LENSES AND BEHAVIOR

Leonard Press, O.D
FCOVD New York, NY

Leonard J. Press, O.D., FCOVD, FAAO, is a 1977 graduate of the Pennsylvania College of Optometry, where he was the recipient of the Bausch & Lomb Research Fellowship award in contact lenses. Following his graduation, Dr. Press served a residency in the pediatric unit of the Eye Institute of the Pennsylvania College of Optometry. From 1979-1982, he served as chief of the pediatric unit of the Eye Institute.

In 1981, Dr. Press was awarded fellowship in the College of Optometrists in Vision Development and achieved his diplomate in the Section on Binocular Vision and Perception of the American Academy of Optometry. He has subsequently chaired committees in both of these organizations. Among his current organizational activities, Len is the representative of the American Optometric Association on the task force to develop national standards for vision screening, co-sponsored by the National Society to Prevent Blindness and the Better Vision Institute.

Dr. Press served as chief of the Vision Therapy Service of the State University of New York, State College of Optometry, from 1982-1989. He is currently chairman of the governing board of University Vision Associates, the clinical practice plan of the college. A frequent lecturer at national and international optometric congresses, Len has authored more than 50 papers in optometric journals. He was the recipient of the award for Best Technical Article by the Optometric Editors Association in 1987 and 1988. Dr. Press maintains a private practice in Fair Lawn, NJ, specializing in pediatric optometry and vision therapy.

INTRODUCTION

If it can be said that the eyes are windows of the soul, it should be stated that ophthalmic lenses are windows of visual behavior. One of the perennial conundrums in optometric visual science is the manner in which ophthalmic lenses can be used to alter behavior. To set the stage for our investigation of this topic, let us agree that visual behavior is malleable, and that a lens is merely one tool through which visual behavior can be shaped. The primacy of the lens as a wedge to the visual system is evident in its numerous applications, having been classified as 1) enhancement, 2) preventive, 3) therapeutic, 4) maintenance, and 5) compensatory.[1]

The timing of lens application is an optometric decision as to when alteration of behavior is desirable. Lenses can be used prior to visual maladaptation to enhance visual performance or prevent maladaptive shifts in function. If visual dysfunction has developed, vision therapy may be implemented through the application of therapeutic lenses. After visual dysfunction has been successfully stabilized or reversed, lenses for the purpose of maintenance are considered. In the event that visual dysfunction cannot or will not be altered, the lenses prescribed are compensatory in nature.

All of the aforementioned lens applications are prescriptive, their utilization having been designated by the prescribing optometrist. The term *corrective* lenses is reserved for circumstances in which the lenses restore visual function to its pre-altered state. In this regard, only lenses used during vision therapy are truly corrective.[2] Far from being semantic in nature, the misnomer of lenses *correcting* visual dysfunction when they are passively prescribed signals a deeper distinction between behavioral and classical optometry. The essence of this distinction lies in the premise of how a lens works.

Classical optics considers the properties of a lens principally in relation to its dioptric components. A lens serves to restore optical conjugacy to an out-of-focus visual system. Consequently, other than magnification factors, there is little difference in the use of convex, concave, or meridional lenses. Consideration is given to the effects of lenses on space perception as a function of base curve alteration, lens SILO, induced cylinder, and power alterations relative to the habitual state. In contrast, behavioral optometry considers the properties of a lens principally in relation to its influence on the distribution of light on the retina, and the corresponding postural shifts that ensue.

The distinction between classical optics and behaviorism is not unique to optometry, having a direct parallel in the ecological versus efferent (inflow versus outflow) theories of visual space perception in experimental psychology. The psychologist J.J. Gibson introduced the term "ecological optics" to account for the patterns of light which arrive at the eye from the environment (inflow) and the information which these patterns convey.[3] He explains much of visual perception in terms of induced change in the complex pattern of light (optic array) arriving at the eye. Although Gibson does not deal with the role of lenses in altering these patterns, he emphasizes the importance of motor behavior as lower-order interpretation of change in the optic array.[4] The ecological approach claims primacy over the efferent (proprioceptive) role of the extraocular and intraocular neuro-musculature with regard to visuomotor behavior. Current thought is that *the truth lies somewhere in between*: Visuomotor coordination in everyday seeing conditions is determined by an interaction between light-based and efference-based information. The basis for this inter-action is known as the Ecological Efference Mediation Theory.[5] One might suspect that the *scientific truth* of how lenses affect behavior could be found in a similar unification theory that mediates classical and behavioral optics.

To appreciate how a lens works, one must be cognizant of the branches of classical optics which touch upon the alteration of light by a refracting medium. Although traditionally associated with ophthalmic optics, the function of a lens placed before a human eye is derived from principles of geometrical optics, physical optics, physiological optics, and visual perception. Forrest grappled with these factors in his quest for understanding how and why we respond to the physiological, psychological, and perceptual effects of lenses.[6] He emphasized the importance of understanding that the action of a lens or prism is on light and not on the organism. The response of the organism is linked to previously experienced natural changes in light stimulation which are now mimicked by changes induced by the lens.

Let us take the function of accommodation to illustrate this concept. Concave lenses alter the light distribution so that an object appears to be closer in space than it really is. The effect of placing a concave lens in front of an observer who is not in need of a compensatory lens is that accommodation is stimulated. The only way in which concave lenses can stimulate accommodation is if the individual had already developed reliable accommodative responses to objects approaching in real space. Hence the reaction to a lens is only as accurate as the degree to which the lens is simulating previously learned responses.[6] Stated otherwise, minus lenses don't *reflexively* stimulate accommodation. Rather, minus lenses signal that an object appears to be closer in space than its location prior to introduction of the lens.

With the thought in mind that lenses may be used as probes of learned responses to the environment, or as a means of altering learned responses to the environment, let us embark on our review of lenses and behavior.

THE BEHAVIORAL CONCEPT OF LENSES

The landmark series of papers by Kraskin entitled "Lens Power In Action" serves as a reservoir of contemporary thought on lenses and behavior. In his introductory chapter, Kraskin[7] asserts that there is no such thing as functioning within the framework of the behavioral concept without the understanding and utilization of lenses, including visual training. Kraskin[8] considers behavioral optometry to be the optometric clinical application of the *Dynamic Concept of Vision* (the Skeffington Approach). He defines vision as the deriving of meaning and the directing of action as a product of the processing of information triggered by a selected band of radiant energy.

