Aniseikonia: A Case Series and Literature Review

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Aniseikonia: A Case Series and Literature Review

Abstract
Introduction
This paper is a review of some of the most common modes of both measurement and treatment of aniseikonia along with a case series involving 10 subjects. While aniseikonia can be caused by various factors such as the spacing between retinal photoreceptors, epiretinal membranes, or cataract surgery, this paper deals primarily with iatrogenic aniseikonia from the correction of anisometropia. Measurements were taken of the subjects' axial length, keratometric readings, autorefraction, and amount of aniseikonia under two conditions: with contact lenses, and with spectacles. The results are put forth in this paper along with a brief analysis.

Methods
A literature review was performed using the following databases: VisionCite, Medline-OVID, and Google Scholar. Pertinent papers are cited along with monograph references, and personal observation from performing the tests mentioned. Autorefraction, keratometry, and A-scan ultrasonography were all performed. The program Aniseikonia InspectorTM by Optical Diagnostics was used on a laptop computer and all tests were performed by the same examiner with the testing order being changed after each subject (pseudo-randomization). A latin square was not used to randomize the order.

Results
The data from each subject is put forth in a table and noteworthy information is explained in subsequent paragraphs. Less aniseikonia was experienced with contact lenses verses spectacles. This finding was upheld in 7 out of the 10 subjects participating, regardless of the cause of their anisometropia.

Conclusion
This paper is in accordance with common trends from other studies, in that patients with axial anisometropia, despite Knapp's law, are best treated with contact lenses. A future study with a larger set of subject utilizing the same measurement parameters, should be able to draw more definitive conclusions in each of the following categories: axial anisometropia, refractive anisometropia, and a combination of the two.

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Aniseikonia: A Case Series and Literature Review

by

Brandon Reed, B.S., O.D. Candidate (2012)

A thesis submitted to the faculty
of Pacific University College of Optometry
in partial fulfillment of the requirements for the degree of

Master of Science in Vision Science

Advisor:
James Kundart, O.D., M.Ed., F.A.A.O.
Table of Contents

Table of Contents ........................................................................................................................................ 3
Signatures ....................................................................................................................................................... 4
Biography ...................................................................................................................................................... 6
Abstract ....................................................................................................................................................... 7
Disclosure .................................................................................................................................................. 8
Introduction .............................................................................................................................................. 9
Measuring Aniseikonia ............................................................................................................................. 12
Treatment .................................................................................................................................................. 17
Research Results ..................................................................................................................................... 20
Conclusion ............................................................................................................................................... 23
Acknowledgements .................................................................................................................................. 23
References ................................................................................................................................................. 24
Appendix ................................................................................................................................................... 26
List of Figures

Figure 1: Brecher test.................................................................12

Figure 2: Size Lenses
(http://www.opticaldiagnostics.com/products/ai/screenshots.html)........................................12

Figure 3: Neutralizing with size lens..........................................................12

Figure 4: Miles test..................................................................................13

Figure 5: Space Eikonometer target (Bannon)........................................13

Figure 6: Space Eikonometer (Benjamin, 2006)..............................................14

Figure 7: Aniseikonia Inspector software.........................................................14

Figure 8: AI results screen
(http://www.opticaldiagnostics.com/products/ai/screenshots.html)........................................16

Figure 9: Target, booklet, anaglyphic glasses
(http://www.richmondproducts.com/PDFs/Aniseikonia%20Tech%20Bulletin.pdf)..............................16

Figure 10: Knapp
(http://www.mrcophth.com/ophthalmologyhalloffame/knapp.html)..............................17

Figure 11: Spectacle Magnification Equation..................................................18
Signatures

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Biography

Brandon Reed holds a Bachelor of Science degree in Vision Science from Pacific University and is a candidate to receive the degree of Doctor of Optometry in 2012. He has a scholarship with the United States Air Force and plans to practice in the military after graduation. Being anisometropic himself was the motivation behind this thesis and he plans to incorporate this knowledge into the treatment of his future patients. He and his wife Jennifer are the parents of three children.
Abstract

Introduction
This paper is a review of some of the most common modes of both measurement and treatment of aniseikonia along with a case series involving 10 subjects. While aniseikonia can be caused by various factors such as the spacing between retinal photoreceptors, epiretinal membranes, or cataract surgery, this paper deals primarily with iatrogenic aniseikonia from the correction of anisometropia. Measurements were taken of the subjects’ axial length, keratometric readings, autorefraction, and amount of aniseikonia under two conditions: with contact lenses, and with spectacles. The results are put forth in this paper along with a brief analysis.

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Key Words: Anisometropia, Aniseikonia, Amblyopia, Knapp’s Law
Disclosure

The author has no monetary or other business interest in Ocular Diagnostics, American Optical, or any other product mentioned in this thesis. The purchase of the Aniseikonia Inspector software from Optical Diagnostics was done by Pacific University at a discounted price.

This thesis contains no material that has been accepted for the award of any other degree or diploma at any educational institution and, to the best of the author’s knowledge and belief, it contains no material previously published or written by any other person, except where due reference is made in the text of the thesis.
**Introduction**

Most clinicians have seen numerous patients with anisometropia. Refraction will reveal a difference in power between the two eyes, but it takes further probing to understand the cause. The refractive power of an eye is composed primarily of corneal power, lens power, and axial length. Each of these elements plays its own role, and small deviations from normal often have significant optical effects.

