The Contrast Between Classical and Behavioral Approaches to Vergence Eye Movements: A Personal Perspective

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ABSTRACT

Drs. Tara Alvarez and Mitch Schieman presented the latest research in convergence and accommodative therapy and their underlying neurological mechanisms at the 2021 COVD annual meeting. The behavioral model originated by Skeffington as it relates to vergence may seem to be at odds with this type of research, and with the classical model of vision. This perspective aims to inform the synergy between behavioral philosophy and classical analysis of vergence anomalies. Incorporating research into our clinical models and approaches yields further insights that can make significant differences in the lives of our patients.

INTRODUCTION

As an optometry student and young doctor there seemed to be two main dialogues in binocular vision and rehabilitation: What I was taught as the classical approach, and what my professors labeled as the behavioral approach. Developing a true understanding of binocular vision is a daunting enough task, let alone when it feels as if many ideas seem to conflict and contrast with each other. I’ve realized, however, that it isn’t exactly two dialogues but a spectrum of views on various aspects of the visual process. Often over various communication platforms such as VTODs on Facebook or the VTOD ListServe, a colleague either entering the world of vision therapy or presented with a challenging patient or parent will ask for studies demonstrating the efficacy of vision therapy. In response some colleagues may provide the CITT study, a handful of case studies from the OEP or COVD journals. Others will denounce the necessity of providing research, indicating that their personal clinical experiences suffice. Ideally, the best understanding of these issues emerges in a fusion of art with science, reflecting clinical as well as research perspectives.

At the annual COVD conference in 2021 Dr. Tara Alvarez and Dr. Mitchell Scheiman lectured on the neuromechanisms of convergence insufficiency and NIH funded studies surrounding CI. The lecture reviewed a collaborative study, The Convergence Insufficiency Neuro-Mechanism in Adult Population Randomized Clinical Trial: Design, Methods, and Clinical Data (CINAPS).

This insightful information seemed to be at the other end of a spectrum reflected in A.M. Skeffington’s four circle model of vision. Analysis of these two seemingly contrasting views has been addressed in various textbooks including Birnbaum’s Optometric Management of Nearpoint Vision Disorders, as well as Press, Taub, and Schnell’s Applied Concepts in Vision Therapy 2.0. Given that it can be a daunting challenge for students and new practitioners to assimilate this information, I thought it might be helpful to review classical and behavioral positions and ideas on vergence eye movements in light of the presentation by Alvarez and Schieman at the COVD annual meeting.
BACKGROUND

Vergence eye movements, specifically analysis of vergence eye movements and treatment of their disorders, seems upon first impression to vary depending on whether one adopts a classical or behavioral optometric approach. While both approaches to optometry have much to offer, during graduate school and even amongst colleagues, it seems that one has to make “either-or” decisions. The classical model with its reliance on numbers, graphs, formulae, and ratios is more amenable to research. This research can help with communication to the rest of the optometric profession as well as other professions. However, there are limitations to research, and studies on human behavior are always open to criticism. Scientific study will often fragment ideas to help create simple explanations. A classical model is data driven and less person driven. Patient care is nuanced and full of intangibles. Conversely, a behavioral approach lends itself to helping those who don’t fit into tidy classification schema or neat little boxes. A behavioral approach explores the underlying adaptive mechanisms which result in the constellation of signs and symptoms associated with vergence eye movement function and dysfunction.

Given this rather wide variation of ideas, neither the behavioral nor classical approach is “right” or “wrong”, and both are compatible with the understanding that vision therapy ultimately deals with changes in brain function. While we should be encouraged by the use of objective brain measurements as presented by researchers such as Alvarez and Scheiman, we also appreciate that a patient with convergence insufficiency (CI) is a fully formed human. By that I mean that a holistic or whole-person approach posits that training with an emphasis on vergence amplitude may not alleviate the fully litany of signs and symptoms with which a patient presents.