Recently Kraskin elaborated upon the behavioral concept of lens application as follows: "The behavioral concept of vision can be stated as the functional utilization and application of lenses directed toward the alteration and control of behavior, which is directly related to the significance of the 20% of the nerve fibers that do not pass directly through the lateral geniculate nucleus, but superior colliculus, and relate to motor, movement, posture, and coordination."[9] Accordingly, the key to applying the behavioral concept of vision is an appreciation of the significance of the 20% of retinal fibers running to superior colliculus and associated with primitive photostatic (light and postural) functions of the visual process.[10]

The source of information cited by Kraskin in the concept of evolutionary photostatic specialization is the first volume of the *Text-Book of Ophthalmology* by Sir Stewart Duke-Elder.[11] In the second volume of *System of Ophthalmology*, Duke-Elder and Wybar expanded this concept as follows: "We have already seen in a previous volume that the visual system was initially developed as a photostatic mechanism concerned primarily with orientation and equilibration; it follows that in lower vertebrates, the afferent pathways from the retinae converge to the postural and gravistatic systems centered in the tectum of the midbrain. As vertebrate evolution proceeded, although photostasis was maintained as a necessary and important function, it gradually became overshadowed by the dynamic aspects of vision with its sensory and cognitive functions."[12]

In his overview of the visual process Kraskin[13] pinpoints the significance and interrelationships of posture, lenses, and behavior, drawing freely from the works of Skeffington and Harmon. He states that the first order commitment of the body as a product of information processing is to come to a desireable balance with gravity and with a minimum of effort expended. The result of the body having come to balance with gravity is called orientation. The functions of accommodation and convergence are embodied in the dynamic postural mechanisms, but are by no means primary. They are involved with the second commitment of the body which is to come to a balance with the activity at hand. Once orientation has been achieved, higher-order commitments of information processing (localization) can occur. Consequently, when a lens changes the orders to the system by altering the distribution of light on the retina, the change in orders is initially directed to the posturing mechanism of the body, not higher order mechanisms.

In line with this hierarchy of orders involved in visual information processing, there are specific adaptive sequelae if the body cannot come to a desirable balance with gravity, or with a minimum of effort. As effort to satisfy the initial commitment to balance is increased, less attention is directed to the higher order activity of task manipulation which results in decreased efficiency. Stress ensues, and the organism tends to grow along that line of stress to reduce stress. Kraskin[14] relates this to the concept of bone elongation. One would intuitively think that it is necessary to stretch a bone in order to elongate it, but the opposite is true. Stretching a bone will induce stress which triggers a response along that line of stress (a shortening) in an effort to reduce stress. Compressing the bone will make it longer by inducing a stress in the direction opposite to the direction in which movement is desired.

The extent of growth along the line of stress is reflected in the magnitude of embeddedness. Increased growth along the lines of stress results in greater postural alteration and adaptation. When the postural alteration is reflected in refractive shifts, the condition is becoming embedded. The optometrist prescribing lenses at this juncture is faced with two broad choices:

1) Prescribe lenses which compensate for the refractive shift, encouraging further growth along the lines of stress, or

2) Apply counterstress lenses which do not compensate for the refractive state, but block the growth along the lines of stress thereby curbing the refractive shift.

Counterstress lenses have greatest potential when the behavior is least embedded,[15] and can be determined from stresspoint retinoscopy[16,17] or other techniques in concert with the analytical evaluation. Plus lenses have the effect of positioning the working distance further in space from the stress point. The significance of this will become even more apparent as we look under the hood of our visual apparatus.

ENGINEERING OF BEHAVIORAL MODELS

For many years behavioral optometrists have noted that lenses play a role in the drive of the individual to maintain homeostasis. When equilibrium in the visual system is maintained, the individual feels most secure in his visual space; the degree of security is a barometer of visual stress. When insecurity exists, there is interplay between tolerance of symptomology and adaptation to reduce symptomology. Lenses can therefore be used to encourage adaptation or to re-route adaptive shifts, thereby impacting upon visual stress. In recent years, visual scientists have taken great interest in applying models of engineering to the nearpoint visual complex. Drawing upon the work of Toates, Krishnan and Stark, and Schor; Ebenholtz presented an overview of these models as related to the accommodative-convergence control systems.[18] Therein lies a strong bridge between classical and behavioral models of visual control worthy of more detailed review.

In the engineering model of the accommodative-convergence control system (figure 1) there are two key loops:

1) *the negative feedback loop* enabling the vergence section to maintain common visual direction while the accommodative section minimizes blur and

2) *the feedforward adaptive loop* which enables adaptation through tonus control of the resting level or dark focus. The negative feedback loop includes two cross-linked feedforward paths of accommodation-convergence (A/C) and convergence-accommodation (C/A) which provide a coordinating system to one another. The controllers of the negative feedback loop (blur and disparity) are rapid, completing their responses in milliseconds. The controller of the feedforward adaptive loop (tonus) is slow, charging and discharging in minutes or hours. Adaptation occurs when the slow controller is sufficiently charged to cause a shift in the resting level which, as we shall shortly see, is reflected in shifts of phoric posture and refractive status.

Given that blur and abnormal visual direction are the error signals in the negative feedback loop, adaptation serves to reduce error signal amplitude and volume over time. This represents a relative shift of control from negative feedback to feedforward. As stated by Ebenholtz:18 "In perceptual terms this shift represents decreased salience for distance and, in general, is in the direction of automatic, robotized behavior patterns." The salience for distance is represented by the element labeled *distance operator* in figure 1. As we shall see below, sacrifice of distance clarity is a purposeful shift which enables more efficiency and automaticity at nearpoint. Minus lenses at distance excite adaptive shifts by re-establishing the baseline level of the distance operator. The proper plus lenses at near would defuse adaptive shifts by partially discharging the slow controller, thereby re-establishing baseline levels of dark focus and vergence.

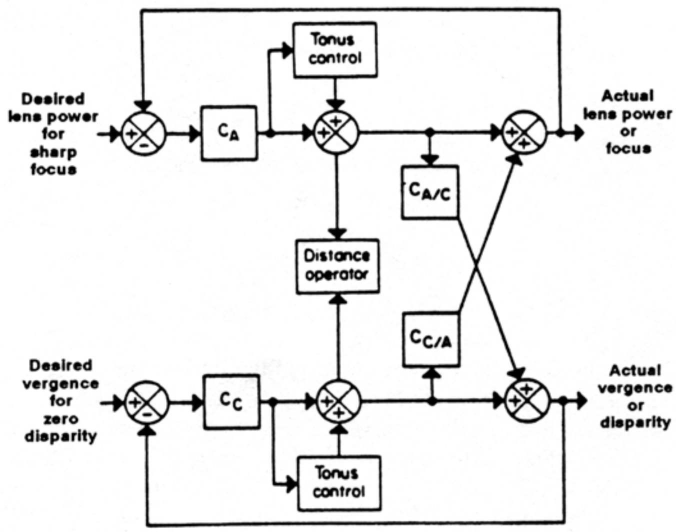

Fig. 1 -Accommodation-convergence control system. C: controller, A/C: accommodative convergence, C/A: convergence-induced accommodation. (Reprinted from ACTA Psychologica)

These servo-mechanisms operate in accordance with the principle that *the organism grows along the lines of stress to reduce stress.* There is ample evidence that prolonged near fixation induces a shift of tonus in the direction of effort.[19] These findings suggest that changes in the resting posture of vergence and/or focus may serve to reset the system's operating range so that the nearpoint visual task is less stressful.[20] Ebenholtz[21] has described this shift as hysteresis, which has been recently analyzed in the context of myopic shifts.[22,23] Most studies show that the inward shift of the dark focus, which represents the tonic level of accommodation, is an adaptive shift which is time-dependent. Longer periods of sustained near work results in longer endurance of the adaptive shift after the near work has been terminated.[24,25] Long-term endurance, or lack of decay of the tonic shift inward, signals an adaptive shift tantamount to embeddedness. Owens and colleagues,[26,27] adopting a functional perspective have proposed that inward shifts of tonic accommodation serve to relieve the effort required by strenuous nearpoint visual tasks.