The average axial length of an eye is approximately 24 mm (Remington, 2005) and optometric physicians are familiar with the common rule of thumb that one millimeter change in axial length usually accounts for a change of around three diopters in refractive error. With as little as one millimeter difference causing such a significant refractive change, it would be easy to conclude that anisometropia (also called aniso in this paper) is a common occurrence. However, while small amounts (<1 diopter) of aniso are seen in a large number of patients, clinically significant anisometropia (≥1D) is much less common outside of premature infants. The incidence varies significantly by age and population percentages vary from one source to another.

**Amblyopia and Aniseikonia**

Anisometropia can cause visual problems both when it is corrected and uncorrected. Uncorrected, patients may develop refractive amblyopia. Amblyopia can exist without aniseikonia but aniseikonia is unlikely to develop or manifest when amblyopia is untreated. This is because the amblyopic eye provides a blurry image and reduces the stimulus to fuse. Amblyopia affects, on average, 3% of the population and the definition is given below (Rutstein & Daum, Aniseikonia, 1998).

<table>
<thead>
<tr>
<th>Amblyopia:</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Amblyopia, also known as lazy eye, is a vision development disorder in which an eye fails to achieve normal visual acuity, even with prescription eyeglasses or contact lenses. Amblyopia begins during infancy and early childhood. In most cases, only one eye is affected. But in some cases, reduced visual acuity can occur in both eyes.” (Heiting, 2010)</td>
</tr>
</tbody>
</table>

**Iatrogenic Aniseikonia**

Correcting anisometropia through the use of lenses also presents unique problems for patients. They will often report diplopia when viewing off-axis targets due to the prismatic effects of the lenses; this is termed anisophoria. When viewing in primary gaze, through the optical center in each lens, this problem is not as apparent. However, an inherent property of spectacle lenses is their ability to magnify or minify images. This is seen regardless of the
portion of the lens used causing aniseikonia. It is estimated that between 20% to 30% of the general population that wear spectacles have a measurable amount of aniseikonia, but clinically significant aniseikonia (about 1% or more) is found in only 3% to 5% of the population (Amos, 1987). The definition of aniseikonia is provided below.

Aniseikonia:
“The relative differences in the sizes and/or shapes of the ocular images of the two eyes. The term ocular image includes not only the retinal image formed by the dioptrics of the eye (with any correcting lens) but also the modification of the retinal image by the distribution of the nerve endings in the retina and their representation in the visual cortex. Because the absolute sizes of the ocular images, as just defined, are incapable of measurement, we measure the relative differences in their sizes, and state this difference in terms of the percentage magnification of afocal magnifying lenses (or ‘size’ lenses) required to equalize the two images”. (Fannin & Grosvenor, 1996)

It should be noted that the above definition has been around for many years and Borish has stated that the definition should be slightly changed, “Aniseikonia has...been and defined limited to the analysis of the physical size of the image on the retina of the two eyes...recent definitions of aniseikonia more consistently define it as a difference in the perceived size of the image seen with the two eyes” (Benjamin, 2006).

Understandably, most patients don’t report a chief concern of “the images between my two eyes aren’t equal and I’m having a hard time fusing”. From the author’s own personal experience, aniseikonia can be difficult to describe. There seems to be no clear cut report from a patient that will illicit an aniseikonia work-up. It has been shown to affect stereopsis (Jimenez, Ponce, Jimenez Del Barco, Diaz, & Perez-Ocon, 2002) and even cause strabismus after unilateral cataract surgery in infants (Rutstein, Update on Aniseikonia, 2010). The results of a survey of 500 patients with aniseikonia is shown in table 1 (Bannon & Triller, 1944) and it should be noted that what might be expected to be the most obvious complaint, distortion of space, was only reported in 6% of subjects, and the rest of the complaints are common to a host of other diagnoses.
<table>
<thead>
<tr>
<th>Symptom</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asthenopia</td>
<td>67%</td>
</tr>
<tr>
<td>Headaches</td>
<td>67%</td>
</tr>
<tr>
<td>Photophobia</td>
<td>27%</td>
</tr>
<tr>
<td>Reading difficulty</td>
<td>23%</td>
</tr>
<tr>
<td>Nausea</td>
<td>15%</td>
</tr>
<tr>
<td>Motility difficulty</td>
<td>11%</td>
</tr>
<tr>
<td>Nervousness</td>
<td>11%</td>
</tr>
<tr>
<td>Dizziness</td>
<td>7%</td>
</tr>
<tr>
<td>General fatigue</td>
<td>7%</td>
</tr>
<tr>
<td><strong>Distortion of space</strong></td>
<td><strong>6%</strong></td>
</tr>
</tbody>
</table>

Table 1: Survey of Symptomatology from 500 patients with aniseikonia (Bannon)

It takes a conscientious clinician to consider aniseikonia as potentially being the problem and if not done often, practitioners struggle to know exactly how to measure and treat it. Like aniseikonia, anisometropia can often go unnoticed. Early detection of children with anisometropia will allow avoidance of amblyopia, and easier adaptation to correction.