During my optometric education three methods were taught to us: Graphical Analysis, Analytical Analysis (OEP 21 point system), and Morgan’s System. Although we were taught about “The Analytical”, or the OEP method, we were not schooled in the protocol or how to utilize it. Most of our education included the labor-intensive plotting of graphical analysis and the use of Morgan’s norms with Duane’s classifications to diagnose and treat vergence issues. These constituted what was considered to be “classical”. OEP’s analytical method was held to be too abstract and less clinically practical.

If a practitioner takes a classical approach, the positive and negative fusional vergence range values are crucial data points. When one takes a more behavioral approach these findings are insights into stress adaptation, sensitivity to change and attention, and even language. However, in practice, I have found that these two concepts are more complementary than competitive, and comparing them gives us insight into the measurement and therapy of vergence eye movements. A classical approach and a behavioral approach can both be compatible with the belief that behavior affects vision and that vision affects behavior. Some of this is reflected even in classical information metrics such as the Convergence Insufficiency Symptom Survey (CISS).

If one is to compare and contrast the most recent work presented by Drs. Alvarez and Scheiman with Dr. A.M. Skeffington, it seems best to begin with the idea that optometry is both an art and a science. However, that can be a double-edged sword. While research in the visual sciences may be essential for the development of our profession, it may fragment an incredibly complex idea. By that I mean that it may be overly reductionist. In other words, studying convergence as reflected in changes during fMRI recordings can give us insight into the neuromechanics of a vision problem. Nevertheless it may not provide practitioners of vision therapy any benefit in understanding beyond the fMRI data. For example, I have found that a patient with a significantly reduced NPC might be able to converge with some discomfort on a pen-in-cap type activity. I also imagine
that I can train a patient to increase his or her positive fusional vergence ranges through pencil pushups. However, that may not transfer to meaningful changes in the patient’s day-to-day environment. It is the awareness of space, the kinesthetic feel of pointing one’s eyes inward, and the availability of selective attention on a central object that makes something like a Brock string bead sliding activity more useful. Expanding fusional vergence range numbers is one thing; training meaningful vergence ranges in space is quite another.

**Historical Perspectives and Research Caveats**

The evolution of therapy and therapy testing begins with the study of orthoptics. Javal may not have been the first to suggest a non-invasive approach for treatment of strabismus, but he was the first to document sequential steps in therapy. Worth noted that visual exercises don’t necessarily increase the power of the muscles but teach the nervous system to respond more readily. In 1928 Skeffington published “Procedure in Ocular Examination” and shortly thereafter he and others formed the Optometric Extension Program (OEP). Skeffington continued to lecture and write throughout the next few decades. Around the same time the American Orthoptic Council was formed. It seems at some point the behavioral model was taught in many optometry schools. However, as research into neurophysiologic control systems in vision science laboratories increased, it seems that a more structural model has taken hold in optometric education.

The split in the profession seemed obvious to me as a student. I had worked for an office which utilized tools and techniques considered to be behavioral, and not taught in optometry school. Now with the experience of a practitioner of nearly twenty years, the difference between a more classical/structural model and a behavioral model seems less of a divide and more of a spectrum of differential thought processes.

Clinical intuition, non-tangible aspects of our day-to-day professional lives, are essential for good clinical decisions. While this can be informed by trust in the scientific study of vergences consistent with “evidence-based medicine”, there are limitations. Most physicians use some treatments that don’t pass the gold standard, double blind, multisite, placebo-controlled studies. Few treatments pass this rigorous standard. Does that mean we shouldn’t search for newer or better treatments, or does it mean perhaps that the standard isn’t reasonable? The evidence-based medicine movement has been banging a drum about the need to improve the quality of research for more than 30 years, but, paradoxically, there is no evidence that things have improved despite a proliferation of guidelines and guidance. Part of the reason for that is the huge difference in conducting an exercise trial which can be as “blinded” as well as a placebo medication trial. Anyone doing exercise will typically know that they are in the exercise group. Even more challenging is that it is hard to make large groups of people do exactly the same exercise, whereas it is easier to make everyone take the same pill. These inherent problems often condemn exercise trials to being judged as of lower quality, no matter how useful or safe the exercise is. Professionally as well as personally, many of us have encountered variability in training and testing. Even an activity involving prism flippers, reading, and polarized suppression control can be subject to variability. Standards can be set in theory, but a slouched child working at ten inches at home is going to perform differently than a child supervised to maintain a working distance of sixteen inches in an office.

