

Why Two Eyes?

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Abstract

In addition to stereopsis, there are several other important benefits to having normal binocular vision. These are reviewed in the context of their functionality, as well as rationale for early detection and intervention of binocular dysfunctions.

Key Words

binocular vision, functional vision, stereopsis, motor control, visual intervention

Each year for the past 10 years, at the beginning of the first lecture in my professional optometric course entitled “Normal Binocular Vision”, I commence with a question, “Why two eyes?” There are several reasons for having two eyes, some obvious and others more subtle. Of equal importance is the assumption that possessing normal binocular vision affords one to reap special visual benefits, with clear implications for those who do not, such as individuals with central binocular suppression, strabismus, and amblyopia.

The immediate response to the above question is “stereopsis,” that is three-dimensional, relative depth perception based on horizontal retinal-image disparity. Indeed, stereopsis is important, especially for tasks requiring fine manipulative skills and spatial discriminations, such as threading a needle, judging the space between one’s car and other cars on a crowded highway, and many sports.¹ However, stereopsis does have its limits with regard to the range of distances over which it is useful. Based on simple geometry, in a visually-normal person with a stereothreshold of 12 sec arc, stereopsis does not provide unique relative depth information beyond about 3000 feet.²

Another obvious benefit from having two eyes is the expanded visual field it affords, which produces a lateral increase of approximately 25%.¹ Clearly, an enlarged visual field would be of benefit to all individuals with regard to ambulation and maneuvering about successfully in one’s environment, as well as in tasks such as

driving, flying a plane, running heavy machinery, etc., in which not seeing an object or person would have catastrophic consequences.

However, once we go beyond these two reasons, the others may not be so obvious, yet are of importance nevertheless. There are at least five other benefits that one derives from having two normally-functioning eyes with appropriate sensorimotor, cortical integrative ability.

First, there is the practical and perhaps evolutionary-based notion of having a “spare eye.” If an individual either loses central vision in one eye, or the eye is enucleated, the fellow eye is immediately called upon to function as the spare “back-up” eye. Certainly, this was critically important for our cave-dwelling ancestors who were exposed to a constant array of physical dangers. However, it is also of importance today for all of us, although more so in some populations. For example, amblyopes have a three-times greater probability of losing vision in their dominant eye than do visually-normal individuals.³ Hence, in these circumstances their abnormal amblyopic eye of necessity becomes their full-time “spare” eye. Fortunately, for many adult amblyopes (~40%) of all ages,⁴ the amblyopic eye subsequently improves visual acuity-wise, and perhaps also along other visual dimensions, after the first several months following the ocular insult to the previously dominant eye. This is presumably due to the initial, pronounced release of binocular inhibitory/suppressive effects formerly imposed upon the amblyopic eye,

as well as the subsequent necessity to function now imposed upon it.

Second, there is improved sensory function at both threshold (~40% in contrast sensitivity) and suprathreshold (~7% in visual acuity) levels due to the neurologically-based phenomenon of binocular summation.⁵ This neural integrative process acts to reduce the static or “noise” inherent in the binocularly-combined input, thereby effectively increasing its signal-to-noise ratio. This acts to increase detectability of objects in the surrounds, especially under conditions of low contrast and reduced illumination. Clearly, this is important for night driving, as well as for the elderly in which there is a slow and gradual reduction of both visual acuity and contrast sensitivity due to age-related neurological and physiological processes.⁶

Third, binocular vergence changes provide relatively crude but important information related to the perceived relative depth of objects in the visual field, especially at closer distances.^{7,8} This information is believed to be derived from the vergence innervational neural signal,^{7,8} similar to that proposed for accommodation.^{9,10} However, it may also be derived from extraocular muscle proprioception.¹¹ Thus, along with retinal disparity, vergence functions as a secondary and confirmatory binocular cue to relative depth, in conjunction with the host of important monocular depth cues (e.g., size, texture gradient, linear perspective, etc.).¹²

Fourth, there is the advantage with respect to spatial localization. With normal binocular vision, one will reap the benefit of precise and stable egocentric localization, i.e., localization of objects in the visual world with respect to the body.¹ Thus, the egocenter, which may be located midway between the eyes or perhaps centered in our trunk, serves as the body’s spatial coordinate reference center. With only one eye, however, spatial localization would be of an oculocentric nature. Thus, it would be eye/foveally-based, and hence constantly changing with eye movements, rather than being body-based and therefore much more stable. This was echoed by Ogle over 50 years ago when he stated,

Binocular vision is the coordinated behavior of the two eyes by which a single perception of external space is obtained and by which its greatest

achievement, the specific sensation of stereoscopic depth perception, is made possible. ... Visual spatial localization is the primary need of the individual if he is to live effectively in the world of objects about him. The means by which we perceive the forms, sizes and distances of objects in space and their relative orientation to each other provide a most complex problem of psychophysiology.¹³

This was later elaborated upon by Ogle when he stated,

... and we find it logical to assign the position of any visual input according to a polar coordinate system—that is, according to an angle and a distance from a reference point that must be the center of the body image (which may be a vague sort of image) of the observer.¹⁴

Lastly, and perhaps related to the above, there is a growing body of laboratory evidence which unequivocally demonstrates that gross motor control is improved when two eyes versus one perform visually-guided tasks.¹⁵⁻²⁰ For example, one’s dynamic arm trajectory becomes “time-optimal” when viewing is binocular, and furthermore, accuracy is improved. These factors have important implications with regard to sports, such as tennis and hockey, as well as other tasks in which very rapid and accurate movements are demanded. Furthermore, it may also be of importance in neurologically-impaired patients, where the additional information provided by the binocular input could be of sufficient magnitude to enhance paretic and possibly even ataxic arm and hand movements, with resultant improvement in many quality of life aspects. Clinically, the improvement of visuomotor skills in patients following successful strabismus surgery has recently been enunciated by ophthalmologists von Noorden and Campos,²¹ in which they state:

Parents of strabismic children whose eyes have been aligned surgically will often volunteer the information that the child’s visuomotor skills have suddenly and vastly improved. This improvement does not seem to depend on the presence of stereopsis. It is noted as long as gross binocular vision on the basis of normal or abnormal retinal correspondence is reestablished.

Jones and Lee¹⁵ substantiated this clinical observation by evaluating human binocular and monocular performance through a variety of exteroceptive and visuomotor tasks. The results indicated that binocular concordant information provides better exteroception of form and color and better appreciation of the dynamic relationship of the body to the environment, thereby facilitating control of manipulation, reaching, and balance.

This opinion is supported by Kushner’s recent and extensive bibliographic listing of ophthalmological papers describing the functional benefits of strabismus surgery.²²

Thus, there are a host of visual benefits derived from having two normally functioning eyes, with these encompassing the sensory, motor, and perceptual domains. Hence, any impediment to normal binocular function may act to reduce one’s visual efficiency and overall level of performance. Such a constellation of practical benefits demands early detection and intervention of binocular dysfunctions in our patients to allow for the potential maximum benefits derived from one’s normal binocular sensations.

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