BrienHoldenVisionInstitute

BINOCULAR SPACE PERCEPTION; ANISEIKONIA I

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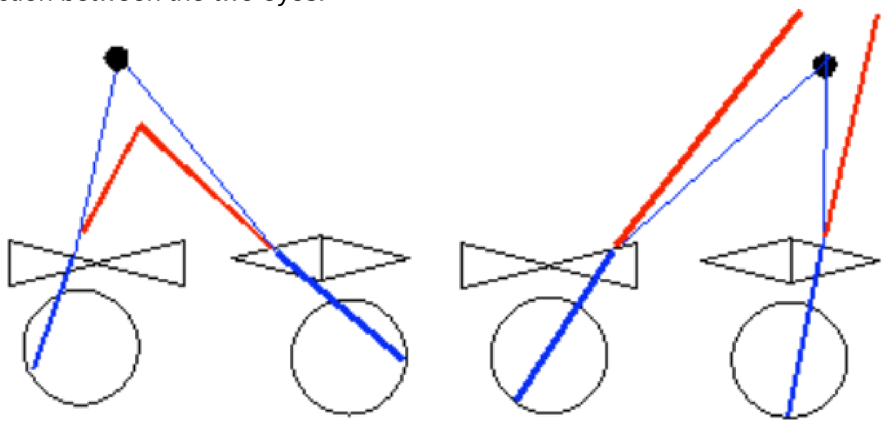
SPACE DISTORTION ASSOCIATED WITH NEW SPECTACLES

PRISMATIC DISTORTION OF BINOCULAR SPACE PERCEPTION	BI or BO prism prescribed for oculomotor anomalies may cause distortions of binocular space perception. BO prism before both eyes causes an objective fronto-parallel plane (such as a wall) to bow inward toward the patient (**Steinman Fig. 4-26**), and the floor may appear to slope downward, away from him/her, as if he/she has become taller. BI causes the opposite effect. A wall will appear to bow outward away from the patient and the floor may appear to slope upward, as if he/she has become shorter. These effects can also vary depending on the tilt of the lenses relative to the patient's line of sight. These effects are caused by the meridional magnification of the prism. Patients who receive new spectacles may be annoyed by this distorted perception due to the prismatic effect of their lenses, but they will adapt and normal space perception will return with time.
ANISOPHORIA CAUSED BY ANISOMETROPIA	Anisophoria is a heterophoria that varies in different directions of gaze. It can be caused by an extraocular muscle paresis (essential anisophoria), but it can also be caused by the prismatic effect of spectacles (optical anisophoria), especially when there is a difference in the correction between the two eyes.  ***Figure 30.1*** *With a more plus correction over the right eye and more minus correction over the left eye, the influence of prismatic effect on perceived visual directions of an object will differ during right and left gaze. In this case the eyes must converge more on left gaze than on right gaze.*

ANISOPHORIA CAUSED BY ANISOMETROPIA	Optical anisophoria can lead to distortions of space perception and to symptoms of binocular stress. A plus lens causes relative magnification of an image and may be thought of as back-to-back prisms. Minus lenses cause relative image minification and may be thought of as apex-to-apex prisms. If for example, a person is more hyperopic in the right eye and more myopic in the left eye, the image seen by the right eye may be larger but the left eye image may be smaller. With oblique viewing in either direction, the right lens prismatic effect will cause images to be displaced more peripherally, while the left lens will tend to displace peripheral objects more centrally. For example, the same object in the right field will be displaced further to the right for OD, but it will be displaced slightly to the left for OS (Fig. 30.1). The opposite would happen for objects in the left field. This causes a different convergence demand (but no change in accommodative demand) in different directions of gaze. It also creates different amounts of disparity for objects the same distance away but in different fields of gaze. In some patients this can contribute to eyestrain, especially when a patient receives a new pair of spectacles with a new anisometropic prescription. With time, most patients adapt to the space distortion caused by the new prescription.

INTRODUCTION TO ANISEIKONIA

Aniseikonia is a difference in perceived image **size** or **shape** between the two eyes, and it is usually caused by unequal optical corrections in cases of **anisometropia**. Remember, however, that vision is more than just optics. After the retina receives the image, it is transmitted to the brain, which can also influence the final perceived size and shape of each eye's image.

For example, consider how the distribution of retinal neurons and **local signs** might affect a person with **axial myopia** in one eye. The greater myopia causes a larger image size, but the longer, larger eye causes the retinal local signs to be stretched over a larger area. The net result is that the perceived retinal size is not substantially different from that of the other eye. If this patient were then corrected by a minus spectacle lens, it could minify the retinal image and lead to aniseikonia.

The neural system is capable of adapting to aniseikonia over time. This shows that aniseikonia is more complex than simply a difference in spectacle powers. Retinal image size (based on optical factors), local sign distribution, neural processing and adaptation all affect the perception.