All that notwithstanding, and despite these concerns, we as a profession should demand good research and critically analyze their outcomes. Without studies behavioral optometry is at risk of following alchemy into obscurity. Alchemy is sometimes seen as the parent of chemistry, and is known as the mystic search for the elixir of life, or the search for a formula that can turn metals to gold. Alchemy did not evolve into modern chemistry; it stagnated and in time
science elbowed it to the side. Both science and alchemy however used the experimental method. Alchemists were unrelenting experimenters and, at one time, alchemy and chemistry were deemed of equal merit. Some people, such as Sir Isaac Newton and Robert Boyle, for example, were both alchemists and scientists. The difference between the professions has been transparency, debate, and consensus. As an example, Florin Perrier, who was Blaise Pascal’s brother-in-law, initiated a series of experiments in 1643 that resulted in the formation of Boyle’s Law in 1662. The ideas behind scientific experiments at this time were shared, documented, discussed, criticized, and repeated in an interminable cycle. Science was to be shared; alchemy was to remain insular.

Those of us who evaluate and treat binocular vision problems should consider this perspective to avoid becoming the alchemy of visual science. Studies may fragment a visual system that is perhaps best understood as whole, but they help create dialogue and debate in our profession. Just as with exercise studies, some behavioral optometrists may criticize the concept of placebo therapy, or whether the control population truly underwent “inert” procedures in training vision and reducing symptoms. For example, a vectogram procedure without increasing disparity vergence may improve a subject’s binocular fixation abilities even though it does not change the vergence demand. Might therapy to improve binocular fixation transfer to improved visual performance when reading? If so, is the procedure truly inert with regard to therapeutic intervention? I will re-visit this question below in the section on contextualizing vision research, as related to the CITT-ART study.

**Philosophical Foundations**

As noted earlier, the treatment of binocular vision is an art as well as a science. In that regard, the philosophy underpinning what is done cannot be ignored. For example, Skeffington’s approach has a philosophy behind it with direct clinical relevance on how to tap into a system that integrates every part of the individual from the eyes, to the ears, to the feet. Students of optometry would benefit from learning elements of this philosophical approach, and those who teach clinical “case analysis” would be well served in incorporating the intersensory integrative nature of the four circle model. While Skeffington’s approach was revolutionary in Optometry at the time, it had antecedents indicative of the intellectual divide in science at large.

In particular, René Descartes was an engineer of the revolution in scientific philosophy. Descartes taught us a new way of thinking, with metaphysical implications. In philosophy there is little agreement when it comes to any of our senses, let alone vision. Rationalists, representing one school of thought in philosophy, tell us to mistrust our senses. Only our intellect and its innate knowledge, they contend, can lead us out of the Socratic cave of darkness into the light. In contrast, empiricists believe that our senses can be trusted and it is only through them that we can understand the world we live in. Yet another group, the transcendentalists, hedge this a little bit. We have our senses and that is all we have, but we must also have faith in things unseen. One of the more famous transcendentalists was Henry David Thoreau. His journals demonstrated strong faith in the things seen. He seemed less interested in the nature of reality and more interested in the reality of nature. He felt that we don’t see things like a camera, but we see things in a conversation-like way. If we are looking at a mug for example, we don’t see the mug in front of us. Rather, from the light waves we perceive, we tell ourselves that the mug is there. Skeffington, Woolf, Kraskin, Manas, and other giants in the field of Behavioral Optometry may have never studied Thoreau directly, but they came to similar conclusions. Don Getz, a behavioral optometrist known for his proficiency in binocular vision, was fond of quoting Thoreau as having said that the flexibility of adaptability is a measure of one’s intelligence. It was a signature statement indicative of the fact that binocular changes must occur at the level of the brain before transferring to the environment.
Another core concept linked to Skeffington was the “emergence” of vision from intersensory integration, yet the idea of emergence did not originate with him. Although debates concerning the reality or precise nature of emergence are largely driven by contemporary scientific theorizing, the basic notion has quite a long history stretching back at least to Aristotle. John Stuart Mill and GH Lewis are considered the first philosophers to use the actual term emergence. They were two of a handful of philosophers in the British “emergence movement” during the late 19th century. Emergence as explained in A System of Logic involves a failure of the total to sum the elements. With the idea that the whole can mean more than a summary of parts, Skeffington was able to articulate the complexity of the visual system as being beyond its components.

