PERIPHERAL AWARENESS

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ABSTRACT

A duality in the visual system has been proposed in terms of retinal anatomy and function, spatial integration and behavior. Peripheral awareness can be conceptualized as one part of this duality. Currently available methods to measure peripheral awareness are discussed along with recommendations for a more precise determination. Clinical optometric implications and usage of peripheral awareness are addressed.

KEY WORDS

peripheral awareness, rod-cone, peripheral-central fusion, ambient-focal, global-specific, field dependent-field independent, form recognition fields, visual- spatial neglect, exo/eso processors

[redacted]ptometrists involved in behavioral vision therapy often seek to enhance the peripheral awareness of their patients.[1] Whether as an aid to reduce an eso posture, training an athlete to attain his or her optimal level of achievement, or rehabilitating a head trauma patient, peripheral awareness has become part of many behavioral optometrists' clinical methods. My purpose is to discuss some of the mechanisms that underlie peripheral awareness, review current methods of its assessment, and the benefits of utilizing it for certain patients in vision therapy.

RETINAL ANATOMY AND FUNCTION

Duality exists in the visual system. At the most fundamental level, it is based in retinal anatomy. Retinal regions are specialized according to their function. The photoreceptor cells are organized in various concentrations and distributions across the retina. The most commonly used means of differentiating these divisions is based upon whether the region functions as a detector of gross form and movement, or to inspect fine detail.[2]

The organizational bias for detection of detail is predicated by the region of greatest concentration of cones per unit area (150,000 cones/mm^2).[3] This "central," cone-rich region is the fovea. It is a small pit occupying approximately 1.5 mm. Within the fovea is a smaller area of approximately 260 micrometers, the central fovea or foveola, which is comprised completely of cones. It is within this area that the anatomy allows for maximum acuity. The fovea, therefore, is functionally the place on the retina which enables a person, by the appropriate eye movement, to locate the image of "whatever is of greatest psychological interest in his visual space."[2]

The rods' main function is to detect movement, ultimately providing the context for the necessary spatial information to enable the individual to survey his/her environment. The rods outnumber the cones by approximately 17:1 with their greatest concentration at 6 mm (20 degrees) from the fovea (150,000/mm^2).[4]

Viewing the object of interest with a retinal location eccentric to the fovea results in decreased acuity. Acuity reduces to approximately 60% of maximum at 1 degree from the fovea.[4] At the point of greatest rod density, acuity is approximately 10% that of the fovea. Thus, at this foveal eccentricity, there is the Snellen equivalent of approximately 20/200. This degree of visual acuity may not be sufficient for the person to inspect the words of a street sign 20 feet away, yet it does allow that person to avoid being hit by a car.

While retinal anatomy is the foundation for retinal functioning, the retina works in a variety of ways, not the least of which is sensory fusion. Sensory fusion is the "unification of visual excitations from corresponding retinal images into a single visual percept, a single visual image."[5] The stimulus for sensory fusion is the excitation of corresponding retinal points. Burian[6] studied the role of the retinal periphery in the elicitation of fusional vergence movements when disparate stimuli were presented with a projection haploscope. It was shown that peripheral stimuli, when appropriately placed, and of adequate strength, could break the fusion of images that were situated on areas corresponding to the macular region. This was the case even when patients were concentrating on the central stimulus and totally ignoring the peripheral stimulus. The contribution of this research is significant; it demonstrated that in addition to providing information to aid mobility in dim illumination and for the perception of motion, the periphery contributes to the stabilization of the relative position of the eyes. This further highlights the periphery in terms of its important role in sensory fusion.

AMBIENT-FOCAL VISUAL SYSTEMS

This duality in the visual system has been studied beyond anatomical and fusional eye movement levels to one of information processing and behavior. Colwyn B. Trevarthen worked extensively with split-brain monkeys.[7] On the basis of his work, he hypothesized that the visual systems of primates have two mechanisms distinct in their anatomical bases, their information processing abilities, and their affects upon behavior. The ambient system is responsible for vision in extensive space, while the focal system is concerned with the visual identification of particular items in space.