Citing the work of Ebenholtz and Miller, Ehrlich[20] reviewed the clinical implications of tonus and dark focus with regard to ophthalmic lens application. The classical view of accommodation assumed that the system was fully relaxed when viewing infinity. This implied that near visual work required accommodation corresponding to the dioptric demand of the stimulus. It is now known that the resting (dark focus or tonic) level of accommodation for non-presbyopes is usually at one meter. If visual work is done at a distance corresponding to the individual's dark focus level, there is no observable shift inward.[20,21] This establishes that the accommodative resting position is the *stress-free* position of the accommodative system. Consequently our goal should be to move the patient outward in the direction of the accommodative resting position in order to minimize near-point stress.

Given that it is not always practical to increase the patient's working distance, lenses may be substituted for spatial movement as reviewed by Shrock[28] and Koetting.[29] The important factor then becomes the dioptric separation of the near task from the tonic (resting) level. As an example, if the near fixation distance is at 40 cm, the accommodative *stress demand* is 1.50 diopters (not 2.50 diopters as is classically conceptualized).

As reviewed by Margach[30,31] the dark loci of centering and identification can be applied to OEP case typings in the derivation of a lens prescription. Margach suggested that the identification lag is approximately 33% to 50% of the identification demand in B-1 and B-2 type cases. This is compatible with the clinical experience that the most common add given to non-presbyopes for a 40 cm viewing distance (1.50 D stress demand) is +0.50 to +0.75. Given that the dark focus is known to be highly variable between individuals, the importance of deriving a nearpoint lens on an individualized basis is underscored. As previously mentioned, nearpoint retinoscopy is particularly useful in this regard, as reviewed by Haynes.[32]

The implications of the intermediate dark focus and dark vergence concepts as applied to lens power are expounded by Forrest in his posthumously published text on *Stress and Vision.*[6] Among the numerous studies reviewed by Forrest, the work of Wolf is cited as lending support to the Skeffington model. Specifically, evidence exists that the increase in convergence due to the effects of near work is a more potent factor than accommodation in the visual stress syndrome. In addition, Forrest reviews the adaptive models that tend to posture convergence closer in space than accommodation, as well as the use of low-plus lenses to posture accommodation further out in space. Forrest included the work of Weisz who related the nearpoint lens power to the lag of accommodation. Weisz considers that low-power plus lenses as determined by MEM retinoscopy allow accommodation to posture closer to the dark focus. As demonstrated by Pierce, the lens value determined in this manner tends to reduce autonomic nervous system activation. The issues surrounding the work of Harmon, Greenspan, and Pierce have been critiqued elsewhere.[33,34]

Forrest takes issue with the Skeffington theory that containment (lack of movement) is the primary stressor in the "socially compulsive, biologically unacceptable" nearpoint task of reading. He states that the containment properties of a task are comparatively minor stressors to the organism. Rather, he continues, the major stress producer appears to be one's attitude and one's mood; one's approach to the near-vision task that is superimposed onto the containment factor. Irrespective of the primary stressor involved, it is increasingly clear that Skeffington was correct in his notion that the role of a convex lens is to allow the individual to localize away in space, thereby attaining a less stressful problem-solving focal posture.[35]

BEHAVIORAL OPTICS

Behavioral optics as defined by Bastien deals with "the effect of lenses on the total action system responding in space as a whole, to space in localized luminous and illuminated incitements, to coded illuminated messages emanating from diverse planes of the environment."[36] It is closely allied with visual optics. As elaborated by Emsley,[37] visual optics is concerned with events arising from the interaction of radiant energy and living organisms in the retina and nervous system, and from the contemporaneous interplay of consciousness.

Geometrical optics and ophthalmic optics are universally applied in daily clinical practice and need no elaboration. Paradoxically, physical optics and visual (physiological) optics, though common to all optometric graduate curriculae, are rarely integrated into clinical models of vision.

Physical optics represents the properties of light, readily identifiable by luminous flux, radiant energy, and similar terms. Physiological optics represents the interplay between egocentric and oculocentric localization. The underpinnings of the construct of a visual space world, so integral to the concept of behavioral optometry, can be found in the balance between one's egocentric and oculocentric localization.

The classic *chicken versus egg* question in physiological optics is: "Does vision educate touch, or does touch educate vision?" From the experiments of Stratton with inverting prisms in the late 19th century through the contemporary work of Rock and Liebowitz, and Owens, arguments have been made for the ability of one sensory system to dominate the other. Rock reviewed evidence from ophthalmic lens experiments that vision not only dominates touch, but is capable of capturing it.[38]

In one experiment, Rock and Victor used lenses to create a conflict between vision and touch. Subjects looked through an apparatus with a concealed afocal lens that minified a square and judged the size of the square accurately (reported its size as expected based on the minification value). The subjects were then asked to use touch alone to judge the size of the square, and were able to do so accurately. But when looking and grasping simultaneously, subjects experienced the square to be smaller, corresponding to how they experienced it by vision alone.

In a similar experiment on shape, Rock and Victor used a cylindrical lens to alter size along only one axis, so that a square looked like a rectangle. Again, the shape percept was dominated by vision and *visual capture* of touch occurred.

In truth, vision and touch educate one another in the construct of a visual space world, with movement as a key facilitator. Renshaw[39] summarized visual reafference experiments as follows: "...we have to learn to interpret the visual signal in terms of active touch and movement. That is, we learn to see things not on the retina or brain, but out there in space where we have to do something about them or where they do something to or for us..." ..."We see things in space not in the same orientation as the distribution of energy on the retinas or in the brain, but in terms of the behavior space of the perceiver." These issues are more fully explored in a subsequent section of this paper entitled *Behavior With Multifocal Lenses*.

OPTICS OF BEHAVIORAL SPACE

In his volume on the physiology of the eye and of vision, Duke-Elder states: "The perception of space and the localization of objects therein is essentially egocentric in nature, being primarily referred to coordinates with reference to the body; the faculty has therefore a gravitational basis and is founded upon the mechanism by which posture is appreciated..." "Projection in space is a complex perceptual synthesis based upon a dual mechanism made up of visual and postural components: the object is projected visually with regard to the eyes, and its projection upon the retina is oriented gravitationally by the postural mechanism which synthesizes impressions from the muscles of the eyeballs and the neck, and from the labyrinth."[40]

Similarly, Harmon asserts that visual space is a derivative of an optic extension of the tonic gravitational reflexes.[41] Whereas Duke-Elder[40] considers postural components principally in the head and neck region, Harmon conceptualizes visual-postural adaptations in vectoral planes from the top of the head to the soles of the feet through the interconnectedness of labyrinthine function with myotatic reflexes. The visual-postural adaptations that a traditionalist would cite are mechanistic and would include ocular-motor responses to altered vestibular function (nystagmus) as well as adaptive neck posture in ocular-motor skews (torticolis in non-comitant strabismus or diffuse neck pain in uncompensated vertical imbalance). The visual-postural adaptations that a behavioralist would cite are warps of visual space and represent a greater effort to achieve gravitational balance. Any stressor agent which leads to changes in alignment of the head and eyes usually will be reflected in refractive or visual-postural distortions.[42] The behavioralist asserts that all acquired ocular defects are reflections of alteration in posture, and most postural alterations will eventually be reflected in the analytical. Kraskin[43] elaborates on specific aspects of postural skew in the neck, upper back, lower back, and pelvic areas in relation to lens application. These concepts are reviewed in more detail in the next section, entitled *Lenses and Postural-Spatial Shifts*.