The idea of emergence is elegant. Permit the following digression into music as an example of the concept in sensory systems at large, as explained by researcher Ian McGilchrist during the Hidden Brain podcast:

“If you look at a score of a piece of music you see individual notes, there are separate notes. When we listen to a piece of music however, we really aren’t listening to separate notes. We are hearing an absolutely seamless flow in which we remember the notes that have just happened and we anticipate where they are going to come next. When analyzing something ‘the scientist’ is attempting to take it apart. One can analyze music by looking at the different instruments that are playing or analyze it acoustically by looking at different wavelengths, tempo, beat and so forth. However, none of that is ‘music’. It’s the connection between the notes, it’s what happens between the notes. A conventional scientific approach is to reduce things down to see what it is made of. Music is made up of notes. But what is a note? A note is a simple tone. But what does that mean? Let’s take an ‘a’ flat, that doesn’t really mean anything. What if we took a ‘b’ if you put 35000 of these together you’ve got Bach ‘B Minor Mass’. When you hear it do the notes explain it? Notes themselves don’t mean anything. So the beauty or the feelings we get from the piece don’t really come from the notes because the notes don’t mean anything. Perhaps we can attribute the beauty and feelings from the gaps between the notes? It’s the gaps between the notes, the gaps that make melody, the gaps that make harmony and so on. But the gaps are just silence. They don’t mean anything either. If one puts these things together, notes that don’t mean anything, separated by gaps that don’t mean anything, we get something, something beautiful. When the notes and the gaps plus whatever happens when they’re all edited together something new emerges. That is an idea of complexity theory that Hegel had proposed.”

Emergence, consequently, is considerably more than the sum of the parts involved. This posits that vision is more than four interlocking circles linking “centering” to vergence, and “identification” to clarity. Beyond terminology or jargon, it is part of the reason why the eyes are not simply cameras, and why artificial intelligence has such a difficult time matching human vision. In research, or even classically when we test vergence clinically, we can dissect its elements into tonic, accommodative, fusional, proximal, and voluntary vergence. While that may be “pure” in the sense of its physiological components, it is reductionistic and can be self-limiting in its failure to fully account for emergent properties of the system. Therefore when treatment is limited to a classical approach, improvement in vergence ranges is of necessity the objective yardstick for success. However, since the visual system is more than the sum of its parts, when we test and train the binocular system we are just as (if not more) interested in the patient’s flexibility, awareness, understanding of space. Skeffington’s philosophy of emergence goes as far to say that the treatment model is not complete without the patient’s ability to communicate these changes.
is linked to a high AC/A ratio, the two components may become antagonistic. In this situation, the interaction between the blur and disparity driven components exaggerates the imbalance created in the vergence motor output. With these mechanical theories, gradient AC/A is often used to guide lens prescriptions and calculate bifocal add power. Conversely, therapy or surgical interventions tap into the non-linear elements of AC/A interactions between the accommodation and vergence subsystems. Students often come away with the thought that the AC/A is a fixed value, that is static in nature, whereas clinicians learn that the AC/A is dynamic and modifiable.

In their presentation of the CINAPS research, Alvarez and Scheiman noted that the neuromechanics of vergence in their study can be traced to the work of Schor, and theories first advanced by Hung and Semmlow. In order to fully appreciate this research, the clinician must have some understanding of three things: 1) models of vergence, 2) understanding of previous Convergence Insufficiency Treatment Trial (CITT) studies, and 3) neuromechanics as demonstrated with functional MRIs (fMRI).

Models of vergence have been developed by various investigators to provide insight into its mechanisms of control. In any discussion about treatment of vergence, it is important to understand source of labelling vergence anomalies which is known as Duane’s classification. This system is based in part on the relationship between accommodation and convergence. Patients with a high AC/A ratio are classified as convergence excess or divergence excess. Patients with a low AC/A ratio are classified as convergence insufficient and divergence insufficiency.

