Vision Science III - Binocular Vision Module

Lecture 18 - Aniseikonia II

(Borish Chapter 5, 32)

PREDICTED SPACE PERCEPTION WITH VARIOUS PRESCRIPTIONS

Based on what we learned about the *geometric*, *induced* and *oblique* effects, as well as SILO, we can predict the kind of space distortion a person should perceive with certain spectacle prescriptions. This discussion, however ignores the anatomic, neurological and adaptation factors that may affect the total perceived aniseikonia.

Although aniseikonia can be caused by the various factors listed above, the only ones we can manipulate are the optics of the correcting lenses. Therefore, the principles of spectacle magnification are particularly important in understanding aniseikonia.

By going through the following logical steps, we can predict how a fronto-parallel plane, such as a flat wall would appear to be distorted due to optical effects of a spectacle correction. Steps:

1) Draw a power cross for each eye, from behind (patient point of view).
2) Draw in the relative magnifications in each meridian.
3) Draw in an ellipse to show the magnification in all meridians.
4) Ask which effects are at work. (Geometric, induced, oblique)
5) Ask which side of the wall would be tilted away and magnified (SILO).

As a general rule of thumb, you can assume that, all other factors being equal between the two eyes, **1.0 diopter** of anisometropia causes approximately a **1%** difference in retinal image size between the two eyes. Minus lenses minify and plus lenses magnify.

Symmetric oblique aniseikonia causes a predictable space distortion. Images appear to be stretched and therefore magnified in the meridians of oblique magnification, as illustrated in the Fig. 1 below.

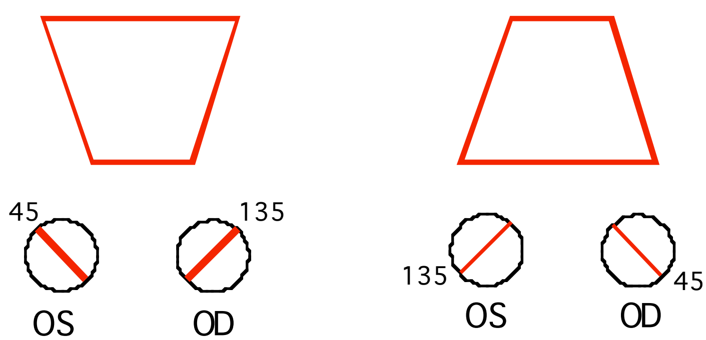


Figure 1. Symmetric oblique aniseikonia causes the type of space distortion illustrated here. Tilted lines indicate the meridian of magnification, from the patient's point of view. A square is distorted into a trapezoid with base up in the left example, or base down in the right example. This is also illustrated in **Borish Fig. 5-20, 21 and 23**.

EXAMPLES WITH VARIOUS SPECTACLE PRESCRIPTIONS

Example A: OD -1.00 -2.00 x 180
OS -3.00 sphere

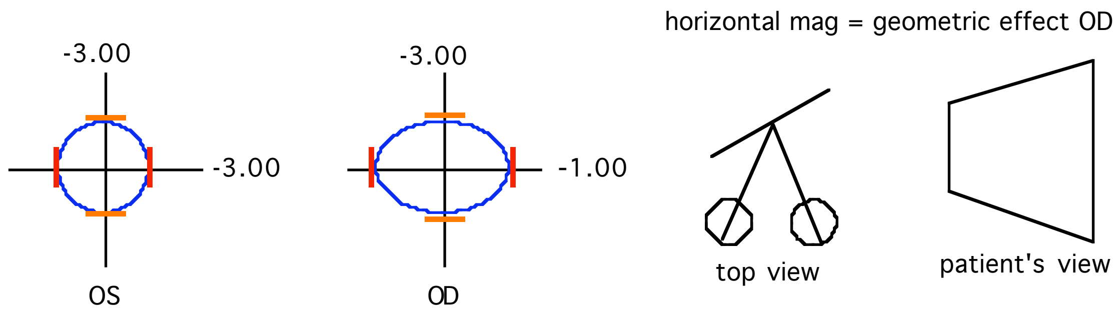


Figure 2. There is a relative magnification in the horizontal meridian of the right eye only; therefore a right geometric effect. This causes an apparent tilt of the right side away from the patient. The side tilted away also appears magnified (large-out). A square in the fronto-parallel plane will appear to be a trapezoid, base-right, as shown.