The principal actions of a lens in the computation of visual space are:

1)To change processing at the retinal level[44]

2)To change processing at the gravitational level[45]

Skeffington postulated that the value of a convex lens at nearpoint was to "localize away in space."[35] Macdonald[46] cited two properties of convex lenses which would account for this effect:

a)**Geometric Optics:** A ray tracing shows that plus increases the convergence of light which has the effect of projecting the real object in space as if it were further from the observer.

b) **Physical Optics:** A plus lens has the effect of flattening the energy gradient input into the system. In Skeffington's terms: "Lenses change patterning of light scatter (photons) on retina, and this is their value".[47]

With regard to geometric optics, Bastien shows that the space expanding effect of convex lenses implicit in ray tracing diagrams is valid only if it maintains or elongates the habitual reading distance.[36] Coining the phrase "visuo-postural reflex" (REVIP) for the patient's response working distance, Bastien notes that a convex lens will not have the SILO effect predicted if it results in a REVIP nearer than the Harmon distance.

The principles of physical optics addressed by Skeffington, Harmon, and Macdonald are identifiable in the contemporary concept of retinal images as point-spread functions. A point-spread function is the bell-shaped cross-section of retinal light distribution resulting from the focus of a point object in space. Since the anatomical and functional organization of the retina and visual pathways does not fit the template of sine-wave gratings, it is preferable to describe the spatial proximal stimulus for vision in terms of retinal light distribution, as reviewed by Westheimer.[48]

In this vein, Harmon[49] stated that one of the functions of a plus lens is to change the distribution of light over the retina in a manner that would maintain resolution but reduce tonus on a near task. Harmon asserted that a change in body tonus integrated with contrast changes in the visual field is interpreted by the individual as a change in distance. Consequently, the use of a plus lens that reduces the number of photons per unit area of the retina and reduces the tonus of the body has the interpretive effect of moving the task away from the individual.

Given these premises of geometrical and physical optics, an intuitive question arises: If plus lenses produce their beneficial effects on tonus due to the reduction in the number of photons absorbed in the point spread function, could not the same effect be attained with an afocal magnifier? The advantage of such a lens would be that it would not create distance blur, thereby simplifying its application in patient prescribing. Harmon[49] acknowledged that this should be the case, and that research should be done in this area. Similarly, Skeffington noted that the alteration of base curve or thickness in lenses to achieve afocal magnification could have the same effect as plus lenses.[50] Most recently, Sutton noted that steeper base curves could be used to alter behavior through its common spatial characteristics with plus lenses.[51] Essentially this is a substitution of the shape magnification factor of lenses (base curve and center thickness) for the power magnification factor.

Skeffington capsulized these possibilities when he stated the following: "The curvature of the lens create changes in the computing. The thickness of a lens brings changes in computing and it's possible to substitute changes in the intensity by employment of lenses in this way as well as with focus changes. In other words, what is happening if you put on any kind of a lens is the changing of energy distribution which throughout the whole circuiting brings changes, desirable and undesirable. A prism brings changes in the tracking computing. A sphere changes the intensities so that the matching for conditioned stimulus is altered. A cylinder changes the area of intensities to better or worsen the matching with the gravitational."[50]

The essence of the optics of behavioral space was captured by Francke in his overview of training lenses.[52] In recounting the monocular minus lens procedure developed by Bruce Wolff, he points out the inconsistencies between predicted image projection (based upon geometric and physiological optics) and experiential image manipulation. Francke entreats the reader to manipulate visual space by capturing an object of regard in the image space of a minus lens and tromboning. The exploratory questions of visual space as viewed through the dynamics of a lens include the following: 1) Where is the image located? 2) Is it coincident with the object? 3) Is there space constancy? 4) Is there size constancy? 5) What is the effect on field of view? 6) Why do they do what they do?

These points lead us to further considerations in the spatial characteristics of lenses as related to behavior.

LENSES AND POSTURAL-SPATIAL SHIFTS

In the organization of visual space volume (the geometry of visual space) we must assume the need for a starting point. This point in man is his egocenter - the internal invariant, which is then matched against the external invariants. This principle is operative in any lens application - be it for compensatory prescribing in the vernacular of lens correction or therapeutic activities such as *loose lens rock*.[53] This matching process is developmental, and enables the individual to attain and maintain equilibrium.[54] As related to visual-postural equilibrium, Leslie summarized Kraskin's *Lens Power in Action Series* and Sutton's *OEP Papers* on the subject as follows: "Body equilibrium requires the patient to come to balance with gravity-orientation by adjusting the center of gravity within the pelvic area, and at the same time coming to balance with the task-localization by an adjustment in the upper back and neck."[42] The reciprocal kinesiologic interweaving between the major fulcra of the body (pelvis and head/neck) and the pivot point of cyclopean projection as manifest in orientation and localization is central to the basis for lens application, and needs elaboration.

Kraskin[13] differentiates refractive status of the body from refractive status of the inner optics of the eye. He defines *orientation* as descriptive of the refractive status of the body, directly reflecting the status of the lower back posturing musculature. This is in contrast with *localization*, defined as the spatial computing status, directly reflecting the upper back and neck musculature. In this model, refractive anomalies, and binocular asymmetries and dysfunctions are initially reflected in postural adaptations, with the end result in the optics of the eye. In classical terms, we can tabulate these effects as follows:

Orientation involves the lower back musculature and is representative of shifts in:
-myopia
-hyperopia
-against-the-rule astigmatism (increased tonus in the horizontal power meridian potentially compensated by minus cylinders to reinforce bilateral asymmetry)

Localization involves the upper back and neck musculature and is representative of shifts in:
-esophoria
-exophoria
-with-the-rule astigmatism (increased tonus in the vertical power meridian potentially compensated by minus cylinders which compress vertical space)[55]

Mixed orientation and localization effects are representative of:
-anisometropia (predominantly orientation)
-hyperphoria (predominantly localization)
-oblique astigmatism (total involvement)

Sutton[51] underscores the point that careful observation and performance measures indicate whether compensatory or training lenses are indicated. Compensatory lenses such as against the rule cylinders create a match of the person with the altered visual environment. The restoration of equilibrium maintains homeostasis and provides security and comfort allowing the path of least resistance to the compensation. This also embeds the adaptation, encouraging further needs for compensation. Conversely, training lenses create a mismatch between the altered visual environment and the optical effects of the lens. If the mismatch is tolerated, greater flexibility has been attained; if intolerable, the mismatch will result in decreased performance.