Various other criteria used to help the clinician identify binocular anomalies. The pilot CITT study in 2005, and data in the comprehensive CITT study in 2008, demonstrated that NPC, positive fusional vergence, and symptom scores improved significantly when compared to placebo treatment. Later studies continued to demonstrate improved NPC and positive fusional vergence with therapy when...
Previous randomized control trials were done with children and young adults, 9 to 18 years of age. The investigator group subsequently attempted to quantify treatment for convergence insufficiency and its impact on reading in children 9 to 14 years of age. The Convergence Insufficiency Treatment Trial Attention and Reading Trial (CITT-ART) was begun in 2015. The results were ultimately published in 2019. A concern expressed by the researchers was that both the control and the test group improved in the reading scores. This meant that treatment of CI may not improve reading ability when compared to placebo therapy as conducted in the study. However, this large scale CITT-ART study in 2019 did demonstrate improvements across all vergence metrics, with over 300 children enrolled.

The CINAPS study identified neural substrates in the brain through the use of fMRI. Alvarez and colleagues were able to reproduce blood oxygen level-dependent signals reliably in specific regions of interest when participants made various vergence eye movements. In essence, the fMRI could be used to identify vergence eye movements as distinct from fixational eye movements. Convergence movements appear to be comprised of two systems, a slow vergence system and a fast vergence system. The researchers found that patients with normal binocular vision findings had different neural activity profiles as compared to patients with convergence insufficiency. The neural substrates correspond to differences between the binocularly normal group and the convergence insufficiency (CI) participants. Two significant brain-behavior correlations were observed for the fast and slow fusional vergence eye movement systems, respectively. A key difference between test subjects with CI as compared to normal binocular vision was that the step vergence peak velocity was lower in subjects with CI. The other main difference was that the rate of phoria adaptation was lower in subjects with CI. These differences were significantly correlated to differences in right cuneus activity and slow and medial cutaneous activity respectively.

CINAPS not only gave us insight into the neurology of convergence but also was used to demonstrate efficacy in the treatment of convergence insufficiency in adults. The stated goal was to gain an understanding of the neural mechanisms of office-based vergence and accommodative therapy (OBVAT). The patients were placed in two groups: active therapy groups and office-based placebo therapy with home reinforcement (OBPT). The OBVAT group used common therapy tools such as a Brock String, Aperture Rule, Vectograms, VTS 4, and Eccentric Circles. In contrast, the OBPT placebo group used traditional vergence/accommodative therapy procedures modified to be monocular rather than binocular (e.g., Brock string monocularly), binocular procedures modified so that there was no change in disparity vergence demand (e.g., computer orthopter, stereoscope), procedures using lenses with no dioptric power (plano or yoked prism lenses), and computer visual perceptual therapy with filter glasses.

After 16 weeks of therapy the groups were compared using standard optometric measurements such as NPC, Positive Fusional Vergence (PFV), and a standard symptom survey (CISS). Comparisons were also made of changes in the neurology. Using functional MRI (fMRI) the researchers evaluated changes in neural synchronization, neural recruitment, and functional connectivity. The findings included that after therapy there was significant improvement in the fast fusional system, including changes in the thalamus as well as the slow fusional system. From a neuroanatomical standpoint, these changes were demonstrated in the cuneus for the OBVAT group but not in the sham group. Uncovering the underlying neural mechanisms in patients with symptomatic convergence insufficiency provides all practitioners with additional insight into the level at which changes occur. Ultimately this may result in additional clinical tools or further ways to modify treatment toward the goal of obtaining optimal outcomes.
The Challenge of the Behavioral Approach

As noted earlier, because the behavioral model has more philosophical underpinnings than research can quantify, its application can feel elusive to students and even daunting at times. Its language may seem to be peppered with jargon absent from research or classical models. For example, Kraskin defined vision as “the deriving of meaning and direction of action as triggered by light.” Understanding vergence testing and its anomalies through the lens of behavioral optometry can be difficult for new practitioners. Terms such as “checking and chaining” for case typing (as opposed to Duane’s classification), as well as differentiating the skeletal and visceral systems when discussing accommodation and vergence, are used in texts that describe behavioral analysis. Checking and chaining during examination of patients is predicated in part on a series of tests that measure the “lateral ductions”.