Example B: OD -1.00 -2.00 x 090
OS -3.00 sphere

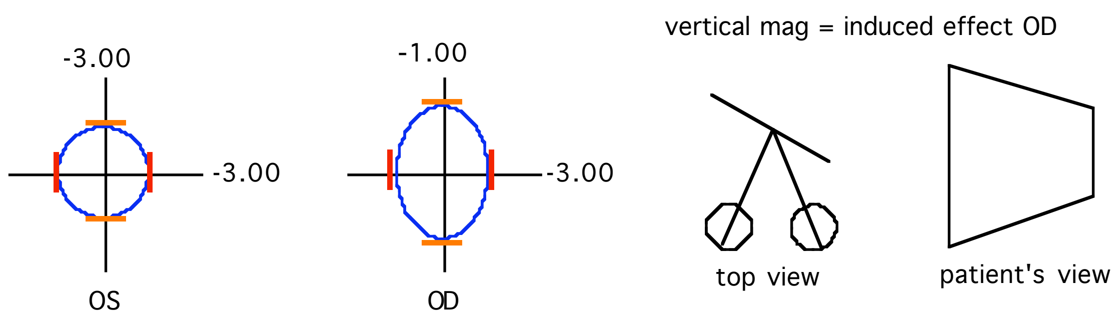


Fig. 3. This Rx causes a relative magnification in the vertical meridian of OD only, therefore a right induced effect. This causes an apparent tilt of the right side toward the patient. The side tilt in, also appears smaller (small-in), so a square in the fronto-parallel plane appears to be a trapezoid, base-left, as shown.

You can apply the same logic to predict how a square in the patient's fronto-parallel plane would appear to be distorted with the following spectacle corrections.

Example C: OD -2.00
OS plano -2.00 x 090

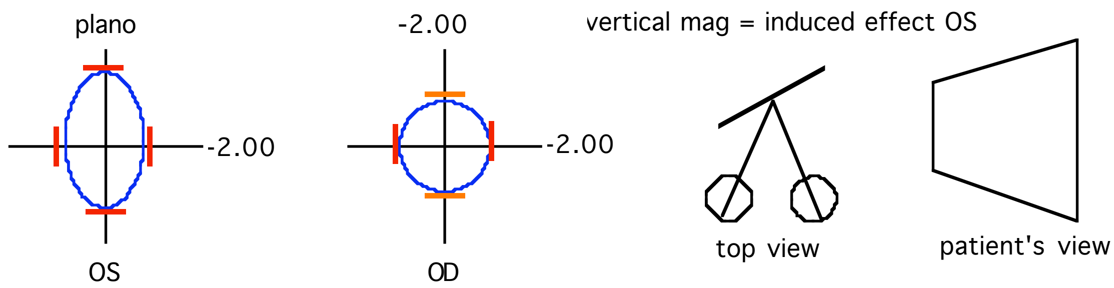


Figure 4. You should predict an induced effect OS, which causes the left side to be tilted nearer to the subject. The left side will be smaller (small-in) and a square would appear as a trapezoid, base-right.

Example D: OD -5.00
OS -2.00 -3.00 x 180

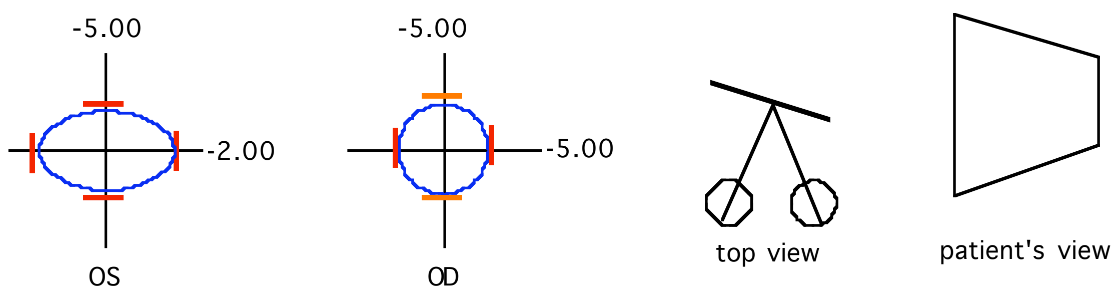


Figure 5. This should result in an OS geometric effect, tilt away from left, left side larger, therefore a base-left trapezoid.

