American Optometric Association

Practice Strategies

Vision: A Collaboration of Eyes and Brain

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Introduction

The fact that vision seems so effortless belies the complexity of the visual process. The term vision refers to the complex of eye and brain.[1] It is this complex that guides a broad spectrum of human abilities.

We walk down a street, step up and down curbs, maneuver around objects and other pedestrians, and adjust our pace, while visually monitoring our position. Moments later, we get into our car, drive at highway speed through traffic, and judge where we are relative to other vehicles while anticipating the flow of traffic. We arrive at baseball practice, where we pick up a bat, walk to the plate, miss a curve ball, foul-off a fast ball, and then hit a single, making numerous conscious and subconscious judgments with varying degrees of success. After practice, we stop by the mall, scan the crowd for our friend, and go to the bookstore to find the book we might want to purchase. Over a no-foam latté, we read the opening chapter, seeing if it captures our attention.

Our vision plays an essential role in each of these activities through the collaboration of eyes and brain.

Three new AOA positions papers provide useful information on eye-brain collaboration, co-management of vision therapy, and the use of tinted lenses and colored overlays for the treatment of dyslexia and other related reading and learning disorders.

Visual Neuroscience

The retina is a thin sheet of brain tissue in the eyes. It is the place where the brain first encounters light.[2] Signals travel back-and-forth between the eyes and the rest of the brain. Visual processing involves several major sub-cortical centers, plus a mosaic of dozens of distinct areas in the cerebral cortex.[3] It is currently acknowledged that vision is the result of parallel, distributed processing in multiple areas and through multiple pathways.[4] For example, information gathered by the retina about color is processed in a different area of the brain than information about movement.[5]

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As another example, egocentric direction describes the perceived location of an object compared to our body. This is derived from a combination of oculometric direction (where our eyes are aimed), position of the eyes in the head, and the head's position relative to the body. The brain uses a reference point midway between the two eyes, known as the egocenter, to compute egocentric direction.[6] Enabling the brain to engage a whole body experience, binocular vision is an intricate organization of biologic and psychologic components.[7]

The majority of nerve cells from the retina project to the visual cortex. However, at least 10% of the nerve cells take a different pathway,[8] stimulating areas of the brain stem dedicated to functions that seem remote to vision, when vision is narrowly defined.[9] The existence of extensive sensory motor pathways supports a broader conceptualization of vision, integrating functions such as balance and visual-auditory localization.[10]

"As surely as the old system (for explaining vision) considered that the problem of knowledge and understanding could be separated from the problem of seeing, so the present one will find it increasingly difficult to draw a dividing line between the two."[11]

Clinical Optometric Science

Many aspects of the optometric examination probe the eye-brain collaboration. Consider the complexity of the evaluation of visual fields. A patient is instructed to simultaneously maintain steady central fixation, attend to central and peripheral stimuli, discriminate threshold stimuli, and demonstrate awareness with an appropriate motor response.

Similarly, the clinical assessment of color vision requires more than the discrimination of colors. Every color test has multiple perceptual components. For example, color vision plates require recognition of form and the emergence of figure from background. Color cap tests (Farnsworth) are predicated on good sequencing abilities and subtle discriminatory skills.

The process of binocular vision is a reflection of complex interactions within the eye-brain continuum. For neural binocular summation to occur, inputs from both eyes to the brain must be synchronized in both space and time.[12] Alignment of the eyes is maintained via ongoing collaboration of eyes and brain. Binocular dysfunctions such as suppression and anomalous correspondence demonstrate cortical adaptations in the eye-brain function to minimize visual confusion and maintain some level of visual performance.[13]

It is evident that, beyond eye health, optometrists evaluate a wide variety of visual abilities. These include visual-spatial orientation skills, visual analysis skills (including auditory-visual integration, visual discrimination, visual figure-ground perception, visual closure, visual memory, and visualization), visual motor integration skills, and visual-verbal integration skills.[14]

Conclusion

Information from neuro-imaging and insights from cognitive neuroscience demand a significant reformulation of the understanding of vision. Vision occurs neither in the eyes nor in the brain, but emerges from the collaboration of the eyes and the rest of the brain. Vision is a pervasive aspect of our existence that permeates all our activities. Vision develops and, due to neural plasticity, can be enhanced.[15] Optometry is the discipline dedicated to the care of all aspects of the visual process.

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