Skeffington’s original analysis included conducting base out ranges first, with blur, break, and recovery noted. Checking is comparing data to expected values, and chaining is a method of grouping data. Perhaps a barrier for many students is the complicated process of data collection. The mindset, at least from what I can gather in reading Skeffington, is that if protocols are not followed precisely the data becomes unusable. The 21-point exam is no longer taught in many optometry schools, and therefore learning the protocol can be difficult. As noted earlier, the language employed can also be a barrier. For example, when Leo Manas describes the accommodative/convergence pattern he notes that “any increased dominance in the voluntary (skeletal) or autonomic nervous system will cause increased stimulation proceeding to the accommodative and convergence pattern.”

A behavioral approach entails considerable flexibility. There is wide variation, and while that may be confusing to students or new practitioners it ultimately confers an advantage when the umbrella of care that is called behavioral optometry is comprised of more than one paradigm. Behavioral optometry as a range of ideas and approaches to care affords a broader definition of binocular vision than fusion buttressed by vergence ranges. For example, behavioral analysis may probe the size of the volume of space selected for action, the language used by a patient to communicate, the clarity of the target, and how body awareness and balance affect fusion.

If we accept that vision is a process, we must also accept that its afferent and efferent components must be integrated. Yet when optometrists focus on the output metrics, we gain only a snapshot of binocular performance in time and space. Vision requires exploration, and testing as well as training this process should involve an understanding of how the patient is exploring binocular space. Clearly, limiting vergence testing to its range behind a phoroptor, or to its nearpoint on the z-axis, needlessly constrains how vergence operates. When a patient is truly exploring during vergence testing as the targets move in free space, astute practitioners can elicit what the patient is feeling. This verbal interchange may not even be possible for the patient initially, and is more apparent during subsequent evaluations when the patient becomes more aware of how she or he is functioning binocularly.

When I test vergence I will ask patients to “tell me what changes and tell me what happens”, rather than merely pose the leading question of “tell me when the target blurs or doubles”. The problem for patients who experience “visual tunneling”, or collapsed binocular awareness, for example, is that they tend to have limited responses and fragmented output. Specifically, as part of the “SILO” response, the patient exploring the process that is occurring will often perceive a smaller image moving further away as base out prism is introduced. This response demonstrates a “full” visual system as described by Skeffington. In other words, in my estimation, the patient who sees and describes the illusion of SILO is performing better than the patient who doesn’t yet have higher vergence numbers.
to break and recovery. I am examining whether the patient can tell me when I introduce a stress or change in centering if there is an associated change in the identification process. Developing that sensitivity and spatial awareness is just as, if not more important than the number at which a target blurs or doubles.

**Clinical Terminology as Applied to Vergence**

Aside from such paradoxes in what vergence ranges may reflect, there can be misnomers in the language employed between behavioral and classical approaches. Consider the following statement made by Skeffington: “The very term duction is a misnomer. A complex activity is represented by the response to a particular demand situation, and to label it a duction is to attach it all of the ambiguities, evasions, and misapprehensions of the past.”

What I believe Skeffington is inferring is that the measurement itself is complex and certainly to a behavioral optometrist means more than just conjugate movements inward or outward. The clinician presents a target and measures with prism. The patient, however, must make a single interpretation based changing input between the two eyes. In order to do this the eyes, have to turn in, or out, to match those inputs. Eventually the distance between the two inputs is too great and the patient sees double.

