Retinally-induced aniseikonia

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Abstract

Purpose: To show that retinally-induced aniseikonia may vary as a function of visual field angle (i.e., field-dependent aniseikonia), how this could be explained, and what implications this has for managing the aniseikonia. *Design:* Observational case series. *Method:* Self-administration using software that can be assumed the predecessor of the Aniseikonia Inspector version 2. Aniseikonia was tested in the vertical and horizontal direction. In each direction aniseikonia was tested for visual field angles of 0.5 to 8 degrees. *Patients:* Three patients with different retinal conditions: an epiretinal membrane (ERM), a retinal detachment (RD), and a retinoschisis. *Results:* All patients had field-dependent aniseikonia, with aniseikonia variations of up to 20% over the measured visual field. The aniseikonia for the ERM patient was similar in the vertical and horizontal direction, while this was not the case for the RD patient and the retinoschisis patient. The retinoschisis patient even had negative aniseikonia in one direction and positive aniseikonia in the other direction. *Conclusions:* When reporting the aniseikonia of patients with retinal conditions, one cannot speak of 'the' aniseikonia (i.e., a single value or a single value for each direction), because it is most likely field dependent. It is also important to use a test that only measures static aniseikonia (direct comparison tests with long viewing times may be less suitable). Correction of field-dependent aniseikonia is relatively difficult, because an optical correction is field-independent. Nevertheless, optically correcting the aniseikonia for part of the visual field often improves the vision comfort considerably. If necessary, an optical correction could be augmented with a unilateral partial transparency occlusion or a unilateral partial field occlusion for more vision comfort.

Introduction

Aniseikonia is a binocular vision anomaly in which the two eyes perceive images of different size and/or shape. It is often associated with optical magnification differences in anisometropia, in pseudophakia, or as a result of refractive surgery. However, as depicted in Fig. 1, besides the optical magnification difference there are two additional factors contributing to the perceived image size difference: the retinal receptor distribution and the cortical processing of the sampled image[1]. A retinal receptor distribution effect has been used to explain the poor relation between calculated retinal image sizes and perceived image sizes in axial anisometropia and consequently the shortcomings of Knapp's law in clinical practice[2-4]. Moreover, aniseikonia is being associated with different retinal conditions in which a change of the retinal receptor distribution (stretching or compression) seems to be the cause of the aniseikonia. Associated retinal conditions are for example: an epiretinal membrane[5-10], vitreomacular traction[6],

macular edema[11-13], re-attached retinal detachment[12,14,15], macular holes[16], and in this article I will also present a case of aniseikonia in a patient with a retinoschisis.
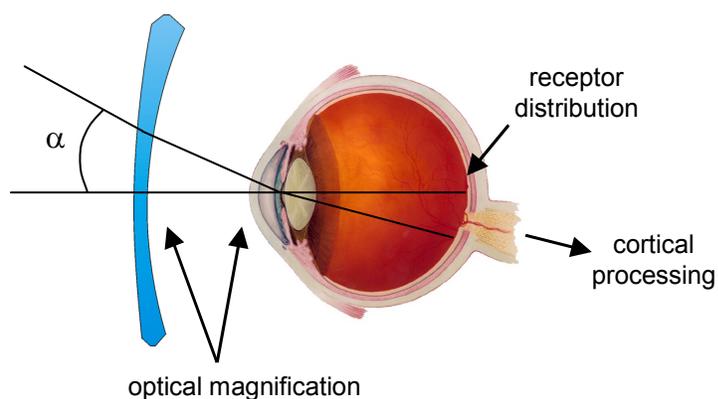

Figure 1: Schematic presentation of the ocular sources determining aniseikonia and the visualization of a visual field angle α (for simplicity the optical and visual axis are assumed equal here).

The general hypothesis of the occurrence of aniseikonia associated with retinal conditions is that due to a stretching or compression of the retina the receptors are displaced, creating respectively micropsia or macropsia (see Fig. 2 and Table 1). If this dysmetropsia occurs in one eye and not in the other eye (or with a different amount in the other eye), then the binocular vision result is aniseikonia with possible symptoms such as headaches, asthenopia, reading difficulties, depth perception problems, or double vision.
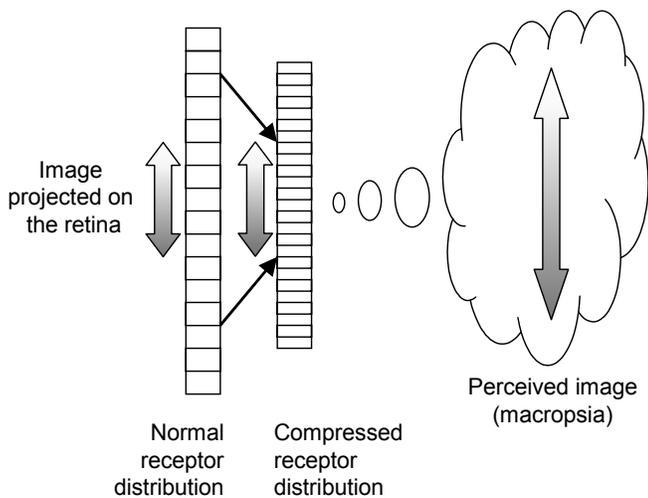

