those that were lost to follow-up were demographically (and clinically, as measured by their HIT score) very similar.

The study population contained patients for whom other treatments were ineffective, providing an opportunity to demonstrate efficacy in a challenging population. The composition of the study population (age, gender, initial HIT6 score) was comparable to existing studies helping to facilitate cross-study comparisons.

Limitations

The study was a one-arm study, so a direct comparison to existing treatments was not possible to control for potential experimental confounders or concurrent coincidental effects. The study was somewhat observational in nature, whereby facets such as strict inclusion criteria or fixed follow-up times was not employed.

Summary of data analysis

The study demonstrated a mean reduction in HIT6 scores of 7.64 that was highly statistically significant ($p < 0.0001$) and had a narrow 95% confidence interval (6.64, 8.82). These results are highly suggestive that the treatment is efficacious in a population for whom other conventional headache treatments were ineffective, a fact that is further substantiated by the high treatment response rate of 81.6% (146 of 179). The data further show that patients who suffered from the most severe headache symptoms reported the greatest benefit in terms of symptom relief.

Discussion

This paper describes a pilot study conducted to evaluate a new treatment for patients with Refractory Chronic Daily Headaches (CDH). Treatment involves the use of spectacles with a contoured prism correction. The basis of the treatment is the hypothesis that one pathophysiologic mechanism for CDH may be chronic irritation of the trigeminal nerve caused, not only by uncorrected heterophorias and deficiencies of accommodative convergence, but also by imbalances of the peripheral and central visual tracking systems. In order to understand the science that serves as the foundation for this hypothesis, it is useful to review what is known about the relationship between peripheral and central visual processing, saccadic and smooth pursuit eye movements, peripheral and central visual tracking, trigeminal nerve mediated extraocular muscle proprioception and CDH.

Overview peripheral and central vision

The evolution of the visual system of vertebrates represents a delicate balance between the biologic advantages of self-preservation and food acquisition. Creatures that graze, but are preyed upon by more aggressive species, have eyes on the sides of the head to provide a panoramic view of their surrounding.

Human beings, living as hunters and gathers, evolved a visual system with eyes forward that optimize binocularity, visual tracking and acuity (Duke-Elder, 2013). The integrative "software" of the human brain gives one the illusion that vision is clear in all fields of gaze. This, however, is an illusion. Unlike a digital photographic image that provides a uniformity of detail and clarity because of a uniformity of pixel distribution, human vision is constructed of two concentric circles with higher levels of clarity existing only in the center of gaze.

This central clarity reflects the high density of photoreceptors clustered in the fovea. The peripheral circle of vision is less clear because of the rapid drop off of photoreceptor density in the peripheral retina.

When one looks at one's hand at arm's length, the size of the thumbnail is roughly the size of our foveal image (Godlove, 2013). Clarity of the vision drops off precipitously outside this small central circle. Roughly one degree away from the area of central vision, visual acuity is reduced by 50% (Green, 1970). It has been demonstrated, moreover, that less than one ten-thousandth of the total visual field can be processed with foveal clarity by the brain at one time (Carpenter, 1988).

In order to allow functional vision in a world of constant motion, the eye must move constantly with the peripheral circle of vision serving as a primary tracking and homing device. Peripheral tracking brings objects of regard close enough to the center of vision for the central tracking system to capture the image and provide enhanced clarity (Duke-Elder).

Understanding the relationship between peripheral and central visual processing systems

The peripheral vision develops before central vision in human infants. At birth, myelinated fibers form rod cells of the peripheral retina course along the peripheral aspects of the optic nerve. These fibers link to the visual cortex as well as the mid-brain and thalamus. Central fibers originate from the macula, mostly from cone cells, and are not myelinated at birth. This absence of myelination accounts in part for the observation that infants lack clarity of vision in early life.

The macula fibers course along the central aspect of the optic nerve and link to central areas of the visual cortex (Padula, Munitz, Magrun, 2012).

Unlike central vision, peripheral visual processing is largely a preconscious activity (Schneider, 1967). Lower vertebrates such as amphibians and reptiles have visual systems that are primarily peripheral in nature and respond almost solely to movement. Often sited research studies have demonstrated that a frog placed in a box with stationary dead flies will starve; whereas the same frog presented with a dead fly placed on a moving string will instantly detect and consume the fly (Lettyin, 1959).

The complex coordination of preconscious peripheral visual processing and more conscious and object-oriented central vision is a hallmark of the more highly evolved visual systems of primates. Preconscious awareness of movement elicits almost instantaneous redirection of the eyes and localization of the object of regard.

As Padula has stated, the coordination of the two visual systems "becomes the grounding or background relationship for the higher visual processes of perception and cognitive function. Without the ambient (i.e. peripheral) visual process, the visual world would become fragmented and isolated in detail" (2012, p.7). Aside from detection of movement of objects, the peripheral system links to the mid-brain to provide a sensorimotor feedback loop to many areas of higher cortical functions (Nelson, 2007). Coordination with the mid-brain provides for stabilization of visual images not only during the movement of the objects but also with movement of the head (Padula, 2012).

The more primitive, preconscious peripheral visual system helps us to detect danger, coordinate motor function, and understand our position in three-dimensional space. It is also fundamental to our ability to track moving objects and direct our central vision to objects of interest or concern. The central system helps us to bring attention and concentration to specific objects and provides us with the ability to derive additional information relating to the details and patterns of objects.

Saccadic and smooth pursuit eye movements and their relationship to peripheral and central visual processing
The visual system is constantly faced with two conflicting demands. The first is the need to move objects of interest from the peripheral retina to the central retina in order to bring images into sharper focus. The second is the need to hold objects still, so they can be better visualized (Godlove, 2013).