**Detection of Anisometropia:**

“Of the various vision anomalies that affect preschool children, anisometropia is the most likely condition to go undetected. There are at least two reasons for this phenomenon. First, unlike strabismus, there is no cosmetic problem associated with anisometropia. Second, unlike a bilaterally high refractive error, there are no obvious behavioral signs, such as squinting, sitting close to the television, or holding toys at a very close distance” (Ciner, 1990)

The techniques used to measure the percentage of aniseikonia will be discussed in a subsequent section. It behooves all practicing clinicians to both understand and implement at least one test for aniseikonia in order to benefit their patients, and develop a solid treatment plan. While opinions vary as to the amount of aniseikonia that will bother a patient, it should be remembered that there is no way of knowing exactly how much aniseikonia will cause symptoms, and this condition should be handled on a case by case basis.

The purpose of this paper will be to both shed increased light on the issues surrounding aniseikonia and present a series of 10 cases involving anisometropia and the amount of aniseikonia with glasses and contacts in relation to corneal power, and axial length.
Measuring Aniseikonia

Many tests exist to measure aniseikonia and each has its pros and cons. It should be noted that the list of tests described in this paper is by no means exhaustive and were chosen by the author as a representative sample of both older and newer tests. Aniseikonia due to anisometropia has been extensively researched over the years and a wealth of information is available to practitioners.

Historical Perspective:
Prior to 1945, theoretical and clinical courses in aniseikonia were given at Dartmouth Eye Institute, and a clinician had to be certified by that institute in order to obtain an Eikonometer. As instrumentation was simplified and techniques for measuring aniseikonia were improved, the obligatory Dartmouth courses were discontinued. However, the initial investigations of the Dartmouth group provided the technical and clinical papers that underlie instruction in professional schools and discussion of aniseikonia in textbooks. (Scheiman & Wick, 2008)

Brecher Test
This procedure has been described as the “Maddox Rod and Two point Light Sources” technique which does a fair job of describing the set up. It carries the name of Dr. Brecher for his original description in 1951 (Brecher, 1951). In theory, the Brecher test is fairly simple. Materials involved include two penlights, a Maddox rod, and some hand-held afocal magnifiers (also known as iseikonic lenses or “size” lenses). The examiner holds the two penlights approximately 20 centimeters apart, pointed at the patient, while the patient holds a Maddox rod over one eye with the axis at 180 degrees.

The patient is instructed to determine the location of the two red lines in relation to the penlights. Each red line bisecting a penlight would be considered zero aniseikonia. If both red
lines seen are shifted to one side then the patient has a heterophoria which can be compensated for by loose prism. If the distance between the red lines does not coincide with the distance between the penlights then an iseikonic lens is held over the opposite eye from the one with the Maddox rod and allows a quantifiable result in the form of a percentage. It has been reported to be as accurate as 0.5% (Amos, 1987). This procedure can also be done with the Maddox rod at axis 90 degrees in order to quantify vertical aniseikonia.

Miles Test

The Miles test is similar to the Brecher in that it uses two penlights but involves two Maddox rods instead of just one. As shown in the picture below, a Maddox rod is placed over each eye horizontally so that the patient will see vertical red lines. It will be noted that only two red lines will be seen instead of four due to fusion. The task is to determine which red lines appears physically closer to them and size lenses are used over the corresponding eye until both red lines appear to be in the same plane (Rutstein & Daum, Aniseikonia, 1998).

![Figure 4: Miles Test](image)

All aniseikonia tests require an astute patient but it would seem that it is even more crucial with the Miles test. Having a Maddox rod placed over each eye can be disorienting and increase the level of difficulty. As noted, success with this test will require a patient who is sensitive to small differences and they must also have a binocular system capable of achieving the fusion necessary to see two red lines instead of four.

Space Eikonometer

The Space Eikonometer was developed in 1940 by American Optical and an Office Model was available by 1951 as depicted in figure 6. It is currently still considered the ‘gold standard’ in quantifying a patient’s aniseikonia. Fannin and Grosvenor stated that this test requires, “single binocular vision, normal retinal correspondence, and at least 20/60 visual acuity in each eye” (Fannin & Grosvenor, 1996). It has been reported that in order to successfully complete the test the subject in question needs at least the intelligence of a 6 year
old (Bannon). In the experience of the author, this is a gross understatement as the ability to
detect subtle differences with this instrument is often difficult for those with good stereopsis
and equal refractive error.

As shown in Figure 5, the subject is presented with the task of adjusting the dials in
order to create what appears to be a symmetrical box-shape with the “X-like” pattern in the
center. “Introduction of magnification by means of adjustable optical systems causes the
spatial relationship of the target elements to change” (Cline, Hofstetter, & Griffin, 1989). Along
with being difficult to understand, another disadvantage of the Space Eikonometer is that it is
only capable of measuring aniseikonia up to 5%. It is currently no longer in production, making
it difficult to find.