Getman recently reiterated the core philosophy of behavioral optometry with regard to lenses: "...The core philosophy holds lenses and prisms as optometry's unique tool to change spatial judgements and decisions, and out of these will come the actions of the end organs that we measure with all our special probes and observations...we must come to the understanding of what the old law holds - that function will influence structure more than structure will influence function."[56]

Kraskin[57] postulates that alterations in posture feedforward motor signals thereby altering structural components of the optical system of the eye (particularly the cornea and crystalline lens). Among the examples of postural alteration given by Kraskin are:

1. **Phoric posture:**[57]
   a) flat scapulae (rounded shoulders) are indicative of esophoric performance and
   b) outwardly winged scapulae (arched shoulders) are indicative of exophoric performance.
2. **Vertical imbalance:**[58]
   a) generally reflected in upper back and neck musculature (subtle body torque involving tilt, turn, or rotation)
   b) not usually manifest unless under unnatural measuring environment of phoroptor.
3. **Anisometropia:**[58]
   a) generally reflected in pelvic rotation, accompanied by some degree of pelvic tilt (secondary shoulder alteration with shoulder usually lowering on the side of the raised pelvis) and
   b) head turn in the direction of the eye with the greater degree of ametropia.

With these thoughts in mind, we can broadly categorize lenses by their affect on orientation and localization:

Orientation is affected by:
-Binocular spheres
-Binocular yoked prism
-Monocular prism

Localization is affected by:
-Monocular spheres
-Binocular base-out or base-in prisms

The spatial characteristics of lenses and prisms, as adapted from Sutton[59] and Kraskin[60] can be summarized as follows:

Plus Lenses
-reduce tonicity of the posture musculature
  -binocular plus reduces tonicity of lower back
  -monocular plus reduces tonicity of upper back and neck
-expands visual space volume
-emphasizes background as opposed to figure

Minus Lenses
-increase tonicity of the posture musculature
  -binocular minus increases tonicity of lower back
  -monocular minus increases tonicity of upper back and neck
-reduces visual space volume
-emphasizes figure as opposed to background

Base-In Prism
-moves visual space outward
-reduces tonicity of posture musculature of upper back and neck
-expands visual space volume
-emphasizes background as opposed to figure

Base-Out Prism
-moves visual space inward
-increases tonicity of posture musculature of upper back and neck
-reduces visual space volume
-emphasizes figure as opposed to background

Base-Down Prism (monocular or yoked)
-moves visual space upward farther from one's center of gravity (effect of looking uphill, re-localizing space away with objects seen as larger) creating postural change as follows:
-eyes move upward
-chin moves upward and outward
-center of gravity shifts forward
-pelvis shifts to tilt downward
-body moves forward on toes

Base-Up Prism (monocular or yoked)
-moves visual space downward and in toward one's center of gravity (effect of looking downhill, re-localizing space inward with objects seen as smaller) creating postural change as follows:
-eyes move downward
-chin moves down and inward
-center of gravity moves backward
-pelvis shifts to tilt downward
-body moves back on heels

Yoked Prism Bases Right
-eyes move to the left
-pelvis rotates to right to counterbalance

-functional midline shifts to left to maintain equilibrium

Yoked Prism Bases Left

-eyes move to the right

-pelvis rotates to left to counterbalance

-functional midline shifts to right to maintain equilibrium

In his text on a behavioral approach for persons with physical disabilities, Padula[61] reviews the postural-spatial effects of lenses and yoked prisms on low functioning individuals.

LENSES AND LEARNING STYLE

Sutton[62] and Horner[63] reviewed the aforementioned spatial characteristics of lenses and prisms with respect to learning styles:

Plus Lenses

- deemphasize figure and emphasize ground, making the reflective child more field dependent, thereby increasing speed.

Minus Lenses

- deemphasize ground and emphasize figure, making the impulsive child more field independent, thereby slowing him down (constricts field so that child says "I have more time to get to this thing within that space").

Bases-Down Yoked Prism

- deemphasize figure and emphasize ground, enabling the central child to function more peripherally.

Bases-Up Yoked Prism

- deemphasize ground and emphasize figure, enabling the peripheral child to function more centrally.

With respect to spatial organization, plus lenses ostensibly have the same effect as bases-down yoked prism and minus lenses ostensibly have the same effect as bases-up yoked prism.[64] Kraskin[60] cautioned that when viewed in terms of their postural-spatial influences, vertical yoked prisms cannot be assumed to have a specific potentiating or decremental effect relative to spherical lens counterparts. Rather, performance tests are vital in knowing when to incorporate and when to remove yoked prism from the patient's lens regimen.

The interrelationship of spherical lenses and yoked prism has its counterpart in the concept of BOP and BIM. This is the training of convergence (base-out) through plus lenses and of divergence (base-in) through minus lenses. This is counter to what is experienced in visual space. That is, objects approaching the observer are usually associated with increased accommodation and convergence whereas objects receding are associated with relaxation of accommodation. We therefore consider BOP and BIM as indicative of attainment of greater degrees of freedom between accommodation and convergence. Otherwise stated, the ability to achieve ranges of BOP and BIM reflects a high degree of spatial flexibility.

Sutton extended the BOP and BIM concept to yoked prisms in the context of a "learning-thinking lens program."[65] Macdonald noted that bases-up yoked prism are typically associated with convergence because the eyes are in downgaze, and bases-down yoked prism are associated with divergence because the eyes are in relative upgaze.[66] To build degrees of freedom, however, it is desirable to perform tasks wherein the secondary axis effects of vertical prism direction are combined with a corresponding mismatch in spherical lens sign. Sutton therefore recommended the combining of binocular yoked prisms with binocular lenses to build spatial flexibility as follows:

1) Bases up with plus lenses
2) Bases down with plus lenses
3) Bases up with minus lenses
4) Bases down with minus lenses

CYLINDRICAL PERSPECTIVES

In-depth considerations of the nature of astigmatism, its causes, and principles of its compensation are beyond the scope of this review. A thorough treatment of the adventitious, purposeful, and environmental influences of astigmatism was presented by Nicholson and Garzia.[67] Aggregating behavioral theories under the heading of environmental effects, they reviewed the concepts of Skeffington, Harmon, Getman, Forrest, and Birnbaum as related to models of astigmatism. Our look at cylinders will be from the slant of a developing visual-spatial continuum.

In their classic series on the function of lenses, Apell and Streff considered the spatial effects of astigmatism and compensatory lenses.[68] They contend that the individual with acquired astigmatism has made an unconscious adaptation to integrate more of the visual field at the expense of a skew in localization. Both with-the-rule and against-the-rule adaptations enable the object of regard to be localized as if it were closer, but from different vantage points:

Against-The-Rule Astigmatism

1) enables y-axis space to be localized closer, but elongates z-axis space, resulting in near-to-far shifting difficulty;
2) is more suitably prescribed for in bifocal form;
3) is often a sign of less plus prescribability;
4) is considered a precursor of myopia and can be transient;
5) gives the individual a greater sense of seeing as if one, as compared to with-the-rule astigmatism.