Trevarthen[7] felt that movement is primarily regulated by the ambient system. The adjustment of posture, locomotion in space, and gross examination of spatial configurations are all within the realm of ambient visual functions. The ambient system is used for general examination of, and self-orientation to the external environment. Highly mobile animals are concerned with an instantaneous survey of the terrain, i.e., which objects are obstacles and how they can be negotiated to avoid collision and enable continuous movement. Visual discrimination over a wide scope needs to be made, but requires only a relatively crude capacity for discerning intricate detail. The vision in the peripheral fields functions well under conditions of dim illumination, yet is responsible for motion detection, and does not create a lasting conscious impression. This ambient vision, although nearly subconscious, provides invaluable and reliable information to allow accurate and quick maneuvering through space. It is Trevarthen's impression that "during large continuous displacements of my body, central acuity is greatly reduced."[7] Scotopic conditions prevail as if the whole visual field contained an equal distribution of receptor cells, rather than a peak in the central or foveal region. In this manner, it is not surprising that the surviving nocturnal primates have effective ambient visual systems.

In contrast, the focal system is used in the identification of a specific item, at a specific time and location. Trevarthen considers the lower, nocturnal primates to have rather crude and rudimentary praxic behavior as compared to the higher primates. The higher primates are diurnal, yet far more active during daylight hours, requiring a system with highly developed acuity and color vision. They are more sedentary and their activities more intricate, requiring the handling and examination of small objects while standing or seated. Hence, the need for adeptness in manipulatory behavior has necessitated the development of complex, spontaneous eye movements and keen vision. Consequently, higher primates are the only mammals with well-developed foveae. They are also the only animals that make eye movements to survey their visual field while keeping the head relatively still. The specialized oculomotor system of these primate reduces the need to make large head movements in order to explore the surroundings. Humans employ their foveal vision with careful choice of various areas of the visual world in front of them.

Trevarthen,[7] using a broad view of the behavioral space of primates, considered vision to have two components. The two monocular visual fields are each "selectively sensitive to change or motion." These fields provide the margins of the ambient system which frame the extent of the whole visual field. Vision here is three-dimensional, yet only capable of gross resolution with poor discrimination of fine detail. The central binocular field in front of the individual is governed by foveal resolution of detail and hue and where fine depth separations are detected stereoscopically. This represents the focal system.

GLOBAL (FIELD INDEPENDENT)/ SPECIFIC (FIELD DEPENDENT)

The cognitive aspect of the duality of vision has been expressed by Sutton[8] who related individual differences in learning and thinking styles by incorporating some of the work of H. A. Witkin.[9] Witkin found that "people differ in the way they orient themselves in space." He placed people on a continuum from global (field independent) to specific (field dependent), and felt that the majority fell near the middle.

Sutton[8] considered the "global" person to have several characteristics or tendencies; they are more attentive to ground rather than figure; are hyperopic and exophoric; visually compute objects in space to be farther and larger than they are; lack awareness of spatial relationships and consequences, yet enjoy the stimulation of space; cannot maintain fixation on moving targets and their eye movements often employ additional generalized head and body movements. Nearpoint of convergence testing reveals a loss of fixation with diplopia or eye drift beyond four inches from the nose.

Sutton[8] felt that the person who is "specific" in his or her visual style emphasizes the figure and has difficulty relating figure to ground; tends to be myopic and esophoric; visually computes objects in space to be closer and smaller than they are; is insecure in space; employs slow and cautious movements; has difficulty with heights, and often experiences dizziness and nausea; maintains visual fixation on a moving target, but has erratic eye movements with a tendency to lock in on the target without the "freedom of flexible skills." On nearpoint of convergence testing, the "specific" person demonstrates stable and accurate fixation within four inches of the nose.

Not all of these observations pertain to all people, and conclusions should not be based upon these observations alone. However, Witkin made some generalizations in terms of development which are more generally applicable. With respect to the global- specific styles of behavior and thinking, he found that younger children have a tendency to be more global and impulsive in their perceptual and behavioral styles. Maturation typically results in the development of a more specific and reflective style. Time alone doesn't guarantee this development. Witkin further suggested that since the human environment demands the development of a specific learning/thinking style, it appears that the people who undergo that maturational process tend to be more successful. He observed that in the geriatric stage of life, the thinking/perceptual styles frequently revert to being more global. "The development of learning/thinking styles seem to follow the spiral of human development--from global to specific, and back to global."[9]

MEASUREMENT OF PERIPHERAL AWARENESS

Accurate visual field testing places certain demands upon the patient. It requires central fixation at all times while indicating whether peripheral stimuli are perceived. The demands are essentially the same regardless of whether one employs the confrontation, tangent screen or automated perimetry method.