Aniseikonia Inspector

The Aniseikonia Inspector™ is a direct-comparison eikonometry test in which the
patient wears anaglyphic (red-green) glasses and is asked to determine if two rectangular boxes
are equal in size. The term eikonometry may be foreign to some; it is simply the measurement
of aniseikonia by presenting different images to each eye by means of polarized or anaglyphic
glasses and presentations.
Figure 7: Aniseikonia Inspector software

Version 3 of the Aniseikonia Inspector software is demonstrated in Figure 7 with direct comparison of two rectangular bars. Version 1 of the Aniseikonia Inspector used two half moons similar in appearance to those used in the Awaya Test (see description of this test later in this paper) but could be varied by the subject on the computer until both halves appeared equal in size. Advantages to this test are that it takes only a few minutes to perform per eye, is fairly easy for patients to understand, and has been shown to be reliable in patients as young as 6 years old (Weise, Marsh-Tootle, & Corliss, 2010). It can be performed with the patient’s habitual spectacle prescription, trial frame, contact lenses, or no correction. Results are given in the form of a percentage that can be positive or negative in reference to the right eye.

A literature search on aniseikonia will turn up multiple articles about the Aniseikonia software. Many of these articles were written by the designer of the program himself and report positive results. In contrast, Rutstein, Corliss, and Fullar concluded that while the Aniseikonia Inspector software is more repeatable than the standard Space Eikonometer, it underestimates the amount of aniseikonia (Rutstein, Corliss, & Fullard, 2006). More studies, and clinical usage, will eventually resolve these differences.

The patient is positioned in front of the monitor at a distance of 36cm wearing red-green glasses. They begin the test by aligning two vertical lines so that they make a straight vertical line and then repeating this with horizontal lines. This allows any fixation disparity to be factored out of the results. The test then begins and the patient simply chooses which rectangular box is larger in height; then the test is repeated while the subject chooses which box is larger in width. If the images are equal the patient can select the “E” button for equal.
The software includes a nomogram for designing isekonic lenses for the patient based on the results, and also provides the option to have the information gathered sent directly to the company in order to have them design the lenses.

As stated above, the results are given in the form of a percentage along with a consistency value. This value may also be a positive or negative value. As stated in the software instructions: “The more inconsistent responses the patient makes, the less accurate the aniseikonia value may be. As a rough guide an inconsistency value of 3, 4, or more should trigger you to look at the raw data, possibly re-instructing the patient and repeating the test.” (De Wit, 2008) The results page also contains a wealth of additional information that will not be covered in this paper such as raw data, field dependency, and aniseikonic ellipse information. An example is shown in Figure 8 (note the aniseikonia percentage results along with the inconsistency value in the bottom right).

Figure 8: AI results screen
The New Aniseikonia Test (Awaya)

The Awaya test falls under the category of direct comparison (unlike the Space Eikonometer which is based on spatial perception). The patient wears red and green filters over their eyes and is asked to compare the sizes of two half circles. They begin by seeing two half circles that are identical in size and are asked if they appear to be equal. If not, they move to a series of circles that represent 24% size difference, and work their way down until they find a set of circles that meet the following criteria:

1. Red circle is slightly larger than the green circle
2. Red and green circles are the same size
3. Red circle is slightly smaller than the green circle

This test is easy to perform but has been reported to significantly underestimate the true amount of aniseikonia (Amos, 1987). Antona et al. agree stating, “We conclude that the repeatability of the New Aniseikonia Test is not very high and recommend that clinicians be cautious when interpreting the results of this test”. (Antona, Barra, Barrio, Gonzalez, & Sanchez, 2006) See section A of the Appendix for the instructions provided in the booklet.

Treatment

Some confusion exists as to the best method of correcting anisometropia to minimize any potential problems with aniseikonia. The majority of clinicians simply put their patients in contact lenses regardless of whether the cause is refractive or axial, but this treatment is sometimes contrary to the conventional recommendation put forth in Knapp’s law. A description of Knapp’s law is below.

Knapp’s Law:
“When a correcting lens is so placed before the eye that its second principal plane coincides with the anterior focal point of an axially ametropic eye, the size of the retinal image will be the same as though the eye were emmetropic.” (Cline, Hofstetter, & Griffin, 1989)
Knapp’s Law operates under four conditions (Fannin & Grosvenor, 1996):

1. The ametropia must be purely axial.
   The correcting lens must be located so that it secondary principal point coincides with the primary focal point of the eye. The position of the principal planes moves as the bend of a lens is increased - the move is toward the surface with the greatest curvature. The secondary principal point of a plus meniscus lens is located a short distance anterior to the front surface of the lens, and the secondary principal point of a minus meniscus lens is located a short distance behind the back surface. Therefore, the back vertex of a plus meniscus lens must be located somewhat closer than 14mm from the cornea and a minus meniscus lens must be placed farther than 14mm from the cornea.

2. The refractive power of the eye must be equal to that of the standard emmetropic eye.
3. The shape factor of the correcting lens must be unity (in reality, the shape factor for both plus and minus lenses is greater than 1 if the front surface is convex).

In lay terms, Dr. Knapp proved mathematically that a patient with anisometropia due to axial length differences will have less aniseikonia with glasses than contact lenses if the above criteria are met. A variety of literature has been published which refutes this idea yet it continues to be taught in textbooks and optometry schools. One such study concluded, “As a geometric optics theory, Knapp’s Law stands on its own merits. However, in clinical practice...it has been shown to fall short...” (Kramper, Shippman, G, Meininger, & Lubkin, 1999). Rutstein and Daum noted that it, “does not accurately describe the size of ocular images arriving at the cortex because it does not incorporate neurologic factors...Knapp’s law perhaps should be considered Knapp’s suggestion” (Rutstein & Daum, Aniseikonia, 1998).