Image movement on the retina results in visual blur. As a visual image moves across the retinal surface, the time needed to convert light energy into a high quality neural impulse is reduced. Primates in general have been shown to be relatively slow in transducing light information at the retinal level (Carpenter).

Saccadic eye movements provide extremely quick readjustments of eye position. The primary function of saccadic movements is to shift objects of concern from peripheral retina to the area of central vision. Smooth pursuit eye movements then take over. The primary function of smooth pursuit movements is to stabilize images in order to provide greater clarity.

Smooth pursuit eye movements track more slowly and compensate for motion of the visualized object, thereby reducing blur (Krauzlis, 2004). Smooth pursuit movements, therefore, are more of a "gaze holding" than a "gaze moving "eye movement (Godlove).

The coordination and synchronization of the saccadic and smooth pursuit eye movements, therefore, would appear to be critical, if the eye is to provide both an effortless transfer of images from the peripheral to central vision, and the stabilization of images centrally.

Trigeminal nerve mediated extraocular muscle proprioception
The existence of proprioceptive fibers exiting extraocular muscles and carrying information to the trigeminal nerve is well established (Ruskell, 1983; Atasaver, 1992; Weir, 2006). Retrograde tracer studies, using horseradish peroxidase, have demonstrated that afferent fibers from the oculomotor nerve course through the ophthalmic branch of the trigeminal nerve and enter the trigeminal ganglion (Atasever). Clinical observations, moreover, confirm the proprioceptive functions of the trigeminal nerve as it relates to extraocular eye movements (Weir).

Patients who have undergone trigeminal nerve ablation either surgically or with thermo-coagulation as treatment for trigeminal neuralgia have been shown to exhibit difficulty with visually guided eye movements (Steinbach, 1986)

Patients suffering from active herpes zoster ophthalmicus also have been reported to demonstrate problems with visual spatial localization (Campos, 1986).

Proposed relationship between peripheral and central visual tracking, trigeminal nerve mediated extraocular muscle proprioception and Trigeminal Dysphoria

It is widely believed that chronic daily headaches occur when activated trigeminal nerve fibers trigger a dilation of blood vessels located on or near the surface of the brain. Activation of the trigeminal nerve is believed to occur from a host of causative factors, including an alteration of sleep-wake cycle; missing or delaying a meal; medications that cause a swelling of the blood vessels; daily or near daily use of medications designed for relieving headache attacks; bright lights, sunlight, fluorescent lights, TV and movie viewing; certain foods; and excessive noise (NHF).

The authors of this study believe that a subset of chronic daily headache patients, particularly those who have proven to be unresponsive to traditional therapeutic modalities, suffer from imbalances of ocular motility including misalignment of the peripheral visual tracking, and central vision fixation. Our hypothesis is that this lack of coordination results in an over stimulation of the trigeminal nerve. The proprioceptive fibers of the extraocular muscles have afferent nerve branches to the trigeminal nerve. These proprioceptive fibers are activated by constant attempts to rectify an imbalance of alignment of binocular peripheral and central tracking. This activity is believed to cause an over stimulation of the trigeminal nerve, which over activates the trigeminal nucleus caudalis. The trigeminovascular system links the trigeminal nerve and the upper cervical region via the trigeminal nucleus caudalis, causing trigeminal dysphoria with pain referred to the head and neck.

Conclusion

Participants in this study were a highly selected group of patients who suffered from CDH. They represent a group of individuals who had failed to receive relief of their symptoms after trying most, if not all, other therapeutic modalities.

All patients were evaluated using a new proprietary device called the Neurolens Measurement Device. This device is designed to measure the contoured prismatic correction needed to create total binocular alignment and guides the manufacture of glasses with contoured prisms, designed to correct the measured imbalance. Patients found to have an imbalance based on evaluation with this instrument were entered into the study and where given spectacles with the recommended contoured prismatic correction.

A unique proprietary manufacturing technique allows the power of the contoured prismatic correction to vary from distance to near vision. Self reported efficacy, utilizing a validated metric for gauging severity of headache symptoms (HIT6), indicated that 146 of the 179 patients (81.6%) had a positive response to the treatment. The two-sided p-value against the hypothesis of no-effect was highly statistically significant with a P-value < 0.0001.

The data further show that those patients who suffered from the most severe headache symptoms upon entering the study reported the greatest benefit in terms of symptom relief.

Based on the findings of this study, we believe that this new therapeutic approach for the treatment of severe CDH that involves no drugs, injections or medications of any kind should be more widely considered.

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Prism Adaptation with Neurolens

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Highlights

- Patients with no binocular vision dysfunction generally adapt to prisms, as they have a normally functioning vergence mechanism.
- Patients who are symptomatic are less likely to adapt to prism and will benefit from a prism correction.
- 6 out of 10 Neurolens wearers did not show any significant sign of prism adaptation.
- The mean change in the Neurolens prism prescription was less than 1/3rd of a prism diopter over time and the stability of the Neurolens prism prescription improved over time.

Abstract

An alignment response to an object of interest in the real world comprises of outputs from two components of the vergence mechanism, a fast (reflex) and a slow (adaptive) responding controller which have different temporal characteristics. Previous studies have reported that the strength/magnitude of the response of this slow adaptive component often correlates with the presence of symptomology in patients with binocular vision dysfunction (BVD). Patients with no binocular vision dysfunction generally adapt to prisms, as these patients tend not to be symptomatic and have a normally functioning vergence mechanism. However, patients who are symptomatic are less likely to adapt to prism and will benefit from a prism correction. The combination of inconsistent clinical practices, inability to accurately measure and represent patients' symptoms, and variability in the individual's ability to adapt to a prism would leave the clinician with a lot of unanswered questions which make them hesitant to prescribe a prismatic correction to their patient. The Neurolens process provides a simple, accurate and repeatable way to assess an individual's binocular vision which would ultimately help the clinician treat and diagnose that patient's condition with confidence. 6 out of 10 Neurolens wearers did not show any clinically significant sign of adaptation to a Neurolens correction. This is significantly lower than the adaptation frequency reported with standard prisms in the previous study (80%) implying that the Neurolens process is more stable and effective than a standard prismatic correction calculated based on the traditional prescribing guidelines. The mean change in the prism prescription was less than 1/3rd of a prism diopter over time and the stability of the prism prescription improved over time.