It is possible to compute the expected change in retinal image size caused by different types of optical corrections (spectacles, contact lenses, refractive surgery, IOLs), but it is difficult to predict how visual processing will influence the **perceived aniseikonia** and subsequent adaptation. Optical calculations are useful for understanding or predicting aniseikonia caused by optical corrections, but the perceived aniseikonia, which is the result of both optical and neural factors, is more important than the calculated **optical aniseikonia**, because this is what the patient actually sees.

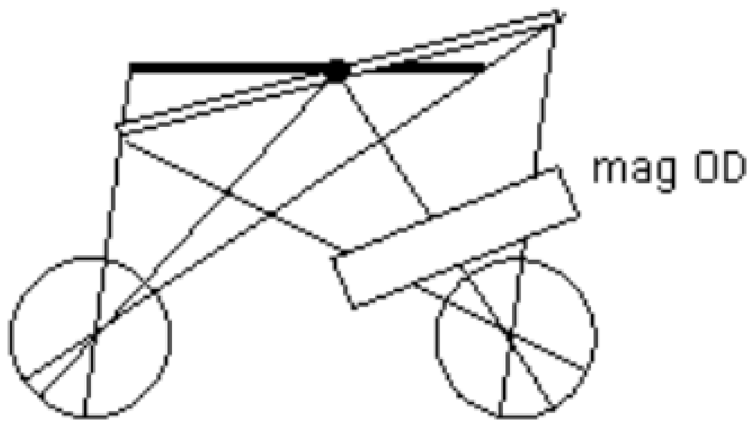
In summary, perceived aniseikonia can be caused by a combination of factors. These include:

- Magnification of the spectacle lenses (or other correcting optics)
- Optics of the eyes
- Distribution of retinal local signs in the two eyes
- Modifications due to neural processing
- Adaptation by the visual system

SPACE DISTORTION CAUSED BY SPECTACLE MAGNIFICATION

A starting point for understanding aniseikonia is the effect of spectacle magnification on space perception, but we should remain cognizant of the other factors (listed above) that may influence what the patient actually sees. Aniseikonic space distortions can be divided into:

- Geometric effect
- Induced effect
- Oblique effect

GEOMETRIC EFFECT	The geometric effect occurs due to magnification of the retinal image in the horizontal plane only. A true fronto-parallel plane appears tilted because the magnification causes horizontal retinal disparities. Figure 30.2 is a rough illustration showing **horizontal magnification over the right eye**, **causing an apparent rotation of a fronto-parallel plane away from the right eye**. The effect is called "geometric" because the perceived orientation of the plane can be predicted from the geometry of the disparities caused by the magnification on one side. Recall Fig. 19.6 in Lecture 19 and our discussion of how magnification affects the shape of the horopter. (Also see Borish Fig. 5-18.)  ***Figure 30.2*** *Illustration of the geometric effect from magnification in the horizontal plane only.*
INDUCED EFFECT	The induced effect is caused by magnification in the vertical meridian only, and it causes an opposite rotation to that predicted for the geometric effect. Vertical magnification over the right eye makes a fronto-parallel plane appear rotated toward the right eye. The exact reason for the induced effect is unknown. Vertical magnification causes a differential vertical disparity in the two eyes, but vertical disparities do not contribute to stereoscopic depth perception. Somehow processing within the visual system causes the vertical disparities to modify actual retinal horizontal disparities. One explanation is that the vertical magnification of the retinal images stimulates a compensatory mechanism in the visual system that, in effect, reduces the overall perceived size to match the vertical size in the other eye's retina. The compensation, however, shrinks both the vertical and horizontal dimensions. The net result is that the horizontal dimension of the image becomes relatively smaller than the corresponding dimension in the eye that had no magnifying lens. This is summarized in Fig. 30.3.

INDUCED EFFECT	 ***Figure 30.3*** *A hypothetical neural mechanism that compensates for vertical aniseikonia, and may cause the induced effect. In this example, the vertical magnification before the right eye has the same effect as a horizontal minification before the left eye. The fronto-parallel plane will therefore appear to be rotated away from the left eye and toward the right eye.* The induced effect causes about the same amount of spatial distortion as the geometric effect for small degrees of aniseikonia (<4%), but for larger aniseikonia, the geometric effect causes a greater tilt. This varies with individuals.