Clinicians are accustomed to putting their patients in contact lenses to reduce the effects of aniseikonia, but some situations require the use of spectacles for a host of reasons. For example, some elderly patients are not interested in contact lenses and may not be capable of handling and caring for them due to other health conditions. Whatever the reason may be, special considerations must be taken in order to successfully prescribe spectacles for a patient with anisometropia.

While it is possible to mathematically design a pair of iseikonic lenses to reduce aniseikonia by using the spectacle magnification equation, it can be challenging. Most practitioners do not have the time, or the desire to calculate it out by hand, as shown in Figure 11. As an easier approach, Ogle proposed that 1.5-2% of aniseikonia be considered for every diopter of anisometropia but some clinicians use 1% per diopter as a so-called ‘rule of thumb’
Using this method has been shown to greatly over-estimate the percentage of aniseikonia and should be reserved for cases of unilateral cataract surgery in children when quantifying the aniseikonia is not possible (Lubkin, 1999)

\[
SM = M_P \times M_S = \left( \frac{1}{1 - ZF_v} \right) \left( \frac{1}{1 - cF_1} \right)
\]

Figure 11: Spectacle Magnification Equation

\( M_P = \) Power Factor, \( M_S = \) Shape Factor, \( Z = \) Vertex distance in meters, \( F_v = \) Vertex power in diopters, \( c = \) thickness/index of refraction, \( F_1 = \) Front surface power in diopters

Clinicians can also avoid calculations by using the Aniseikonia Inspector software which can both measure the patient’s aniseikonia and design lenses to minimize it, while still allowing the user to specify the parameters. Figure 11 is a screen image of the program design for a pair of spectacles that also use a contact lens to lessen the amount of aniseikonia. It should be noted that index of refraction, powers, frame dimensions, and even a diagram that gives an idea of the size difference between the potential lenses is provided.

Measurement of aniseikonia should be considered based on symptoms in patients with at least 1 diopter of anisometropia and some core data should be gathered: keratometry, axial length if possible, refraction, and lensometry if the patient has a previous prescription. With this data, it is possible to use methods such as the spectacle magnification equation, Aniseikonia Inspector software, or even the recommendations put forth in the Aniseikonia cookbook (see Appendix B).
### New (iseikonic) Rx

**Patient name:** #07: Aphakia, Monocular  
**Patient ID:** 100002  
**New RxID:** 1  
**Aniseikonia inspector version:** 3.0

#### Contacts Rx OD
<table>
<thead>
<tr>
<th>Sphere (D)</th>
<th>Cylinder (D)</th>
<th>Axis (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>+13.75</td>
<td>---</td>
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</table>

#### Contacts Rx OS
<table>
<thead>
<tr>
<th>Sphere (D)</th>
<th>Cylinder (D)</th>
<th>Axis (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

#### Glasses Rx OD
<table>
<thead>
<tr>
<th>Sphere (D)</th>
<th>Cylinder (D)</th>
<th>Axis (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-5.00</td>
<td>-0.50</td>
<td>92</td>
</tr>
</tbody>
</table>

- **Front curve (Sphere):** 3.00 D  
- **Material:** CR-39  
- **Center thickness:** 2.1 mm  
- **Bevel:** 50 %

#### Glasses Rx OS
<table>
<thead>
<tr>
<th>Sphere (D)</th>
<th>Cylinder (D)</th>
<th>Axis (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-4.50</td>
<td>-0.50</td>
<td>90</td>
</tr>
</tbody>
</table>

- **Front curve (Sphere):** 2.25 D  
- **Material:** CR-39  
- **Center thickness:** 1.9 mm  
- **Bevel:** 50 %

#### Frame dimensions
<table>
<thead>
<tr>
<th>IPD</th>
<th>Vert. decenteration (vd)</th>
<th>Eyewire distance (ew)</th>
<th>Eye size (A)</th>
<th>Eye size (B)</th>
<th>Bridge size</th>
</tr>
</thead>
<tbody>
<tr>
<td>64.0 mm</td>
<td>0.0 mm</td>
<td>12.0 mm</td>
<td>50.0 mm</td>
<td>35.0 mm</td>
<td>20.0 mm</td>
</tr>
</tbody>
</table>

#### Comments
- Remote & Robertson patient #7  
- Rigid contact lens + glasses (p.347).  
- Galilean telescope OD to correct both aniseikonia and induced anisophoria.

---

**Figure 12:** AI Rx description
Research Results

In this case series we gathered the following measurements from 18 subjects: autorefraction, auto-keratometry, A-scan ultrasonography, Brecher with both contacts and glasses, and lensometry on their habitual lenses if possible. The first 10 subjects shown in table 2 were also tested with the Aniseikonia Inspector software with their contact lenses, and then again with their glasses. Both the autorefraction and auto-keratometry were done simultaneously with a Grand Seiko open field autorefractor and the A-scan was performed using an E-Z Scan AB5500+ Ophthalmic Ultrasound Scanner. It should be noted that some subjects’ autorefraction did not match exactly to their habitual spectacle prescription but were retained in the study. All subjects were recruited by email and were students of Pacific University College of Optometry. Each participant was pre-presbyopic, and between 20-30 YO.