Vergence Mechanism and Prism Corrections

Optical prisms are one of the most commonly employed treatment modalities to correct binocular (vergence) dysfunctions involving eye misalignments, including heterophorias, fixation disparities and tropias. There is an inter-clinician variability in prism prescribing guidelines which is driven by factors such as clinicians' opinion or knowledge on prism corrections and binocular vision. There is anecdotal clinical evidence on the efficacy of prism treatment on patients with various binocular dysfunctions. Some clinicians also argue that prism corrections are not good given an individual's ability to adapt to prism corrections. This lack of consensus is coupled with a lack of evidence-based clinical standards on how to effectively use prisms to correct binocular dysfunctions[1]. There are three main reasons why a prism correction tends to be unstable: (i) individual differences in a person's innate ability to adapt to a prism; (ii) presence of a latent eye misalignment that may not have been detected during the initial eye examination; and (iii) our inability to measure an accurate and repeatable clinical parameter that assesses the vergence mechanism and consistently represents the symptomatology experienced by the patient.

The vergence system is unique, in terms of its cross-coupled relationship with the accommodative mechanism and its ability to adapt naturally. Broadly speaking, an alignment response to a stimulus in the real world comprises of outputs from two components of the vergence mechanism: a fast (reflex) and a slow (adaptive) responding controller.

Although the neural correlations of the two components are not well established, several experimental studies confirmed their response patterns along with their temporal characteristics[2]. When a person shifts their fixation from distance to near, the initial response to that new object of interest is initiated by the reflex system. If the near fixation is prolonged, the slow adaptive system takes over the response to maintain alignment without any perceivable discomfort. Previous studies have reported that the strength/magnitude of the response of this slow adaptive component often correlates with the presence of symptomology in patients with binocular vision dysfunction (BVD)[3].

The ability to adapt to prism also correlates with this overall ability to adapt[3]. In other words, people with a better functioning adaptive controller tend to adapt more to prism corrections. Patients with no binocular vision dysfunction generally adapt to prisms, as these patients tend not to be symptomatic and have a normally functioning vergence mechanism[3]. However, patients who are symptomatic are far less likely to adapt to prism and far more likely to benefit from prism correction[3, 4]. That said, it is critical to remember that some patients may have latent deviations that require more than one prism correction before they are completely compensated and stable. In fact, a previous study reported that about 80% of individuals in a sample of 46 symptomatic subjects adapted to a standard prism and needed a change in their prescription over the next few years[5].

Furthermore, clinicians tend to use subjective and imprecise techniques to measure patients' binocular vision, including phoria, fixation disparity or fusional vergence. Some practitioners measure any one of these parameters to decide the corrective option while others tend to employ a combination of measurements before deciding the appropriate treatment for their patient's condition. Multiple studies have concluded that none of these clinical measurements correlated well with the subjective symptomology experienced by the patients[6]. This combination of inconsistent clinical practices, inability to accurately measure and represent patients' symptoms and variability in an individual's ability to adapt to a prism would leave the clinician with a lot of unanswered questions, making them hesitant to prescribe a prismatic correction to their patient. It also raises two critical questions:

- What is the best way to identify and treat patients with BVD?
- If there is a better way, do we have evidence to understand if—and to what extent—prism adaptation contributes to this issue?

The Neurolens process: a better way to do BV testing

Figure 1: The Neurolens process

The Neurolens process consists of three major components: a lifestyle index, a Neurolens measurement and a Neurolens correction (figure 1). Potential patients who can benefit from a Neurolens correction will first be identified using a simple questionnaire (Neurolens lifestyle index) which quantifies common symptoms associated with binocular vision dysfunction, such as headaches. Symptomatic patients would then undergo an eye alignment measurement using the Neurolens Measurement Device, Gen 2 (NMD2).

The NMD2 is an objective, accurate, precise, simple and efficient way to measure eye alignment and calculate a patient's AC/A[7]. The NMD2 does not rely on subjective responses, thereby eliminating both clinician and patient biases or variabilities. The objective measurement of the NMD2 is achieved by employing an eye tracking system that robustly tracks patients' eyes in a continuous fashion while the eyes are being dissociated and associated. The NMD2 is simple in the sense that it employs an iterative procedure, which takes the misalignment measurements into account and provides a final Neurolens prism correction (Neurolens value). Unlike prescribing guidelines such as Sheard's Criterion, Percival's Rule or the 1:1 rule, the Neurolens value utilizes a proprietary algorithm that was developed based on patient outcomes across hundreds of thousands of measurements. The Neurolens value obtained by the NMD2 represents the distance prismatic correction that can be readily used by clinicians to treat their patients.

Neurolens correction involves a proprietary contoured lens design which seamlessly varies the prismatic correction provided to the eyes at different distances. This design allows clinicians to treat their patients with a distance prism correction and additional correction at near. Given that Neurolens doesn't provide the same prismatic correction across the lens—thereby eliminating the need to over-prescribe at distance to receive an appropriate correction at near—it is reasonable to expect that a patient's likelihood to adapt to this prism would also be limited. The Neurolens process provides a simple and repeatable way to assess binocular vision and treat patients with confidence.