Seems simple enough, doesn’t it? The measurement, however, is not indicative of the magnitude of eye movements. Independently, when covered, many of our patients with low vergence amplitudes can move his or her eyes inward and outward to the nose and far enough laterally to the outer canthus. The movement required for a duction then is likely more than a measurement of contractility and extensibility of eye muscles. The measurement of vergence, therefore is likely a reflection of a more complex ability than muscle output. The measurement can also give the practitioner insight into attention. For example, the SILO illusion that the target is moving closer or further on the z-axis gives us insight as previously noted. Some patients develop better insight even though their vergence numbers decrease. To classical practitioners qualitative changes such as SILO take a back seat to increased prism vergence ranges. To the behavioral practitioner, increased sensitivity to SILO can be more indicative of how the visual system is improving than are vergence ranges. Sensitivity to changes, awareness of depth and space, and the patient’s ability to vocalize these changes are all essential in the behavioral analysis of vergence eye movements.

How a patient’s visual system responds to changes in location with a plus or minus lens can also give a practitioner insight. Some patients demonstrate a “tight” system that is rigid to change, and others are “loose” with perhaps less sensitivity to change. A behavioral analysis is also likely to include an understanding of embeddedness. An embedded system is likely to benefit from therapy where as a non-embedded adaption might do well with lenses alone. Even the most classically trained vision therapy doctor has much to gain if he or she understands this methodology and patient feedback.

Skeffington’s so-called duction analysis also includes developing an understanding of two areas of operation: skeletal and visceral. Simply put the skeletal system is the means by which the patient meets and contends with the forces and energy outside of self. The visceral system is the way in which the patient controls the inner environment. The more energy one puts into one of these systems, the less is available for the other. From a visual perspective, skeletal is the way we seek and hold onto an image, whereas visceral is the system we use to define and discriminate the image. These two operations must work in harmony at all times. There is nothing to gain if one can seek and hold onto an image but cannot define and discriminate it. To maintain unity of the visual system tolerances are made between the skeletal and visceral system.

The classical terms we use for these tolerances are exophoria and hyperopia. The exophoria operates to keep the integrity of orientation, the hyperopia operates to keep the
The recovery is when these systems rematch space and discrimination.

**Nuances of Vergence as Related to Vision**

Seeing is learned and, like most things learned, it is at first ineffective, energy-consuming, and spastic. As we learn to see, we will attempt to use the least amount of effort to perform extraneous tasks, and to simplify performance as greatly and rapidly as possible. As we learn to utilize vision, as with any other learned skill or ability, our performance improves. As reflected in vergence testing, the results become smooth, effective, energy-saving, and economical. If we conceptualize fusion as the synthesis of excitation from two sense receptors into a single precept, vergence testing provides insight into this synthesis as to how the individual processes the spatial area nearer to the patient from the plane of regard.

Differences that arise are rarely rooted in the defect of eye muscle tensile strength or range of motion. The ability to perform well during vergence testing is more indicative of neuro-motor signaling indicative of sensory processing deeper in the central nervous system. If the base-out range to blur-out is high, it is a sign that the drive to center is nearer, and that the patient is demonstrating a usable range of convergence without loss of usable range in accommodation. If the prism base-out to break is reduced, that is indicative of interference in this learned association.

Reduced performance qualitatively or quantitatively is expected if the skill of fusion is operating in space in an inefficient, ineffective level. Vergences can therefore be viewed as an appraisal of space world relationships and behaviors. Because seeing in binocular space is three-dimensional, and circuits between the two eyes must be continuously integrated and updated, a time factor is also included. The movement produced by a horizontal prism in free space is not a lateral movement range, but a movement toward or away from the patient. Vergence measurements can therefore be indic-
SYNOPSIS AND CONCLUSIONS

The classical approach utilizes standards for vergence testing and therapy to improve measurements. The behavioral approach tells us that vergence measurements are insights into three-dimensional space, adaptation to stress, and sensitivity or awareness to change. This contrasting view might be apparent in Brock string work. As part of the therapy for CINAPS, Brock string therapy was utilized. A classical model may perhaps include instructions on clarity, anti-suppression, and positive fusional range improvements. Directions may include “look at the bead, keep it clear, keep the illusion of two strings crossing at the bead, watch the bead as it moves closer.” A behavioral approach may include awareness of surroundings, emphasis on posture, ability to articulate what is seen, and comfort and awareness of sensation as the bead is brought closer. Some patients will have better eye posture, “put the x at the bead” when the therapist brings awareness of head, body, feet, posture, or when the therapist directs the patient to be aware of his or her surroundings. The classical model used in the CITT, CITT-ART, and now the CINAPS is one that describes accommodation and lack of ability to converge as the problem.