These methods do produce qualitative and/or quantitative result as to the extent of the anatomical visual periphery and the presence or absence of a field defect. However, they do not truly measure peripheral awareness. Peripheral awareness is the ability to simultaneously perceive what is central and appreciate what may or may not be off to the sides. It is not a question of the "seen" versus the "not seen" in visual field testing. Rather, peripheral awareness involves incorporating peripheral stimuli into one's visual world, rather than just noting whether the stimulus is present or not.

The Wayne Peripheral Awareness Trainer (PAT)[a] requires central fixation with simultaneous response to peripheral target lights of equal size across the array for point scoring to take place. In this respect, the PAT is similar to the automated perimeters (see Figure 1).

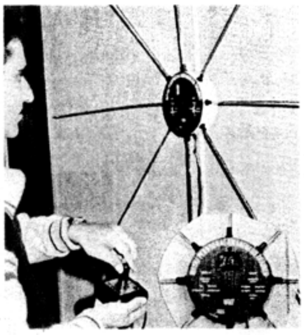

Figure 1. Wayne Peripheral Awareness Tester (PAT)

However, it is assembled in such a way that the patient can be seated or standing, and doesn't require near immobilization of the head, thus being far less confining for the patient. The PAT can test peripheral awareness and reaction time in eight field locations. It is capable of automatically adjusting the stimulus speed according to the patient's proficiency.

Since acuity varies across the retina as one tests more and more peripherally, targets presented to test peripheral awareness should not be of uniform size. For example, if a target presented to the eye falls 4 degrees from the center of the fovea, then it should be of Snellen acuity size equivalent to between 20/60 and 20/70 in order to be minimally resolved and seen;[10] at 9 degrees, it must approximate the size of 20/100 to 20/150 targets.

The ideal method for peripheral awareness measurement would incorporate the Wayne PAT with a means of presenting targets of the appropriate size to the retinal periphery. The fixation monitoring apparatus of the PAT helps to insure that the patient is maintaining the proper central fixation. Ideally, the targets should be dynamic as opposed to static due to the retinal periphery's specialization for motion detection. Presenting targets to the periphery that are a certain factor larger than threshold based on eccentricity and visual angle could make accurate quantification possible. This would allow for reevaluation at a later time to determine if there has been an improvement after therapy emphasizing peripheral awareness.

It appears that Lawrence W. Macdonald, O.D., based his Form Recognition Fields Card[11] upon the principle that acuity varies across the retina. Hence, the targets on the card that are presented more peripherally were larger than the more central ones (see Figure 2). Macdonald stressed the importance of efficiency in simultaneous visual central-peripheral interactions. He believed that vision therapy should ultimately provide the patient with a "balanced and dynamic central-peripheral relationship."[11] The objective for using the Macdonald card in a programmed approach to vision therapy is "to expand the amount of visual information that may be comprehended per given unit of time."[11]

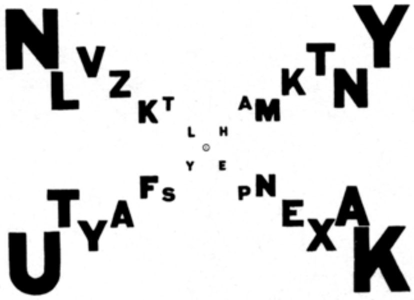

Figure 2. Macdonald Form Recognition Fields Card.

To utilize the card, the patient should be wearing the appropriate lenses for near. One eye is then occluded and the target is held at 13" in front of the non-occluded eye. The patient should be relaxed and his body should be devoid of all extraneous movement. The patient fixates the central dot target, or letter, as on the original card. The patient is instructed to maintain clarity of the central letter/target while attempting to recognize the next four letters around the central one. If the patient is unable to do so, he or she is then instructed to look off center at one of the letters for its identification, then back to the central letter while maintaining the recognition of the given letter out of the corner of his eye. The patient is then to work progressively outward and recognize the next letters in each subsequent block of four letters. The goal is for the patient to gain the ability to see all of the letters while simultaneously looking at the center letter/target.