Commercial data

To test the above hypothesis that patients are less likely to adapt to Neurolens contoured prism correction, commercial data was collected from Neurolens wearers who had at least one follow-up measurement, with at least one year having elapsed between the initial visit and the follow-up visit. A total of 1,183 Neurolens wearers that met these criteria were evaluated. 182 of these individuals had two follow-ups, and 30 had three follow-ups since receiving their initial Neurolens prescription.

Refractive and prism prescription after one follow-up

Group		HPRISM	VPRISM	OD-SEQ	OS-SEQ	NEAR ADD
Overall	Average change in Rx	0.19416737 Δ	0.045224 Δ	-0.10228 D	-0.09256 D	0.058115 D
(n = 1,183)	% Individual with no change in Rx	**52%**	**93%**	**43%**	**42%**	**80%**
	% Change in Rx =< 0.25PD	**62%**	**94%**	**76%**	**75%**	**91%**
Adults	Average change in Rx	0.19416737 Δ	0.045224 Δ	-0.10228 D	-0.09256 D	0.058115 D
(n = 637)	% Individual with no change in Rx	**51%**	**91%**	**42%**	**42%**	**92%**
	% Change in Rx =< 0.25PD	**63%**	**95%**	**70%**	**72%**	**92%**
Presbyopes	Average change in Rx	0.19279661 Δ	0.045339 Δ	-0.10265 D	-0.0928 D	0.058263 D
(n = 542)	% Individual with no change in Rx	**53%**	**90%**	**44%**	**42%**	**58%**
	% Change in Rx =< 0.25PD	**60%**	**92%**	**76%**	**76%**	**89%**

52% of individuals showed no change in their horizontal prism prescription; surprisingly, this was more stable than the percentage of individuals who showed no change in refractive error. There was not a significant difference in prism adaptation as a function of age; but overall, more presbyopes had no change in the prescription at the follow up visit. Overall, vertical prism prescription remained stable in over 90% of individuals.

Refractive and prism prescription after two or three follow-ups

Data after 1st follow-up (n - 182)					
Parameters	**HPRISM**	**VPRISM**	**OD-SEQ**	**OS-SEQ**	**NEAR ADD**
Average change in Rx	**0.306264 Δ**	**0.06044 Δ**	**0.023352 D**	**0.015797 D**	**0.054945 D**
% No change	**45%**	**93%**	**37%**	**35%**	**77%**
% Change =< 0.25PD	**58%**	**95%**	**77%**	**76%**	**92%**

Data after 2nd follow-up (n - 182)					
Parameters	**HPRISM**	**VPRISM**	**OD-SEQ**	**OS-SEQ**	**NEAR ADD**
Average change in Rx	**0.120165 Δ**	**0.04533 Δ**	**0.083104 D**	**0.085165 D**	**0.037088 D**
% No change	**57%**	**93%**	**37%**	**34%**	**80%**
% Change < 0.25PD	**61%**	**94%**	**74%**	**73%**	**91%**

45% of individuals showed no change in their horizontal prism prescription at the first follow-up and that number improved to 57% at the second follow-up, suggesting that the stability of the prescription improved over time. As shown before, prism prescription stability was better than the stability of the refractive error prescription. Overall, vertical prism prescription remained more stable in over 90% individuals.

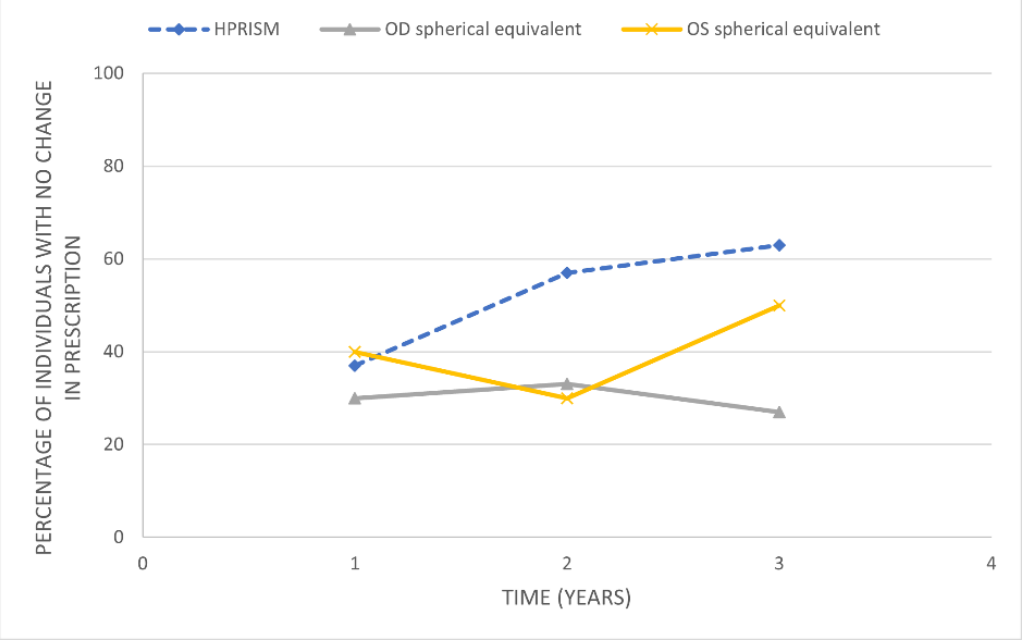

Figure 2: Percentage of individuals no change in horizontal prism (dotted blue line), along with OD and OS spherical equivalent (OD - grey and OS- yellow) were plotted as a function of time.

Evaluating those with three follow-ups since their initial Neurolens prescription, 37% of these individuals showed no change in their horizontal prism prescription at the first follow-up; that number improved to 57% at the second follow-up and to 63% at the third follow-up, further supporting increased stability from visit to visit. The mean change in the prism prescription was less than 1/10th of a prism diopter over time. As shown before, prism prescription stability was better than the stability of the refractive error prescription, which was found to be as low as 27-50% across different follow up visits.