<table>
<thead>
<tr>
<th>Subject</th>
<th>AR OD</th>
<th>AR OS</th>
<th>AK</th>
<th>Brecher</th>
<th>Brecher Spec</th>
<th>Lensometry</th>
<th>AI Contacts</th>
<th>AI Glasses</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-1.75-0.75 x 117</td>
<td>+1.25-0.50 x 018</td>
<td>00:43.75D 05:44.00D</td>
<td>24.88 mm</td>
<td>23.04 mm</td>
<td>0%</td>
<td>0%</td>
<td>OD: -2.00-0.50 x 089 DS: +0.50-0.25 x 099</td>
<td>2%</td>
</tr>
<tr>
<td>2</td>
<td>+0.75-0.50 x 018</td>
<td>+3.75-0.75 x 077</td>
<td>00:43.75D 05:43.75D</td>
<td>22.52 mm</td>
<td>22.44 mm</td>
<td>0%</td>
<td>8%</td>
<td>OD plano DS: +3.75-0.50x000</td>
<td>Contacts: OD: Plano DS: +3.75x000</td>
</tr>
<tr>
<td>3</td>
<td>-6.50-0.50 x 018</td>
<td>5.75-0.25 x 005</td>
<td>00:47.50D 05:45.75D</td>
<td>25.85 mm</td>
<td>24.39 mm</td>
<td>0%</td>
<td>0%</td>
<td>OD plano</td>
<td>0%</td>
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<tr>
<td>4</td>
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<td>-0.50-0.50 x 018</td>
<td>00:43.75D 05:44.00D</td>
<td>25.00 mm</td>
<td>25.11 mm</td>
<td>0%</td>
<td>0%</td>
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<td>0%</td>
</tr>
<tr>
<td>5</td>
<td>-6.75-0.25 x 075</td>
<td>5.75-0.25 x 075</td>
<td>00:46.35D 05:46.25D</td>
<td>25.08 mm</td>
<td>24.22 mm</td>
<td>0%</td>
<td>0%</td>
<td>OD plano</td>
<td>0%</td>
</tr>
<tr>
<td>6</td>
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<td>0.000</td>
<td>00:45.000 05:44.00D</td>
<td>24.79 mm</td>
<td>24.04 mm</td>
<td>7%</td>
<td>7%</td>
<td>OD plano</td>
<td>0%</td>
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<tr>
<td>7</td>
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<td>25.92 mm</td>
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<td>0%</td>
<td>OD plano</td>
<td>0%</td>
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<tr>
<td>8</td>
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<td>-2.50-0.25 x 017</td>
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<td>22.17 mm</td>
<td>23.04 mm</td>
<td>0%</td>
<td>0%</td>
<td>OD plano</td>
<td>0%</td>
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<tr>
<td>9</td>
<td>-1.75-0.25 x 174</td>
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<td>00:41.25D 05:42.00D</td>
<td>25.21 mm</td>
<td>25.33 mm</td>
<td>0%</td>
<td>0%</td>
<td>OD plano</td>
<td>0%</td>
</tr>
<tr>
<td>10</td>
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<td>25.33 mm</td>
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<td>OD plano</td>
<td>0%</td>
</tr>
<tr>
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<td>24.17 mm</td>
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<td>0%</td>
<td>OD plano</td>
<td>0%</td>
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<tr>
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<td>24.43 mm</td>
<td>25.17 mm</td>
<td>0%</td>
<td>0%</td>
<td>OD plano</td>
<td>0%</td>
</tr>
<tr>
<td>13</td>
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<td>23.35 mm</td>
<td>23.61 mm</td>
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<td>0%</td>
<td>OD plano</td>
<td>0%</td>
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<tr>
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<td>-0.75-0.50 x 102</td>
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<td>22.57 mm</td>
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<td>0%</td>
<td>OD plano</td>
<td>0%</td>
</tr>
<tr>
<td>15</td>
<td>-1.50-1.00 x 006</td>
<td>2.25-2.00 x 173</td>
<td>00:42.75D 05:43.50D</td>
<td>27.38 mm</td>
<td>25.08 mm</td>
<td>0%</td>
<td>0%</td>
<td>OD plano</td>
<td>0%</td>
</tr>
<tr>
<td>16</td>
<td>-3.25-1.25 x 158</td>
<td>-1.75-1.25 x 092</td>
<td>00:43.25D 05:43.25D</td>
<td>21.49 mm</td>
<td>22.64 mm</td>
<td>0%</td>
<td>0%</td>
<td>OD plano</td>
<td>0%</td>
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<td>-4.75-1.75 x 177</td>
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<td>27.36 mm</td>
<td>25.96 mm</td>
<td>0%</td>
<td>0%</td>
<td>OD plano</td>
<td>0%</td>
</tr>
<tr>
<td>18</td>
<td>-6.00-0.50 x 015</td>
<td>-6.50-0.25 x 121</td>
<td>00:43.50D 05:44.00D</td>
<td>26.53 mm</td>
<td>26.34 mm</td>
<td>0%</td>
<td>0%</td>
<td>OD plano</td>
<td>0%</td>
</tr>
</tbody>
</table>

Table 2: Component analysis of 18 subjects with anisometropia and aniseikonia.
A correct interpretation of the results from the Aniseikonia Inspector should be viewed in light of the following comment by Dr. Gerard DeWit, “An aniseikonia of –5% means that the image of the right eye needs to be become 5% smaller to correct the aniseikonia (or the image in the left eye 5% larger, or a combination of both).”