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<td>OBLIQUE EFFECT</td>
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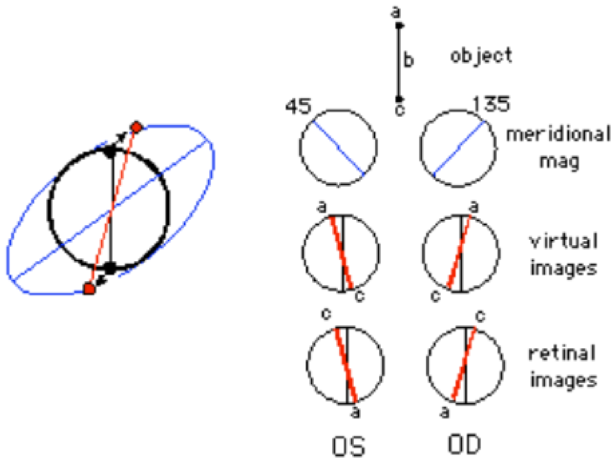
Fig. 5-20 in Borish illustrates the oblique effect. It shows the effect of a meridional magnifying lens at 45 degrees before OS and at 135 degrees before OD**.
** Note that the angles are measured from the patient's, not the doctor's perspective.
The reason for the perception, illustrated in Borish Fig. 5-20, is illustrated in Fig. 30.4 (below). The meridional magnifier causes a tilted virtual image of the line for each eye, which is inverted and reversed on the retina. The image of c is located on both temporal retinas, which causes a crossed disparity for c. Point c (bottom of the line) will therefore appear closer than its true position.
Point 'a' is imaged on the nasal retina of both eyes. This causes an uncrossed disparity, so the top of the line will appear to be located beyond the fixation point. The perception of a checkerboard seen through meridional size lenses with this orientation is illustrated in Borish Figure 5-21. The checkerboard appears to tilt away at the top and toward the observer at the bottom.


Figure 30.4 The left image shows how meridional magnification causes an apparent tilt of a vertical line toward the meridian of magnification. The right series shows how a vertical line, viewed through a 135 degree meridional magnifier over OD and a 45 degree magnifier over OS, causes the top of the line to appear to tilt away from the person, while the bottom of the line appears to move closer. Inspired by Reading RW. Binocular Vision. Butterworth Publishers, Woburn, MA, 1983, Fig. 13-13
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INTERACTION OF THE EFFECTS

An **overall magnification** (equal horizontal and vertical magnification) before one eye will cause both geometric and induced effects. Since these effects are opposite, they tend to cancel each other out, and the net result may be less perceived aniseikonia than would be expected from the computed magnification.

Assume that a 1.0-diopter difference in spectacle power causes a 1% magnification difference between the two eyes. If a person has the following spectacle prescription, you might expect about a 3% aniseikonia, if you ignore the interaction of the geometric and induced effects.

OD	plano
OS	+3.00

The geometric effect would cause a 3% horizontal magnification of the OS image, but the induced effect would cause a 3% horizontal minification of the image in the same eye (or 3% horizontal magnification of the OD image). The net result is no perceived aniseikonia. For this reason, overall power differences between the two eyes are often less problematic than differences in oblique magnification. Large oblique cylindrical differences between the two eyes may result in space distortions that are not balanced by either the induced or geometric effect. This may explain why some patients have greater difficulty adjusting to oblique astigmatic prescriptions than to those with horizontal or vertical axes.

Symptoms of aniseikonia include headaches, asthenopia, difficulty reading and even photophobia. Various references suggest that this may be a problem in approximately 5% of patients. Interestingly, symptomatic patients with aniseikonia usually don't report problems with spatial distortion. In addition to differences in spectacle-induced magnification, differential prismatic effects can cause an anisophoria, as we discussed near the beginning of this lecture.

SIZE CONSTANCY, TILT AND THE SILO EFFECT

As we demonstrated in the discussion of an oblique magnification, another basic principle of space distortion is that the side that is tilted away from the observer appears larger. This is based on the principle **of size constancy**. Even though stereoscopic disparity creates the illusion that part of the surface is tilted away, the angular size of the object is nearly the same. For a more distant object to have the same angular size as a nearer object, it must be larger. This is the same logic used to explain the moon illusion.. This is illustrated in **Borish Fig. 5-21**.

This helps us understand the **SILO effect**, which stands for small-in, large-out. As the eyes converge (turn in) due to BO prism, the fixated object often appears to become smaller. Convergence gives you the impression that the object is moving in toward you. Normally, as an object moves closer, its retinal image size increases. If it's not getting larger, it must be getting smaller—or so the visual system must think. Size constancy then explains the apparent decrease in object size as it moves in.

When BI prism stimulates divergence, your visual system senses that the object is moving out. Normally as real objects move away, their retinal image size decreases; the retinal image, however does not decrease; it must therefore be increasing in size—again the visual system's presumed logic. This explains "large-out." Steinman comments on this effect on p. 184 of his textbook. Interestingly, some patients experience the opposite perception from that expected according to SILO; that is, SOLI, meaning small-out and large-in.
This is probably due to processing within the brain.

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