Discussion & Conclusion

Unlike previous studies on prism adaptation[5], commercial Neurolens data collected from individual eyecare practices across the country indicate that only 48% of patients who received a Neurolens correction for the first time had a change in their Neurolens prescription at their first follow-up (after 1 or 2 years). It is important to remember that this change in prescription could be due to emergence of the latent deviation in the patient not detected during the initial testing. The stability of the Neurolens prescription improves over time, suggesting the eye misalignment—both manifest and latent—is accurately compensated over time. This could also indicate a change in the individual's vergence posture due to either an improving fusional vergence mechanism or prism adaptation. 80-85% of the patients who provided us a 60-day follow-up symptomology survey reported relief in their symptoms after wearing Neurolenses and were willing to recommend Neurolens to their friends and family. Therefore, we believe that most of these patients who reported symptom relief post Neurolens wear had an improved fusional vergence mechanism. So, do patients adapt to a Neurolens correction? Approximately 6 out of 10 patients did not show any sign of adaptation to a Neurolens correction as of their second follow-up. This is significantly lower than the adaptation frequency reported in the previous study (80%)[4], suggesting that the Neurolens process is more stable and effective than a standard prismatic correction calculated based on the traditional prescribing guidelines. As has been shown time after time, prism is a very effective optical tool used to relieve symptomology associated with binocular vision dysfunction. Given the lack of consensus on measurement and treatment guidelines, it is not surprising that most clinicians are hesitant to provide prismatic corrections to their patients who are likely to benefit from the treatment. The Neurolens Measurement Device (NMD), coupled with a customizable contoured prism design, provides a comprehensive and straightforward way to accurately diagnose and treat binocular vision dysfunction.

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Better Binocularity, Higher Productivity

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Digital Vision Syndrome and its Impact on Productivity

The modern digital lifestyle—coupled with a dramatic, COVID-driven shift to remote working and learning—has led to a dramatically-increased usage of digital devices for both leisure and work. In fact, in the US people are spending 8-12 hours a day on average using digital technology, including phones, tablets and laptops/desktops. This increase in screen time leads to an increase in the demand on our eyes' accommodative and vergence mechanisms, which constantly try keep our visual percept clear and single. This increased demand (stress) when sustained could eventually lead to visual disorders which manifest as headaches, eye strain or tired eyes. This association between visual disorders and digital usage is commonly referred to as Digital Vision Syndrome (DVS), or Computer Vision Syndrome (CVS). Recent studies revealed that the majority of digital screen users have reported some degree of symptomology—including headaches and eye strain—which significantly impact their productivity.[1]

Although the symptoms associated with digital usage are typically temporary, they can cause significant, recurring discomfort that can have a significant negative impact on a person's productivity. This person also may require frequent breaks and possibly even increased attention or oversight; both of which could further exacerbate the productivity challenges.[2]

One of most common causes of DVS symptoms are binocular vision disorders (BVDs) involving an issue with either the accommodative or the vergence mechanism. Typical treatment options for BVDs involve plus lenses, standard prisms (base in, out, up or down) or vision therapy. Traditionally, only symptomatic patients with considerable phoria and/or abnormally small fusion reserves were identified and treated for BVDs. There are several reasons why symptomatic patients with smaller phoria are often not treated. One of the primary reasons is the historical inability to accurately measure smaller eye misalignments. As a result, only patients with a larger phoric posture or reduced fusional reserves are diagnosed and treated, while individuals who could benefit from small prismatic corrections are overlooked. Further, prescribing guidelines such as Sheard's Criterion or Percival's Rule only identify symptomatic individuals with abnormally large phorias, reduced fusional reserves or both, while individuals who are considered to have "normal" phoric posture are either left undetected or treated for something else. Finally, there is a common, pervasive myth that the magnitude of phoria is correlated to the symptomology that an individual experiences.

Although it is standard practice for clinicians to measure eye misalignments such as phorias or fixation disparity, it has been difficult to accurately identify and treat phorias in small increments of 0.5PD or less until the launch of the Neurolens process in 2018. How has the advent of the Neurolens process transformed the treatment of BVD? What has the process of symptom identification, accurate measurement and novel treatment taught us? What clinical evidence is there that Neurolenses can relieve individual symptoms and improve productivity?

Neurolenses and Symptom Relief

The Neurolens process is comprised of three basic steps: a symptom screener—otherwise known as a "lifestyle index"—is used to gauge a patient's level of symptomology; the Neurolens Measurements Device, Gen 2 (NMD2) is used to accurately measure the patient's binocular health and provide prescribing guidance that their doctor can readily use to prescribe a correction; and finally, contoured prism technology is used to treat the patient and relieve their symptoms.

The NMD2 is an objective, accurate, precise, simple and efficient way to measure eye alignment and calculate a patient's AC/A.[3]

The NMD2 does not rely on subjective responses, thereby eliminating both clinician and patient biases or variabilities. The NMD2 is simple in the sense that it employs an iterative procedure, which takes the individual's measurements into account and provides a final, outcome-based Neurolens prism correction—or Neurolens value. The Neurolens value obtained by the NMD2 is used to prescribe Neurolenses, which incorporate a proprietary contoured prism into the lens design. Unlike a standard prism, the Neurolens contoured prism design allows clinicians to treat their patients with a distance prism correction and additional correction base-in at near.

Commercial data collected by Neurolens from individual optometry practices across the country clearly showed that patients who received even small amounts of prism correction reported significant improvements in their DVS symptoms.[4] Given the overwhelming evidence, it is safe to say that the Neurolens process provides a comprehensive but simple way to accurately diagnose and treat DVS, allowing patients to get both clear and comfortable vision. But, given that Neurolens technology reliably relieves these symptoms and the associated discomfort, can it also improve a person's productivity?