The aniseikonia present in subject 1 was due to their axial length difference of 1.84mm and it should be noted that there was a 4% difference between contacts and glasses. With contacts, the image of the right eye was actually 2% larger than the left and with glasses it was 2% smaller. The left eye is the more hyperopic eye. Subject 2 had a difference in axial length of 0.92mm, no difference in keratometry (K’s) readings, and more hyperopia in the left eye. With glasses, the right eye measured 4% smaller than the left compared to 1% larger with contacts on. These first two subjects both had aniseikonia due to axial length differences and both had greater aniseikonia with glasses than contacts.

Subjects 3-5 all had a difference in both K’s and axial length contributing to their aniseikonia, but all had greater aniseikonia with glasses than contacts. Subject 6 had fairly equal axial length (0.15mm difference) and a 1 diopter difference in K’s. They showed only 1% more aniseikonia with glasses and both were small amounts. Subjects 7 and 8 had a difference in both K’s and axial length and subject 7 showed 4% more aniseikonia with glasses over contacts. Subjects 8, 9, and 10 were the anomalies showing more aniseikonia with contact lenses than with spectacles. In the case of subject 10, whose aniseikonia is due to axial length and was the only subject whose results coincided with Knapp’s law, it was significant.

Most of the subjects in this series had less aniseikonia with contact lenses which is not surprising but those whose anisometropia is due to axial length are at odds with Knapp’s law. A future study with more subjects will be able to more clearly define trends and provide a better comparison to the recommendations put forth in Knapp’s law.

The results of the Brecher test will not be analyzed in this paper due to the fact that the endpoints were unreliable. The subjects in this study struggled to both understand and complete the subjective task of determining the distance between the penlights and the Maddox rod images. Various other factors reduced the reliability such as variable phorias, and previous surgeries (see Table 2). All participants were capable of completing the Aniseikonia Inspector software and feeling confident in their responses.

Most of the subjects in this series had less aniseikonia with contact lenses, which is not surprising; however those whose anisometropia is due to axial length are at odds with Knapp’s law. A future study with more subjects will be able to more clearly define trends and provide a better comparison to the recommendations put forth in Knapp’s law.
Retrospective records search

If eye care professionals both failed to notice and did not record myopia due to insufficient measurements and flawed case history, would it mean that the myopia doesn’t exist? Likewise with aniseikonia? Based on this question, a report was generated identifying ICD-9 (International Statistical Classification of Diseases and Related Health Problems - Version 9) coding from each of the five clinics owned and operated by Pacific University (Forest Grove, Oregon), with the number of times both anisometropia (ICD-9 367.31) and/or aniseikonia (ICD-9 367.32) was coded in the last 5.5 years. Anisometropia was much easier to diagnose and was coded a total of 109\(^1\) times, making an average of 19.8 per year. As mentioned before, aniseikonia requires more clinical investigation and was only coded once in the same period. It is possible that only one patient in those 5.5 years had symptoms due to aniseikonia but it seems more likely that clinicians simply need more training on how to recognize, measure, and treat it. However, it should be noted that these numbers may be low due to the fact that some clinicians may have chosen other ICD-9 codes for billing purposes.

Conclusion

Investigative work is at the heart of eye care and providing optimal care for patients with anisometropia and subsequent aniseikonia requires extra effort on the part of the eye care provider. Researching and implementing a method of measuring and then treating clinically symptomatic aniseikonia should be a priority, along with a heightened awareness of the symptoms. The “ideal” method of reducing aniseikonia by placing the patient in contact lenses is not always possible with every patient. For this reason, an understanding of how to design isoeikonic spectacles and then measure the reduction in aniseikonia will serve as a great service to patients.

**Aniseikonia Battery:**
Clinicians should gather the following data to aide in using any of the treatment modalities explained in this paper:
1. Refraction
2. Keratometry
3. Lensometry of habitual lenses
4. A-scan if possible
5. Subjective measurement of percentage of aniseikonia

\(^1\) 18 out of 109 were antimetropic (one eye hyperopic and one eye myopic)
Acknowledgements

The author would like to thank his wife for her consistent support throughout this endeavor along with Dr. James Kundart and all the willing participants in this study, whose involvement was much appreciated. Also, to all those who have paved the way in vision science.