With-The-Rule Astigmatism

1) enables z-axis to be localized closer, resulting in centrally fixated object appearing larger than objects to the side;
2) accepts more plus than with-the-rule astigmat;
3) gives individual greater sense that the two eyes are seeing individual views of the world as compared with the against- the-rule astigmatism.

Murroughs considered the differential spatial effects of cylindrical lens power meridia.[69] It is well known that oblique axes cylinders induce the greatest spatial distortion, with declination effect being maximal when one lens is at axis 45 and the fellow lens at 135. A behavioral correlate of the tilt effect occurs when the minus cylinder axis is at 45 degrees in the right lens and at 135 degrees in the left lens. Since the floor appears to slant upward, patients feel as if they are climbing uphill and report feeling tired.

Valenti[70] discussed the role of cross-cylinder lenses in inducing movement. He uses cross-cylinder techniques in vision therapy for problem solving, using the patient's response as feedback to give understanding about the direction of movement. As an example, the patient is presented with the crossed grid target with cross-cylinders in place and asked which lines are darker. The patient who perseverates will report that whichever lines were initially darker remain the darker lines; or similarly if both sets look equally dark, no amount of plus or minus is able to change the percept. This lack of movement shows stagnation in the system which is usually a sign of stress or fatigue. The patient must be taught that he or she is the center of control, and can alter their perception by doing something differently.

One begins by using cross-cylinders of higher magnitude and asking patients how things look, as well as what changes they can make. The observer notes whether the patient localizes in front of the plane or behind the plane. Since cross-cylinders form a spatial vector, the patient can be expected to develop a feeling tone consistent with above and below. Once sensitivity is displayed, smaller magnitude of cylinder power can be used.

BEHAVIOR WITH MULTIFOCAL LENSES

It has been stated that every optometrist who has ever modified a prescriptive lens based on projected patient acceptance has prescribed behaviorally.[71,72] This has been axiomatic for the prescribing of multifocal lenses, wherein choices of segment type, position, and power are highly individualized. Undoubtedly the increasing demand for progressive addition lenses has focused attention upon the perceptual, behavioral, and physiological characteristics of lens application.

Recent developments in progressive addition lenses have brought renewed attention to the basic mechanisms of sensorimotor adaptation. In an earlier section of this paper entitled *Behavioral Optics* reference was made to the classic experiment of Stratton with inverting prisms. Mathieu[73] reviewed the adaptation of the presbyope to progressive lenses from the standpoint of Stratton's experiment. Of particular interest in this regard is the study conducted by Gauthier et al.[74]

Gauthier et al.[74] investigated the ability of subjects to adapt to changes in visual space induced by lens magnification and progressive lens prescriptions. They observed large individual variations in visuo-manual adaptation experiments that closely correlated with large individual variations in adaptation to actual lens prescriptions. They suggested that these differences were due to previous experience involving age, sensorimotor skill, motor learning, and higher-level central nervous system processes. Moreover, both inflow and outflow theories of eye position mediate limb perception in space, general kinesthetic body sense, and visual awareness. They proposed a mixed model combining efferent (outflow) and afferent (inflow) information to describe properties of direction and distance perception in the visuo-oculo-manual system.

Recently, Young[75] provided a concise overview of three key variables in progressive lens design which influence adaptation:

1) abrupt spherical power change in the corridor
2) unwanted cylinder
3) varying prismatic effects

Young[75] discusses lens adaptation in terms of foveal and extrafoveal vision, reminiscent of Trevarthen's classification of ambient and focal. He describes extrafoveal vision as that which is utilized for gross form and space perception, and assists in maintaining orientation and localization. Perception of the field of view relative to the change in position of the eye or head of the viewer introduces the element of dynamic vision (not to be confused with dynamic acuity). As applied to progressive lens adaptation, foveal vision is affected more by abrupt spherical changes and unwanted cylinder. Extrafoveal vision is particularly susceptible to varying prismatic displacement.

The designing of a lens to minimize variation in peripherally induced prism is known as orthoscopy. Even with the best of today's orthoscopic designs, the peripheral visual mismatch created through illusory motion entails flexible problem-solving abilities on the part of the patient. It is striking that we ask patients to adapt to these conditions with minimal Socratic guidance as compared with the structuring of lens application in formal vision therapy programs.

Behavioral optometry has not as yet designed programs to guide patients through adaptation difficulties to specific lenses. Assuming that vision therapy can stave off presbyopic rigidity, but cannot obviate the eventual need for multifocal compensation, one is left with the impression that a successful vision therapy patient would enjoy a relatively smooth transition to a progressive addition lens. To paraphrase Thoreau, the flexibility of a patient's adaptability will be the measure of his success with progressive addition lenses.

LENSES AND PERFORMANCE

Spherical Lenses

As mentioned in our previous section on *Engineering of Behavioral Models*, variations of nearpoint retinoscopy have been successfully used in selecting the appropriate nearpoint lens for optimal performance. Improved performance with appropriate lenses as reflected in physiological measures[76] as well as eye movement recordings[77] is well-known. The positive behavioral effects of low power plus lenses has been demonstrated on performance tests such as the motor-speed and precision sub-test of the Detroit Test of Learning Aptitude[78] and the Winter Havens Copy Forms Test.[79]

One point which recurs in the survey of literature on lenses and performance is the acknowledgement that lenses are not always beneficial to performance. Aside from the studies mentioned above, a pertinent example of this is the study by Friedhoffer and Warren.[80] Finding that sustained nearpoint visual demands resulted in constriction of the central visual fields, they measured the effects of +0.50 and +1.00 sph OU on this constriction. Their findings indicated that +0.50 sph OU offset constriction of the central field to a greater extent than +1.00 sph OU.

The use of cortical measures of performance for determining the effect of lenses has been suggested. Ludlam has proposed that measures of alpha-rhythm attenuation be used in judging beneficial effects of plus lenses.[81] Spafford, Lovasik and Holterman noted that low power plus lenses can enhance the waveform and amplitude of the binocular visual evoked response.[82] As noted by Margach[83] electrophysiological findings consistent with a behavioral approach to lens application is welcome corroboration of clinical regimens. Margareten recently reported that the binocular VEP measured at one meter with varying amounts of plus can indicate the optimal low plus add for non-presbyopes to within a quarter diopter of sensitivity.[84]

A recent study by Wildsoet and Foo[85] raised pointed questions about reading performance and low plus lenses. When comparing eye movement recordings of subjects wearing plano lenses versus their habitual low plus prescriptions, no statistically significant difference between the two sets of lenses were found. In addressing possible explanations for the discrepancy between their results and the positive effects elicited by Sohrab-Jam in a similar study[77] they noted that some of their subjects may have been wearing inappropriately prescribed plus lenses. They raised the inevitable issue of the placebo effect, as well as the consideration of when low plus lenses at near have affected sufficient cure so as to no longer be indicated.