Neurolenses and Reading Speed

Correcting eye misalignments—and particularly fixation disparity—has been demonstrated to lead to improvement in binocular distance and near vision.[5] This has led to logical and prevailing assumptions that eye misalignments reduce the ability to perform daily tasks, especially at near. This obviously includes activities like reading a book or reading text on digital devices. Given this direct connection, it stands to reason that effectively correcting binocular vision with Neurolenses would have a positive impact on productivity. However, it is of course important to demonstrate this hypothesis and measure the level of impact more scientifically.

To achieve this, a rate-of-reading test was leveraged as a direct metric to gauge productivity level. To test the impact of Neurolenses on productivity, a double-masked parallel arm study was designed with two subgroups: Treatment and Control. Subjects who were identified as potential Neurolens candidates were randomly assigned into one of the subgroups. Each group consisted of 30 young adults. The Treatment group received a pair of Neurolenses with a prescription based on the practitioner's Rx using the subject's best corrected vision—and kept within half a prism diopter of the Neurolens value outputted from the NMD2. The Control group received a premium single vision lens which yielded the best corrected vision for the individual. Reading speed was assessed initially using the Wilkins Rate of Reading Test (WRRT). This test enables rapid measurement of reading speed using text passages that have no semantic content and demand minimal word recognition skills.[6]

Other tests during this initial visit included measurements typically performed during a routine optometric examination, including visual acuities, refraction, slit lamp, BV evaluation and fundus examination. If the individual did not have any clinically significant abnormality in the eye that would impact their vision, they were randomized into either the Treatment or Control group. Every individual enrolled in the study wore the randomized study lens assigned to them for 7±2 days. Reading speed was then re-evaluated after the wear-in period. Of note, this reading test was only given to individuals who could correctly read the words at 40cms.

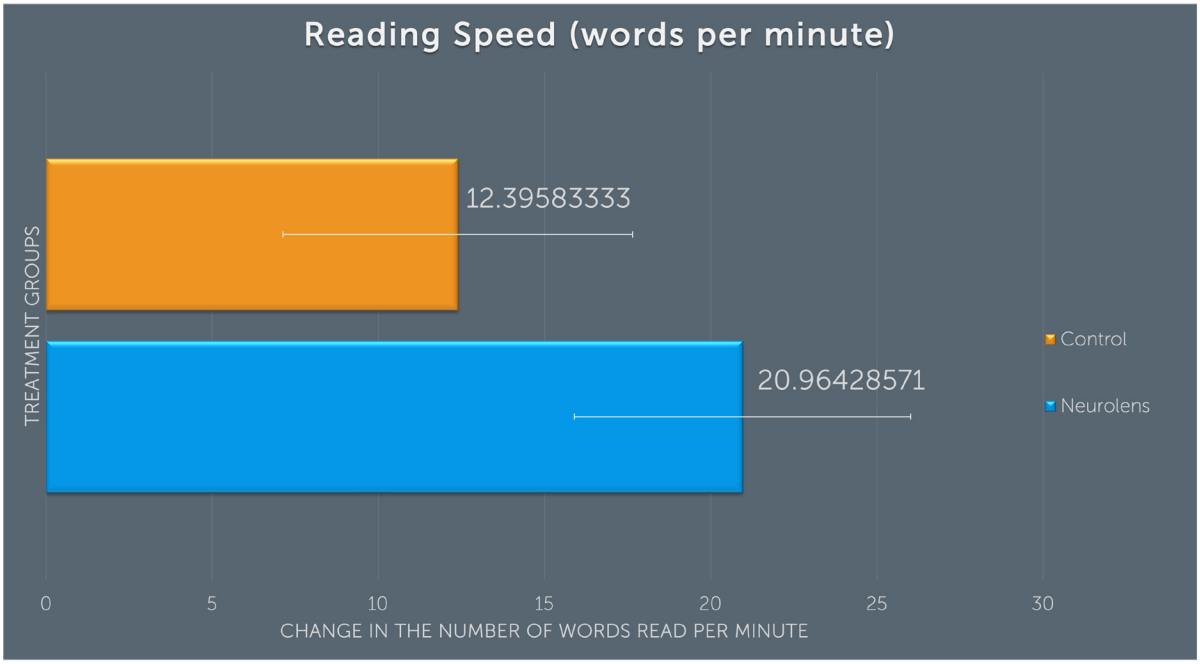
Procedure

Each qualifying study participant was tasked with reading aloud all the words printed on a reading chart—as quickly as possible, without errors. The investigator randomly chose one of the four versions of the chart (chart A, B, C and D). An online version of the chart was also developed, programmed so that the test would automatically close one minute after initiating. As the patient read the chart, the investigator noted each error by marking the score sheet above the word that was misread. After the one-minute test was administered, the investigator marked the score sheet with an oblique line (/) to indicate how far the patient was able to read in the allotted time.

The investigator then calculated the number of words correctly read per minute for each passage. This procedure was repeated twice using two different versions of the test and the final reading speed measurement was ascertained by taking the average of the two measurements. Errors typically impacted the overall measured words-per-minute, either by reducing the number of words correctly read, or by increasing the time taken to read them. So, an improvement in the reading speed would indicate that the patient had more comfortable vision while reading the chart and made less errors when reading.

Results

Of the 60 young adults enrolled into the study, 27 patients received the Control lenses and 28 received Treatment lenses—i.e., Neurolenses. Three patients were lost to follow-up. The two measurements taken at each visit were averaged and were compared between the two visits for all participants. ANOVA was used to assess the difference in the reading speed with the type of lens used (Control vs Treatment) and baseline reading speed as the two variables.



The mean (±SD) improvement in the reading speed with the Treatment (20.96 ± 13.06) and Control (12.39 ± 12.46) lenses were analyzed. ANOVA analysis revealed a statistically significant improvement in the reading speed with Neurolenses compared to the Control lens ($F = 4.45$; $p = 0.03$).