Aniseikonia:
“The 400-word entry in the 29 January 1669 issue of *Giornale de letteratithat Malebranche is what we would now call a letter to the editor, by Sig Giovanni Alfonso Borelli, titled “Alla virtù ineguale degli occhi”. Borelli reports that while viewing distinct and conspicuous objects, he sees them of different size through his two eyes. He made comparisons between the two eyes viewing a round hole in a window of a dark room. In addition, he hung a black ball in the middle of an open window, viewing it first with the right and then with the left eye, and found a difference in the images. This effect was observed not only in his own eyes but “anche à molto amici” — also in many friends” (Westheimer, 2007).
References


Appendix

A)
THE NEW ANISEIKONIA TEST by Shinobu Awaya, M.D. (Awaya, 1957)

CHARACTERISTICS
A pair of halfmoons, one red and the other one green is placed, facing each other at their rectilinear edges with a small cross mark in the center of the interval between the two halfmoons. When viewed through a pair of red-green glasses, the red halfmoon is visible to the eye with the green glass, while the green halfmoon is seen by the eye with the red glass. Figure No. 0 presents a pair of halfmoons of equal size and Figure No. 1 shows a pair of halfmoons in which the green one is 1% smaller than the red one. Figure No. 2 shows 2% difference and the green halfmoon decreases by 1% in a stepwise fashion in each of the following figures. Thus, the number of the figures coincides with the difference in percent between the two halfmoons (Plus Aniseikonia Series). In the next series (Minus Aniseikonia Series), there is a stepwise 1% increase of the green halfmoon in each figure to a total of 24% in Figure No. 24’. For example, in Figure No. 5’ the green halfmoon is 5% larger than the red halfmoon.

HOW TO MEASURE
The red glass is put on the more ametropic eye and the green glass is on the other eye, in case the refractive status is known. For example, if a patient’s right eye is more ametropic, the red glass is put on the right eye and the green glass on his left eye. Start with Figure No. 0 with the following steps:

(1) Shown figure No. 0 to the patient and ask him which of the two halfmoons appears larger. If both look equal in size, no aniseikonia is present.

(2) If the right green halfmoon looks larger, he is instructed to look at the following figures until he can find that figure in which both halfmoons appear equal. If, for example, this is the case in Figure No. 7 the patient has 7% aniseikonia, i.e. a 7% enlargement of the image in his right eye.
If, on the contrary, the right green halfmoon appears smaller than the left red one in Figure No. 0, the patient is instructed to look at each of the figures in the Minus Aniseikonia Series and to find the figure in which both halfmoons appear to be of equal size. As in the Plus Series, the number of each figure coincides with the amount of aniseikonia as expressed in image size difference.

When measurement of aniseikonia in the horizontal or oblique meridian is required, the text book is tilted so that the rectilinear edge of the halfmoon coincides with the meridian to be examined.

B) Aniseikonia Cookbook (Polasky, 2002)

THE NON-INSTRUMENT PRESCRIBING TECHNIQUE FOR THE CORRECTION OF ANISEIKONIA

TO DECIDE WHETHER PATIENT HAS ANISEIKONIA:

CHECK FOR:
- an anisometropia, especially if the anisometropia is secondary to a change in an optical component of the eye such as incipient cataract, keratoconus, or refractive surgery
- symptoms: headache, asthenopia, visual distortion
  (other possible causes for symptoms have been eliminated)
- longstanding symptoms
- previous Rx has no effect
- difference in K's
- patch helps (indicates binocular problem)
- fit over helps (piano power clip-on size lens)
- metamorphopsia with a history of maculopathy such as macular edema or epiretinal membrane. (see page 11)
- a size difference is measured on a clinical test for aniseikonia

NO ANISEIKONIA . . . If no special Rx is to be given but anisometropia is present, give equal base curves and equal center thickness if one eye is hyperopic. If neither eye is hyperopic, use standard corrected curve lenses and minimum center thickness. →STOP

ANISEIKONIA is present and you wish to design a special correction.

PRESCRIBE Rx

A. Draw power diagram to compare corresponding meridians (right eye to left eye)
B. Use 1.00% mag. per diopter of anisometropia to determine magnification difference
C. Start with eye that does not need magnification. Reduce shape mag. in this eye to a minimum.
D. Give magnification to other eye (eye with most (−) or least (+)).
   1. Decide on amount of magnification correction to be given... usually can under correct with good results (subtract 0.50-0.75% from predicted amount).
   2. Increase shape mag. of other eye until it is greater than the shape mag. of the other eye by the amount selected in (D-1).
      a. Use shape nomograph to do the calculation.
      b. With P.D. rule on magnification desired (left column), rule will cross center thickness line and front curve line (right column). This combination of C.T. and F, will give the desired mag.
      c. Many combinations of F, and C.T. are possible. To control power magnification: - on (−) lenses use thicker and flatter - on (+) lenses use thinner and steeper
E. See samples for overall, meridional and other combinations.
SHAPE MAGNIFICATION NOMOGRAPh

FOR RELATION
\[ \frac{1}{M} = 1 - \frac{1}{nF_1} \]

\( M \) = Magnification
\( F_1 \) = Front Curve
\( t \) = Center Thickness
\( n = 1.523 \)

O.D. SAMPLE 1

SHAPE MAGNIFICATION NOMOGRAPh

FOR RELATION
\[ \frac{1}{M} = 1 - \frac{1}{nF_1} \]

\( M \) = Magnification
\( F_1 \) = Front Curve
\( t \) = Center Thickness
\( n = 1.523 \)

O.S. SAMPLE 1