Example E: OD -2.00 -3.00 x 045
OS -2.00 -3.00 x 135

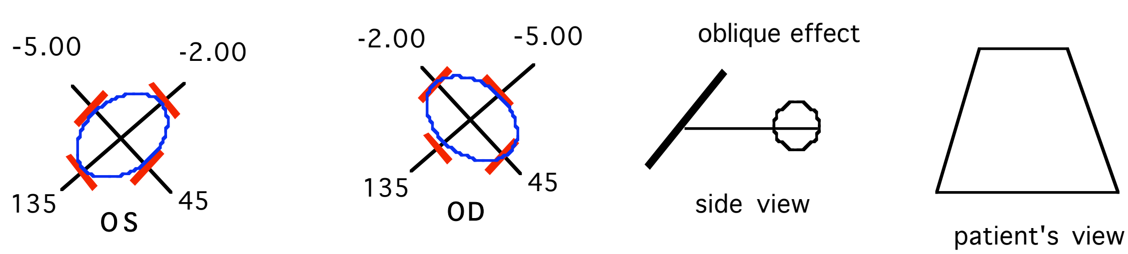


Fig. 6. This would cause a magnification in the 135-degree meridian of OS and the 45 degree meridian of OD. The symmetric oblique magnifications are shown and they would cause a trapezoid, base-down distortion. The magnified inferior portion would also appear to be tilted out (large-out).

Example F: OD +2.00 - 3.00 x 135
OS +2.00 - 3.00 x 045

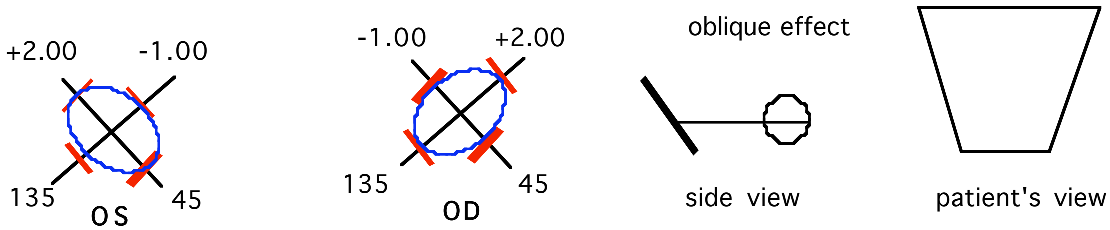


Figure 7. You should be able to predict an oblique effect, upper part tilted away, upper part larger.

DIAGNOSIS AND MANAGEMENT OF ANISEIKONIA

The same symptoms associated with aniseikonia (headaches, asthenopia, difficulty reading) can be caused by more common refractive or binocular problems, so before assuming that aniseikonia is the problem, you should first correct the refractive error and treat any binocular problem such as heterophoria. Uncorrected astigmatism is a much more common cause of headaches while reading than aniseikonia. If you have ruled out these problems, and symptoms persist, consider aniseikonia.

Other information that might indicate aniseikonia:

- Anisometropia - especially meridional. You normally would not suspect aniseikonia unless there was a significant anisometropia. Whenever there is a large anisometropia, you should be alert for aniseikonia.
- Symptoms are most noticeable when the Rx is worn.
- Difference in keratometer data between the two eyes
- A monocular patch gives relief.

As rough guide, aniseikonia caused by anisometropia will cause a 1% difference in retinal image size for each diopter of anisometropia. Magnification differences of 10% or less can cause symptoms. If the size difference is larger than 10%, it will be difficult for the patient to fuse the images. In addition to aniseikonia, anisophoria, caused by different lens powers, will make fusion more difficult, especially with more peripheral angles of gaze. In theory, a large anisometropia might also require different accommodation between the two eyes, which can also contribute to symptoms.