Conclusion

Clear and single binocular vision is essential for normal visual behavior. Our eyes' accommodative and vergence mechanisms achieve this normal visual behavior by focusing and aligning objects of regard in the real world. Increasing screen time leads to an increased demand (stress) on these mechanisms. Mounting evidence shows this leads to a breakdown of these systems causing symptomology. The discomfort caused due to these visual disorders could ultimately affect individual's productivity—with reading speed being a logical analog for productivity level while working or learning. This has significant economic implications, due to increased time needed to complete tasks and oversight required to keep productivity at acceptable levels.

Full digital well-being is only possible when an individual has both clear and comfortable vision. The Neurolens process helps clinicians accurately identify, measure and treat patients with DVS by not just relieving their symptoms but also by enhancing their productivity.

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Neurolens®: a game-changer for your patients and your bottom line

Rick Guinotte (CEO, Acquios Advisors/Acquios Alliance)

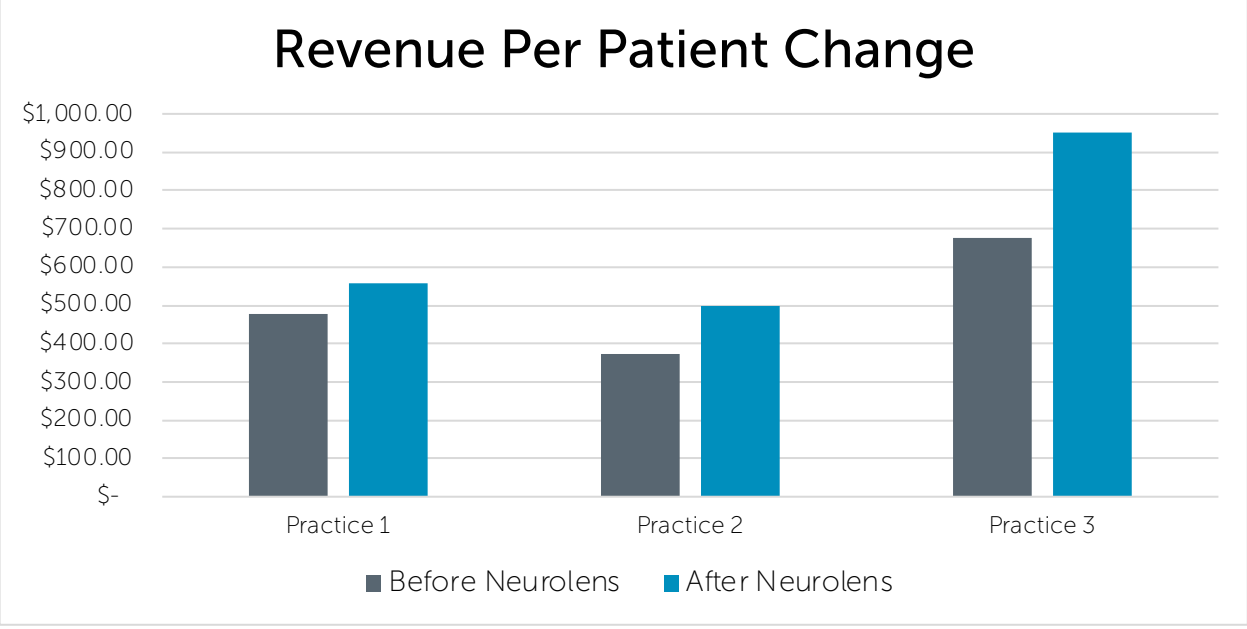
Background

Over the past few years at Acquios Advisors, we have seen a new technology enter the industry and quickly become a game changer for patients' quality of life. We have seen firsthand what a change this technology has brought to many offices around the country. That technology comes from Neurolens, an organization that has proven that it is—and will continue to be—an effective driver of success for practices seeking new technology and products to offer their patients.

I have worked with many clients who have invested in Neurolens; and when a client asks me if Neurolens is a good investment, the answer is easy. To drive the point home, I always advise them to begin surveying their existing patients to help them grasp the opportunity, i.e., the number of people that will benefit from this technology. Unquestionably, success with Neurolens technology ultimately rests on the doctor. In my opinion, this is the primary reason that the technology has been—and will continue to be—a sure-fire path to success for a doctor-driven practice. When I speak with clients about how Neurolens technology has impacted their practice, we review their statistics regularly. Over and over, from Connecticut to Texas and everywhere in between, we see one of every 4-5 first pairs of glasses ordered in these practices is a Neurolens. That's 20-25% of total spectacle lens sales.

To better understand the specific financial impact that Neurolens has on eyecare practices, we took a closer look at a few locations that have adopted the technology in recent years. One has had the technology since March 2018, another since December of 2019 and another invested in October 2020.