Koetting recently issued a monograph on his study of convex lenses for near and reading performance in certain learning-deficient children.[86] Nearpoint lens addition was determined on the basis of the fused cross-cylinder net finding. No statistically significant differences were observed between treatment groups wearing nearpoint lenses as compared to distance lenses with respect to the principal dependent variables on the reading subtests of the Stanford Achievement Tests. However, statistical significance was obtained in gains on composite scores of the lens wearers with low hyperopia when results with progressive addition lenses were compared with the single vision distance prescription. Koetting's candor in accounting for the generalized lack of statistical significance is noteworthy: "...it is likely that many of these children may have had other factors more critical than visual stress negatively influencing their achievement in school. Such factors might have been more prominent than stress occurring through prolonged visual activity associated with near distances - the stress that was to be relieved through the application of the treatment convex lenses. Such factors might have included a host of etiologies of learning difficulties, not the least of which might have been language complications with respect to a large number of the Hispanic children."[86]

Non-yoked Prism

Performance with bilateral (non-yoked) prisms was measured by Sheedy et al. on tasks involving word reading and VDT letter counting.[87] They used infra-red sensors to record eye movements while having young adult subjects read word charts. Eye movements were recorded through symmetrical binocular prisms varying from 12 BI through 12 BO. They found only the 12 prism diopter BI condition to have statistically significant difference in performance decrement as compared with the zero prism diopter control condition.

Yoked Prism

Performance measures are increasingly used in the analysis of yoked prisms. Kaplan[88] uses spatial observations of performance such as ball play in addition to projective performance tests such as VO Star, Cheiroscopic Tracings, Bimanual Circles, and Vectograms. His suggested powers for directive changes are generally two diopters bases-up for exo projectors and three diopters bases-down for eso projectors.[89] In addition, he provides a theoretical construct of eye muscle potentiation for use of larger amounts of prism (up to 15 prism diopters) in movement awareness activities such as walking rail.[90]

Kraskin emphasizes the disruptive, spatially rearranging properties of low power yoked prisms. This is in keeping with his philosophy of counterstress lenses, previously reviewed in the section on *The Behavioral Concept of Lenses*. Aside from the postural alterations previously noted in the section on *Lenses and Postural-Spatial Shifts*, Kraskin uses changes in stereo testing as a guide to prescribing counterstress yoke prisms. Specifically, the prism base is prescribed in the direction that *decreases* performance on the stereo test. The prisms are no longer significant when they do not decrease performance, or when their opposites do not improve performance. Kraskin's guideline for utilization is generally one prism diopter less than that which creates an awareness of space distortion, not generally exceeding four prism diopters.[60] Kraskin[91] and Saltysiak[92] have reported on the use of the Lowman balance beam in conjunction with yoked prism, particularly with base direction to the left and right.

Moskowitz[93] proposed use of the following performance tests for assessment of yoked prism effects:

1. Nearpoint of convergence
2. AC/A ratio
3. Fusion in motor fields
4. Van Orden Star

Satty[94] evaluated these performance measures in ten patients after application of yoked prism and observed the following:

1. Nearpoint of convergence improved
2. AC/A ratio increased
3. No significant change occurred in motor fields
4. Organization on Van Orden Star was variable

Although this study was too small and inadequately controlled to allow generalization, it is indicative of ongoing clinical attempts to apply yoked prism with the savoir-faire of spherical lenses.

Valenti[95] recently introduced a technique to directly assess the direction of distorted space upon the introduction of counterstress yoked prism. He describes the construction of a board which allows the patient to map his perception of visual space by locating four coordinates on the underside of the board. Valenti gives the following example:

> An anisometropic patient who shows more myopia in the right eye is likely, according to Harmon's research, to have a head turn to the right. This causes the eyes to habitually fixate more to the left. The prism board measurement is likely to show space distorted to the patient's left as a result of tonic stimulation of ocular musculature to the left. The indicated prism direction would be bases right, in order to exaggerate the spatial distortion to the left. The amount of prism used generally ranges from 3 to 8 prism diopters, and is only considered if there is anisometropia which is manifest in spatial distortion. The patient is instructed to use the glasses for three 1 hour periods daily while moving. Prisms are discontinued when distortion is reduced and anisometropia is minimized or eliminated, with plus lenses prescribed for maintenance in accordance with book retinoscopy findings.

Horner[96] suggested several performance measures of yoked prism. He used the Harmon Square Test both to test asymmetry as well as study performance with yoked prism. In addition, he used two bathroom scales to study the relative weight distribution during postural sway with yoked prism in place.

In a similar but more scientific vein, an instrument known as the Electrodynagram Gait Analyzer was introduced by Jacobs and Cantwell as a tool to measure the effects of yoked prism.[97] Their attempts to equalize gait by application of various yoked prism powers appears to be the electrophysiologic anti-gravity analog of Harmon and Pierce's upper torso postural measures.

In a well-controlled experiment, Sheedy and Parsons attempted to delineate factors involved in patient acceptance and postural adjustment to vertical yoked prism.[98] They averaged measurements of head posture with the aid of a bite bar, and perceptual direction through use of a mirror pointing device, at the beginning and end of a two week trial period. One group of subjects alternated between a 2 prism diopter yoked bases down prescription and a no-prism prescription. The other group of subjects alternated between a 4 prism diopter yoked bases down prescription and a no-prism prescription. The subjects showed a 50% acceptance rate of the 2 prism diopter lenses, but a 90% rejection rate on the 4 prism diopter spectacles. Interestingly, the subject who preferred the 4 prism lenses noted that it helped a back problem.

Of note in the Sheedy and Parsons study[98] was the fact that head posture was significantly higher at the end of two weeks in the four diopter prism group as compared with the no prism condition. Only 25% of demand in elevation was met by increase in elevation of the eyes. Most of the change in head posture occurred during the two weeks of wear and not upon initial placement of the prism. The change in head posture of the two prism diopter group was insignificant. They speculated that the source for change in head posture may have been in the neck or in back posture, and may have been a reason for the rejection of the 4 prism diopter spectacles. Although more studies of this nature are needed to bolster clinical impressions, they, in concert with the preceding discussion, manifest the following observations and generalizations:

1. Every ophthalmic prescription induces yoked prism effects when the patient looks off the optical centers.[99]
2. Yoked prism ground into an ophthalmic prescription for general use is usually limited to small amounts (generally in the range of four prism diopters) and split equally in value between the two eyes. They may be prescribed as counterstress lenses (initially decreasing performance) or as compensatory lenses (initially improving performance). The counterstress prism base direction will be opposite to the direction of the compensatory prism base direction.
3. Counterstress prism exaggerates adaptation in the direction opposite to which movement is desired. As an example, base-up prism results in a body shift that moves the center of gravity forward. This is therefore the counterstress direction for myopia and the compensatory direction for hyperopia.[100]
4. Small amounts of yoked prism are used to re-organize visual space by replacing maladaptive behavior with new behavior. An example of this is the use of yoked prism bases up as compensatory lenses to enhance the nearpoint function of VDT operators.[101]
5. Larger amounts of yoked prism are used to re-organize visual space by first disorganizing visual behavior through kinesthetic re-afference.