If aniseikonia is caused by an anisometropic spectacle Rx, the easiest solution is to correct the person with **contact lenses**. This will certainly eliminate the problem of peripheral prism, unequal accommodation and possibly minimize unequal image sizes.

KNAPP'S LAW

Knapp's law (1869) is a classic concept that often comes up in discussions of aniseikonia, but it is more of academic (i.e., boards) than clinical interest.

It is based on the geometry of the Gullstrand schematic eye and the formula for *relative spectacle magnification*, which is different from *spectacle magnification*. In the case of an **axial anisometropia**, the formula for relative spectacle magnification (RSM) is:

$$RSM = \frac{1}{(1+gF)} \quad (1)$$

RSM - relative spectacle magnification
g - distance of the correction from the anterior focal point of the eye in meters (0.0157 m in front of cornea)
F - back vertex power

Relative spectacle magnification is the ratio of the corrected retinal image size to the image size in the Gullstrand schematic eye (emmetropic).

In an **axial anisometropia**, Knapp's law says that a spectacle correction placed in the eye's anterior focal plane (vertex distance ~ 15.7 mm, so g = 0.) will result in no aniseikonia. That is, if the anisometropia is axial, you should correct the patient with spectacles rather than contact lenses.

In the case of a refractive anisometropia, the formula is:

$$RSM = \frac{1}{(1-hF)} \quad (2)$$

RSM - relative spectacle magnification
h - distance of the correction from the entrance pupil of the eye in meters (0.003 m inside the cornea)
F - back vertex power

In the case of a **refractive anisometropia**, Knapp's law says that a refractive correction in the corneal plane will result in minimal aniseikonia. That is, if the anisometropia is refractive (not axial—both eyes the same length), you should correct the person with contact lenses.

To summarize, Knapp's laws suggests that in:

- axial anisometropia, correct at the spectacle plane. Remember AS.
- refractive anisometropia, correct at the cornea (k). Remember RK.

Practically speaking, Knapp's law is not very important because

- It's difficult to know if the person's anisometropia is either axial or refractive.
- It does not take into account the many other factors (such as retinal stretching, neurological processing, etc.) that determine perceived aniseikonia.

MANIPULATING SPECTACLE MAGNIFICATION TO CORRECT ANISEIKONIA

If you conclude that anisometropia is the cause of the patient's symptoms your first step should be to attempt to correct the patient with contact lenses. If that doesn't work, it may be necessary to design a spectacle Rx that will minimize differences in magnification between the two eyes. This approach is based on the formula for spectacle magnification (Eq. 3). Spectacle magnification is the ratio of the uncorrected to corrected retinal image size.

$$SM = (shape\_factor)(power\_factor) = \frac{1}{\left(1 - \frac{t}{n}F_1\right)} \times \frac{1}{\left(1 - hF_{bvp}\right)} \qquad (3)$$

SM - spectacle magnification
t - center thickness in meters
n - index of refraction
F_1 - front surface power in diopters
h - eye's entrance pupil to lens distance (vertex distance + 3 mm - converted to meters)
F_{bvp} - back vertex power in diopters

Since the power of the lens will be fixed by the refractive error, only four parameters can be modified to alter the magnification caused by the spectacle lens. These are the

- vertex distance (power factor)
- center thickness (shape factor)
- index of refraction (shape factor)
- front curve (shape factor)

When manipulating the **power factor**, a greater vertex distance causes a greater effect. Since plus lenses magnify and minus lenses minify, the following principles are true:

- For a plus lens, a greater vertex distance causes more magnification (larger image)
- For a minus lens, a greater vertex distance causes more minification (smaller image).

Three aspects of the **shape factor** may be manipulated. Since most spectacle lenses have *convex front surfaces*, the following rules apply to both plus and minus lenses.

To increase magnification or increase image size choose:

- Thicker lens
- Lower index
- Steeper front curve

To decrease magnification or decrease image size choose:

- Thinner lens
- Higher index
- Flatter front curve

The effects are opposite if the front surface is concave, but this is relatively rare, except in very high myopic prescriptions.