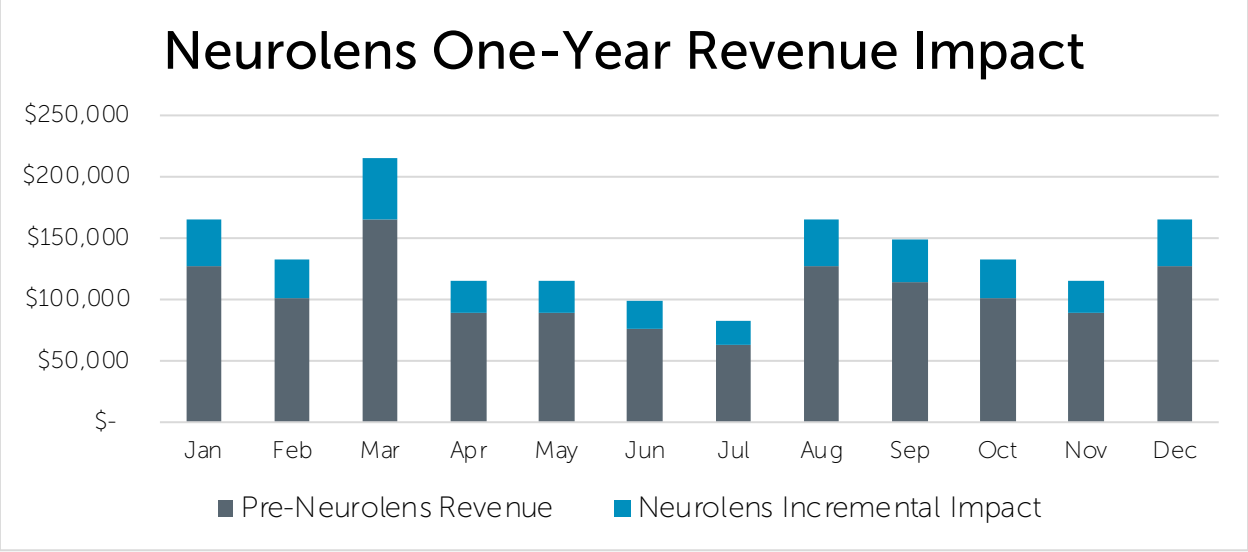
Fundamentally, there are two ways to increase your top line: see more patients or increase your revenue per patient. Our investigation has shown that this technology increases top line as well as bottom line in the most efficient manner possible. Neurolens makes it easy for a practitioner to increase their receipts by seeing the same or fewer patients per day while still increasing their bottom line. Specifically, the practices studied saw their revenue per patient (revenue collected divided by the number of comprehensive patients seen) improve from $476.00, $372.00 and $675.00 to $559.00, $500.00 and $950.00, respectively. Next, we'll take a deeper look at how this change impacted the practices from a financial standpoint.



Financial Impact Investigation

One of the many impacts of the pandemic is that it has forced eyecare providers to reduce the number of patients seen per hour and per day. As such, we directed many practices to measure their ROI on the number of vision plans they accepted, and the overall penetration of third party payers in their total book of business. Many optometrists were understandably hesitant to drop less profitable vision care plans for fear that their business would slide backwards. As a non-covered lens option, Neurolens has proven to many practice owners that patients will go outside their third-party plans for a life changing product when educated about the benefits. In fact, the price per transaction for a pair of Neurolenses in these three offices ranged from $650 to $1,000, with an average of $800.

This has an obvious accelerating impact on overall per-patient revenue. As alluded to above, the offices studied had average revenue per patient of $507.88 prior to adopting Neurolens technology. After implementing Neurolens, their average receipts per patient grew to $661.26, an increase of $153.38. To contextualize, a practice servicing 2,500 patients per year—or about 48 per week—while seeing patients four days per week (12/day), will experience revenue growth of $383,425.



Looking at the costs side of the equation, the list price for the neurolens Measurement Device, Gen 2 (nMD2) is $34,900. To put this in perspective, a practice generating $700,000 per year, with a pretax net percentage of 30%, (pretax net being money remaining after paying your Cost of Goods and all operating expenses minus Owner's compensation), the contribution margin will be about 70%, bringing the breakeven point to about $50,000. Contribution margin, simply put, is the money you need to generate to pay for the device, coupled with the costs of operating the device day-to-day. For example, staff time will need to be allocated to confirming appointments, conducting screenings and measurements, running the optical and so on. Of course, space and utilities used within the practice are part of the equation as well.

Based on the aforementioned average Neurolens transaction of $800, and a breakeven point of $50,000, this equates to 62.5 pair of Neurolenses sold. Conservatively assume one of every five first pairs of glasses sold is a Neurolens; to achieve the breakeven you only need to see 312.5 patients.

Neurolenses are also financially risk-free for patients, as the company extends a guarantee on their technology that providers are empowered to extend to their patients. If a patient is unhappy and/or dissatisfied with the product, the patient and practice are out zero dollars. This satisfaction guarantee not only protects the practice and patient from financial risk, it also demonstrates the level of confidence Neurolens has in the effectiveness of the technology.

Of note, the number of refunds reported by the offices reviewed in this sturdy were minimal and did not negatively impact the results or the ROI realized with this technology. In fact, several of the few patients who did elect to be refunded and refitted in traditional lenses later reported that they, in fact, did experience better visual clarity and comfort with Neurolenses than with the traditional lenses they were subsequently dispensed.

The practices studied also found that marketing Neurolens technology was simple and cost-effective. While marketing costs obviously vary by market, the offices studied reported that their marketing/advertising budgets were in the 2-4.5% range. Networking with medical professionals in the area is obviously a key opportunity for Neurolens providers. From headache clinics to neurologists to general practice MDs, building effective referral networks is especially important when you are implementing technology in your practice that provides an optical solution to a medical problem. Practices also found that direct-to-patient outreach through email, direct mail, social media, radio and newspapers effectively helped drive patients' interest in the Neurolens solution. This stands to reason given the high prevalence of related symptomology among the general population. By far the most successful marketing tactic employed is leveraging platforms such as social media to share testimonials from patients who explained how their overall quality of life has improved; not only through better vision, but also through the reduction—or even elimination—of frequent symptoms such as headaches.

Conclusion

Bottom line: Neurolens is a game changer. It's a rare thing when an investment can have a dramatic impact on your top and bottom line while also delivering proven patient outcomes and bringing new awareness and appreciation for the optometric profession. I have seen many practices—old and new, big and small—invest in Neurolens technology with great success. This technology is not only for the million-dollar businesses, but for all optometry practices. Your patients want to feel better, and they will invest in you and your practice if you provide solutions that help them do so.

If you have any questions about Neurolens,
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