THE IRLEN TINTED LENS

The May 1988 interview of the psychologist, Helen Irlen, on CBS's *60 Minutes* program vaulted the Irlen tinted lens into national prominence. The response of dyslexics to the television debut of the lens was reminiscent of the reaction of Ed Sullivan's studio audience to the introduction of The Beatles. Around the country, optometrists phones rang off the hook the following morning with the identical request: "What can you tell me about the new tinted lenses for reading problems?"

Optometrists have taken a strong interest in evaluating these lenses because of the claims of positive affects on various visual symptoms by their proponents. Irlen presented the scotopic sensitivity syndrome as a distinct type of visual dyslexia, related to difficulties with light source, intensity, and color.[102] Characteristics of the patient with scotopic sensitivity syndrome as reported by the Irlen Institute[103] are as follows:

1. light or glare sensitivity
2. red or watery eyes;
3. falls asleep when reading; headaches; burning or itchy eyes; words double, move, look fuzzy, or disappear
4. rubs eyes; must take breaks while reading; reads close to page; squints
5. skips words or lines; re-reads words or lines; loses place; reading performance deteriorates with time
6. unequal spacing when reading; errors copying from the chalkboard; misaligns digits or columns
7. eyestrain, fatigue, or headaches when using computers
8. difficulty with depth perception and judging distances.

The similarity between this checklist of signs and symptoms and that which is contained in *The Educator's Guide to Vision Problems* published by OEP is striking.

As reported by Clayton[104] the scotopic sensitivity syndrome is often found in a complex of other disabilities including eye muscle imbalances, and may be hereditary. She states that it is a distinctively different visual problem from visual acuity and refractive errors. Therefore, she continues, "Visual examinations from ophthalmologists, opticians, and optometrists will not detect this condition. It is a different syndrome from that which is evaluated by a developmental optometrist or orthoptist, where they are examining eye learning and ocular motility. Therefore, vision training will not correct this condition."

The Irlen system consists of approximately 70 tints with two densities of each tint. Following a comprehensive analysis by a vision specialist, the patient completes a questionnaire rating the extent of any signs and symptoms such as indicated above. Reading performance is then observed by a trained specialist, and compared with performance through some tint overlays and ultimately non-optical tinted lenses. Rosner and Rosner reviewed some of the available literature on the use of Irlen tinted lenses.[105] They concluded, as did Reeves,[106] that significant methodologic flaws exist in the research purporting to support the benefits of the lenses. Although testimonials abound for the benefit of these lenses,[107,108] recently reported studies[109,110] do not as yet have sufficient controls to convincingly support the claims made.[111] As has been suggested by Fuerst[112] so many of the symptoms attributed to scotopic sensitivity can be alleviated with either a standard 10% ophthalmic tint, and/or standard accommodative and binocular dysfunction treatment regimens, that it is difficult for optometrists to rationalize the Irlen program as it currently exists.

It should be borne in mind that optometry is no stranger to the application of colored filters to alter mood or performance. These issues are explored below in the context of Syntonics[113-116] and Seasonal Affective Disorders.[117-119]

SYNTONICS

Syntonics is defined in the Dictionary of Visual Science as "A system of corrective procedures in which selected frequencies of the visible spectrum are utilized, usually by means of color filters, with the implication of therapeutic value in the colors themselves."[113]

Margach[114] related the definition of syntonics by The college of Syntonic Optometry as follows: "That branch of ocular science dealing with (the use of) selected frequencies of the (electro-magnetic) spectrum, which when applied through the optic and nervous mechanisms of the eye, effects (sic) such reflex action in the associated and supportive physiological functions as to bring the organism into proper environmental relationships for the emendation of the visual sense. It is strictly an optometric development which in no manner invades the field of other professions, and is primarily for the correction of amblyopia, asthenopia, phorias, headaches, opacities, low reserves, and other departures from normal." Margach questioned the validity of syntonics in the course of reviewing sources of successful case reports. He considered it to be unconventional and cultist, yet intriguing in its plausibility as related to principles of photobiology.

Lieberman[115] challenged Margach's portrayal of syntonics as a cult, and presented a comprehensive review of the physiology of light stimulation. Central to this review is the differentiation of visual and non-visual neural pathways for light reception. The common link of these systems is their direct and indirect effects on behavior through the endocrine system, and specifically the pineal gland and hypothalamus. The differential effects of specific colors of behavior is mediated through activation and arousal states of the autonomic nervous system and visual cortex in response to colors. Generally speaking, the red end of the spectrum stimulates the sympathetic system and the blue end of the spectrum stimulates the parasympathetic system.

There are few research studies available on syntonics. The most extensive study to date was conducted by Lieberman[116] on the effect of syntonic stimulation of certain visual and cognitive functions. For his pre and post experimental measures, Lieberman selected the following functions:

1) visual fields as measured by stereocampimetry
2) visual memory for objects as determined by a subtest of the Detroit Test for Learning Aptitude.
3) visual memory for symbols as determined by the Monroe Visual III test
4) auditory attention span as determined by a subtest of the Detroit Test for Learning Aptitude.
5) speed and accuracy of saccades as scored by the Pierce Saccade Test.

Lieberman's experimental group underwent 20 treatments of fixating a light source of specific frequency with a duration of 20 minutes for each treatment. The choice of light frequency administered was based on phoric posture and other (unspecified) optometric findings as well as case history and (unspecified) clinical experience. The control group received no treatment, and there was no sham treatment group. Curiously, Lieberman noted that it was not reasonable to administer placebo treatment to the control group since this too might have had an affect. The results of the testing indicated significant change for the experimental group as compared with the control group in size of the visual field and in visual memory, with no significant change in saccadic accuracy and speed or in auditory memory.

Although one can point to flaws in the Lieberman study, it is an important first step in the effort to substantiate syntonics through prospective measures. One cannot help but be drawn to parallels in the concept of colored filters as applied in Irlen Lens methodology (see section on "The Irlen Tinted Lens" above) and colored filters in syntonic optometry. There are broad implications for the optometrist in considering the subconscious influence of ocularly transmitted light on the individual, as reviewed by Hutchins.[117] As an example, the therapeutic use of light in countering depression during seasonal affective disorders has received widespread attention.[118] Certain individuals become depressed during winter months when there is less daylight. Phototherapy with full spectrum lighting has had profound effect on some patients. Optometrists may need to consider the implications of using ultraviolet blocking lenses with such patients.[119]

CONCLUSION

There are two major points underlying in our overview of lenses and behavior which should be elucidated:

1. Behavioral responses to lenses and prisms are observable and measurable through space and time. When significant change occurs in spatial awareness, performance as well as personality is affected.[120]
2. The lenses and/or prisms most appropriate for individual patients must be determined on an individual basis, for individual needs, and be periodically re-evaluated. An inappropriate nearpoint lens can result in poorer performance or greater discomfort than no lens at all.[121]

The author wishes to acknowledge the following individuals who contributed in their own way, to the formulation of this paper: Drs. Robert Greenburg, James Bosse, Nathan Flax, Martin Birnbaum, Mrs. Margaret Lewis and her staff at the Harold Kohn Library of SUNY State College of Optometry, and the women who pour the coffee at Dunkin' Donuts.

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