Nowhere in the original writing were the words "peripheral awareness" mentioned. However, the Macdonald Card is considered by many, and documented by some,[1,12] to be the definitive method utilized to enhance peripheral awareness. According to Robert Kraskin, O.D.,(personal conversation), Dr. Macdonald had used the card in practice as a tool to help determine the appropriate near prescription. He had the patient try several pairs of plus lenses for near and decide which pair allowed for the greatest recognition field based upon the number and quality of letters read while maintaining fixation at the center. Nevertheless, the Macdonald card appears to be the first clinical device to measure peripheral awareness, albeit in a gross manner.

Although essentially the same, the Rothman card[13] is modified so that no letters are duplicated. Each letter on the

Rothman card has the same spacing and format as the Macdonald card, but the particular letters are slightly different. The card is used in therapy in much the same ways as the Macdonald card in expanding the amount of information comprehended at any given time,[11] but, in addition, allows the patient to choose from a variety of letters without repetition.

CLINICAL IMPLICATIONS

Sports Vision

Optometrists who are actively involved in sports vision or vision therapy are probably the most versed in "peripheral awareness." Sports vision can encompass many different aspects of optometric practice, from contact lens fitting and protective eyewear to specific enhancement techniques to help improve athletic performance. Seiderman and Schneider[14] compiled a table that rates various sports vision skills to their importance in 35 major and minor sports. In some 29 sports, central-peripheral awareness had ratings of "very important." Although the rating system is not scientific, and the list of 35 sports not exhaustive, it's obvious that peripheral awareness should not be ignored when addressing sports vision therapy.

Nearly all sports demand good, if not superior, peripheral awareness. Possessing a relatively large field of vision is an obvious asset in terms of sports performance. The maximal utilization of the periphery without ignoring the particular central task at hand is central-peripheral awareness and interaction at its best.

In basketball and football, for example, both the offensive and defensive players must have an awareness of where the ball is, where his or her teammates are, and where the opponent is at all times. Henderson and Hobson[15] concluded that all of the players in their study had visual fields larger than normal. Francis Stroup[16] found that there is a difference in the field of motion perception in basketball versus non-basketball players. This suggests that the larger range of field is a factor that greatly contributes to basketball ability. In 1975, Williams and Thirer[17] published their study of the relationship between vertical and horizontal peripheral vision in male and female athletes and non-athletes at Florida State University, and concluded that both vertical and horizontal fields of vision are larger in athletes as compared to non-athletes.

Head Trauma Rehabilitation

As reported by the U.S. Department of Health, Education, and Welfare in 1974,[18] trauma is the leading cause of death in youth and early middle age and is the third leading cause in all of the United States behind cancer and vascular diseases. There are several forces by which head trauma can cause brain injury: direct compression of brain tissue, shearing forces, tension, or tearing of brain tissue.[18] Patients suffer the ill effects of these types of injuries both emotionally and physically. Visual field loss is not uncommon in head trauma patients. The types of loss can vary from hemianopias, altitudinal field loss, and quadrantanopsias to other nonspecific ones.

Visual-spatial neglect is often found in head trauma patients in the absence of a demonstrable visual field deficit. These patients have a tendency to fail to perceive a part of a stimulus only when multiple stimuli are presented. For example, when more than one stimulus is presented to the patient, he or she may not see portions of it. Reitan and Wolfson[18] presented a case, patient C.D., who neglected stimuli presented to his right side. When C.D. was asked to read a sequence of words, he omitted the last word which had been presented to the far right of the bottom line. When the word was pointed out, he seemed surprised that it was on the page. Reitan and Wolfson report "it is not at all uncommon for patients with right cerebral lesions to have difficulties perceiving the left side of stimulus configurations."[18]

Optometrists are increasingly involved in the evaluation and treatment of perceptual deficits that result from head trauma. Patients have disturbances in spatial relationships, visual memory, visual motor integration, discrimination of right and left. Where there is a true field loss or neglect, peripheral awareness enhancement can be a valuable therapeutic or rehabilitative tool. In most cases, the field loss is permanent and cannot be "trained away." Rather, the patient can be taught to become maximally aware of the portion of the field that has remained. Eccentric viewing and proper head posturing alone may not be enough. The use of certain optical aids, including prisms in addition to peripheral awareness techniques, may enable the patient to accomplish a variety of tasks--from simply being able to safely maneuver through his or her home to, eventually, job-related travel.