The latest research suggests that positive fusional vergence and accommodation will improve with therapy, but also that differences in poor convergence and good convergence are likely rooted in brain structure and chemistry. This is where one can see the overlap in a more behavioral understanding. Phoric posture, vergence, and accommodative-mergence interaction are all neurological manifestations of the binocular visual process. Therefore, vision therapy must involve brain work intended to change neurology. A behavioral approach includes the understanding of biologically unreasonable stress, adaptations, spatial awareness problems, posture problems, and attention problems, but encompasses much more. That is because all of vergence testing and vision therapy engages brain work and
insight. It resides at the nexus of vision and cognition.

As a practitioner I wonder about the extent of insight that vergence movements can provide. Is the analytical sequence the best, or only way, to gain more information of our patient’s spatial representation of the world? Vergences could also be insight into the adaptation of near point stress. As one who feels the big picture is equally important in testing and treatment, the data seem to a window into a fluid and dynamic system. Similar to the idea of Graphical Analysis, but without using Sheard’s or Percival’s criterion, I think that vergence testing gives us insight into “zones”.

Optometry students are taught in school about the zone of clear, single, simultaneous binocular vision bounded by vergence ranges (ZCSBV). Beyond that, in the book Shape of the Sky, Dr. David Cook postulates that we have a zone of simultaneous awareness (ZOSA). Expansion of this awareness zone is essential in treatment of vergence disorders. I suggest that within the ZOSA there is a smaller zone of engagement, and within this area there seems to also be a zone of comfort. While graphical analysis may seem cumbersome and constrained by Sheard’s or Percival’s criterion, I have found that viewing the vergence numbers in a spatial way can be helpful. It seems to me the vergences give us insight into the size and location of these areas. (See Figures 1, 2, and 3).

Modern studies involving functional MRIs and century old ideas involving a more holistic approach help us understand treatment and testing. A common potential flaw in any scientific study of humans is the risk of bias when observing behavior. Studies involved data collection in which inferences are made. Layered onto this is our interpretation of study results. For example, Scheiman recently discussed the results of the CITT-ART study. The results were seemingly disappointing relative to its goals at the outset. In the study, the investigators found no difference between placebo group and the therapy group in reading comprehension. To a naysayer the results may be interpreted as evidence that vision therapy doesn’t work. However, a closer look at the data shows improvement in reading for both groups by a notable score. Some would argue that the placebo therapy was inert to independent vergence training,
but loaded with visual attention therapy. Did the study prove that working with symptomatic children with convergence insufficiency on oculomotor and perceptual therapy improves reading scores just as much as vergence and accommodative therapy? It depends on the perspective of the reader.

Whether our vergence testing and treatment includes strict protocols tested and restated under laboratory conditions, or whether we take a more philosophical or behavioral approach, we should always remain open-minded. After reading a little about who A.M. Skeffington was, I think he would be excited to see problem solvers trying to solve problems. From what I can gather, all clinicians and visual scientists need a bit of curiosity. Behavioral optometrists understand that the vergence system is a highly complex process tasked with many inflections and alterations that can be made when needed to meet the demands of the situations presented to a person.

It is not necessary, and I would argue that it can be counterproductive, to divide doctors into classical practitioners or behavioral practitioners of Optometry. The latest research in vergence eye movements, is reviewed by Alvarez and Scheiman, lends support to the notion that vision is the result of a collaboration between the eyes and the rest of the brain. Toward that end, it is more productive to view vision therapy as akin to brain therapy, rather than as physical therapy for the eyes.

Most of us, if not all can attest to the thousands of lives changed through optometric vision therapy. My hope is that young practitioners do not view our profession as two camps competing over the “right” testing protocols and treatment modalities, but as a continuum of exploration and ideas to help patients further. Having both an understanding and appreciation of the classical approach as well as the behavioral approach can help every clinician excel.

REFERENCES

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