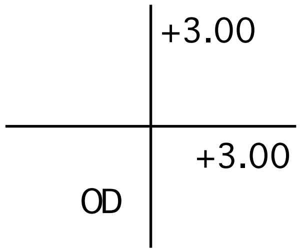
CLINICAL EXAMPLE
The following example comes from the Aniseikonia Cookbook (Polasky, 1874).

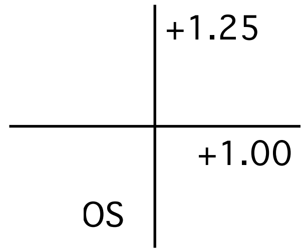
From a review of the patient's symptoms and his refraction, you diagnose aniseikonia

OD +3.00 sphere
OS +1.25 - 0.25 x 090

To design spectacles that will reduce the aniseikonia by manipulating the <u>shape factor</u>, go through the following steps:

STEP 1: Draw the spectacle Rx on a power cross and compare the powers in corresponding meridians.





STEP 2: Estimate the aniseikonia using a 1% magnification difference for every diopter of difference between the two eyes. In this case, OD is about a 2 diopters more plus than OS, so the OD image should be about 2% larger.

STEP 3: Start with the more plus eye (OD) and design the shape factor to keep image size to a minimum. Referring to the notes above, ...

To decrease magnification or decrease image size choose a:

- Thinner lens
- Higher index
- Flatter front curve

For example, you might choose the following:

- center thickness = 3.5 mm
- index of refraction = 1.5 (stay with standard index in this case)
- front curve power = +6.25 diopters

From the spectacle magnification formula (Eq. 3), the shape factor magnification would be 1.015, which is a **1.5 % magnification**.

STEP 4: Determine how much magnification to give to the other eye. Since OS will be about 2% smaller than OD due to the difference in powers, and the OD has a shape factor of 1.5%, you would want a shape factor magnification of OS by 2%+1.5% or about 3.5%. It's probably better to slightly undercorrect, so aim for a shape factor mag of 3%.

From the notes above, you can maximize OS image size by the shape factor in the following ways:

To increase magnification or increase image size choose:

- Thicker lens
- Lower index
- Steeper front curve

For example, you might choose the following:

- center thickness = 4.5 mm
- index of refraction = 1.5 (stay with standard index in this case)
- front curve power = +10.00 diopters

From the spectacle magnification formula (Eq. 1), the shape factor magnification would be 1.031, which is a **3.1 % magnification**.

Originally you were expecting about 2% of aniseikonia due to the anisometropia (power difference alone). Now, with these parameters you would have the following:

OD: 2% greater than OS (due to power difference) + 1.5% shape factor = 3.5% mag

OS: 3.1% shape factor = 3.1 % mag

Instead of a 2% difference, you have reduced the aniseikonia for about 0.4%.

Note that this is just an approximation. To be more precise you could easily set up an Excel spread sheet and compute the exact power and shape factors to determine the exact spectacle magnification for each eye. This was just a simple example to illustrate how two parameters (the center thickness and front curve) could be manipulated to reduce the aniseikonia.

You could further decrease the image size for OD by,

- decreasing the vertex distance (harder for a plus lens)
- use a higher refractive index

You could further increase image size for OS by,

- increasing the vertex distance (harder for a plus lens)
- use a lower refractive index

SPACE EIKONOMETER

When you estimate aniseikonia based on the spectacle Rx alone, keep in mind that you are ignoring important factors that can cause the *perceived* aniseikonia to be different from that calculated by spectacle magnification formulas.

- Aniseikonia due to optics of the eyes themselves.
- Anatomical and physiological factors (retinal receptor distribution, neural processing)
- Adaptation to dissimilar image sizes

In addition, any stereoscopic space distortion associated with aniseikonia (a stereoscopic phenomenon) might be mitigated or ignored by the visual system if it gives more weight to the monocular depth cues. Of course, if images sizes are large enough that they exceed Panum's area, binocular fusion will be difficult.

For small amounts of aniseikonia (<4%), the best way to determine how much aniseikonia a person has from all factors, optical and neurological, is to actually measure his *perceived* aniseikonia. An instrument has been designed for this purpose by the American Optical Corporation. It's called the **Space Eikonometer (Borish Fig. 29-5)**, and it will be the topic of one of our labs.