Hyperactive Children

Some anecdotal evidence exists to suggest that vision therapy to enhance effective central-peripheral interplay can positively influence a student's poor attention span. One may want to decrease a patient's peripheral awareness to accomplish this goal. The "hyperactive" child who is thought to have an "attention deficit disorder" may actually be too peripherally aware, and needs to ignore distractions in the periphery. Getman[19] reported that visual peripheral awareness plays a significant role in "busy classrooms where distractions are a common trait of the environment." He discusses the beneficial influence of Cruickshank's individual study carrels on some children's learning abilities and styles.

Peachey, as reported by Getman,[19] conducted a study to determine if improved central-peripheral visual field relationships could positively influence the classroom performance of hyperactive children. Short term results of the study suggest that those subjects trained in general spatial activities and peripheral field judgments demonstrated the greatest number of gains. The group trained on tasks unrelated to central-peripheral type experiences showed the least. As evidenced by the students' medical records, some of those who participated in the project were able to discontinue the medication that was administered to help reduce their hyperactivity.

Exo/Eso Processors

Forrest[20] viewed patients with fusional instabilities as representing "manifestations of different types of disorders in the integration of central-peripheral interaction." He felt that high esophores and exophores exhibit difficulty with organization of peripheral awareness relative to central information. They attempt to resolve this disorganization in very different ways. The high exos cannot integrate the central and peripheral information provided; they tend to alternate attention between center and periphery in response to the particular situation at hand. He or she functions at a lower area in both areas of visual space. The exo processor may develop an intermittent microtropia with small foveal suppression in one eye in an attempt to maximize the peripheral information. He or she may be more likely to tolerate diplopia than an eso processor. The exo deviation responsible for the diplopia can allow for a panoramic view.

Exo processors' performance may be poor on both central and peripheral tasks. The eso processor, in contrast, is superb on a central basis, but inferior on a peripheral basis. Eso processors don't need to survey all of the surround as much as they need to zero in on one particular central detail and analyze it completely.[20]

Training these types of patients involves different tasks aimed at particular goals. The exo or more peripheral processor has to learn to incorporate sequence and rhythm, along with more in-depth analysis and discrimination of detail in the central visual field. The eso or more central processor requires more work on spatial, simultaneous, holistic and peripheral activities which implore the use of imagery.[1]

Activity in the sympathetic nervous system may account for excessive stress placed upon the visual system. Benson,[21] a cardiologist, considers relaxation to be a mechanism opposite to intense sympathetic activity. He advocates meditation to reduce stress because its accompanying physiological effects nearly mimic those of reduced sympathetic activity. Perhaps teaching the eso processor certain relaxation techniques may enhance and ultimately improve peripheral awareness.[22] Some of the techniques can be a supplement to peripheral awareness activities both in the office and as home therapy.

To function solely as either type of processor is very inefficient. Both are important, however, "one cannot be considered to be really inferior to the other."[20] Each one provides its own part of "the picture." Identification of detail, color and combined units of diffuse information that provide predictability across the system enable individuals to gain maximal information for visual processing.

CONCLUSIONS

The concept of central-peripheral components of the visual process has long been recognized by behavioral optometrists. It is felt that for effective functioning, the components must act in a dichotomous fashion at certain times, but interactively at others. It comprises a complex mechanism but becomes more understandable when viewed as part of a multifaceted duality of the visual system.

Present methods to assess peripheral awareness do not allow for precise quantification. In spite of this, peripheral awareness enhancement has been used to reduce nearpoint stress, improve visual and academic performance, and in the rehabilitation of head trauma patients.

A future paper will address the objectives and techniques that have been used in vision therapy regimens to develop or enhance peripheral awareness.

NOTE

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