Figure 2: *Schematic presentation of the change in perceived image size when the receptor distribution changes. Note that in this schematic the receptors are drawn equidistant, while in reality the distance between the receptors will be variable. However, of importance here is only the change in receptor distribution before and after the onset of the retinal condition. (For a more accurate image, see Fig. 4).*

Table 1: *Usual type of dysmetropsia for different retinal conditions*

Retinal condition	Usual type of dysmetropsia
Epiretinal membrane	Macropsia[5-7,10]
Macular edema	Micropsia[11-13]
Re-attached retinal detachment	Micropsia[12,14,15]
Macular holes	Micropsia[16]

In many references dealing with aniseikonia associated with retinal conditions, the aniseikonia is only measured for one particular field angle (i.e., angular distance from a peripheral point to the center of the fovea in object space, see Fig. 1). This means that only one pair of binocular corresponding retinal points are found. The purpose of this article is to show that for retinal conditions the amount of aniseikonia may vary as a function of the visual field angle (i.e., field-dependent aniseikonia), how this could be explained, and what implications this has for the management of aniseikonia.

Patients
Although aniseikonia is considered a manageable ocular discomfort suffered by a significant amount of patients[17,18], not many eye care providers are currently equipped to manage aniseikonia. As the developer of the aniseikonia management software tool 'The Aniseikonia Inspector™', I sometimes get requests from patients to investigate their aniseikonia (in collaboration with their eye care provider). Since the software is written for a regular personal computer and easy enough to self-administer, the patients reported in this study each agreed to be tested on their home personal computer using the internet and e-mail as a way of communication. This article will present the field dependency of aniseikonia in three patients with the following unilateral retinal conditions as the probable cause of the aniseikonia: 1) an epiretinal membrane OS, 2) a reattached rhegmatogenous retinal detachment – macula off OD, and 3) a retinoschisis OS.

Patient 1 has also been described in more detail in a previous article[5]. This 60-year-old male judge with a visual acuity in both eyes of 20/20 wore spectacle lenses with the following prescription: right eye, 0.00 –0.25x95; left eye +0.75 −1.25x85. The remarkable finding in an ophthalmic examination included an early cortical cataract in the right eye, vitreous detachment in the left eye, and an epiretinal membrane (ERM) in the left eye.

Patient 2 is a 62-year-old manager with a visual acuity in both eyes of 20/20 and a spectacle lenses prescription of: right eye, -5.75 -1.00x75; left eye –4.75 −1.75x90. The patient was diagnosed with a rhegmatogenous retinal detachment (RD) – macula off in the right eye approximately half a year before the aniseikonia measurements. He underwent cryotherapy to the

retina, vitrectomy, and injection of gas/air into vitreous right eye.

Patient 3 is a 42-year-old male professor in science with a visual acuity in both eyes of 20/25 and a contact lens prescription of: right eye, -16.75; left eye: -14.00. Based on optical coherence tomography images, the patient was diagnosed with a retinoschisis in the left eye involving also the macula. The retinoschisis seemed to have developed a little more than a year before the aniseikonia measurements and was still present during the aniseikonia measurements.

The basic complaint of all patients was that the images in both eyes looked different in size. The RD-patient (2) and especially the retinoschisis patient (3) also complained that the images in the affected eye were altered in shape (a circle looked elliptical). In all patients the aniseikonia led to reading difficulties, possibly causing headaches or asthenopia. The main complaint of the RD-patient was the reduction of spatial awareness and depth perception, which also affected the patient's psychological well-being.

Methods

The aniseikonia in these patients was measured using custom software, which can be assumed the predecessor of the Aniseikonia Inspector™, version 2 (Optical Diagnostics, The Netherlands). The test method is based on the so-called direct comparison method in which a haploscopic condition is created by using red-green spectacles and color matched red-green haploscopic targets. A series of images of two adjacent rectangles (each image with differently sized rectangles) is presented to the patient, each image for only 0.5 seconds. While fixating at the center between the rectangles the patient has to identify for each image which rectangle is perceived as larger. This gives a psychometric curve from which the patient's aniseikonia is extracted using a maximum likelihood procedure. The visual field angle at which the aniseikonia is measured, is set by the size of the rectangles and a fixed distance between the patient's eyes and the computer screen (the rectangle subtends twice the visual field angle). More detailed information about the test method can be found in reference 5.

Results

Figure 3 shows the aniseikonia measurement results for the three patients as a function of field angle in two directions (vertically and horizontally). Included is also the data of a normal control subject (the author) looking with his left eye through a 4% size lens to show that optically induced aniseikonia is either not or little field dependent[5], in accordance with the general perception of aniseikonia. It shows that for all three patients the aniseikonia has a clear field dependency. The absolute values of the aniseikonia are relatively high, considering that patients may start to suffer from aniseikonic symptoms with aniseikonia values as low as 3% (and even less in sensitive individuals). The high aniseikonia values also agree with the fact that the patients noted that they all saw a clear image size difference between the two eyes by closing one eye at a time. For smaller (but still binocular vision challenging and symptomatic) aniseikonia values an image size difference might be difficult to notice by closing one eye at a time.
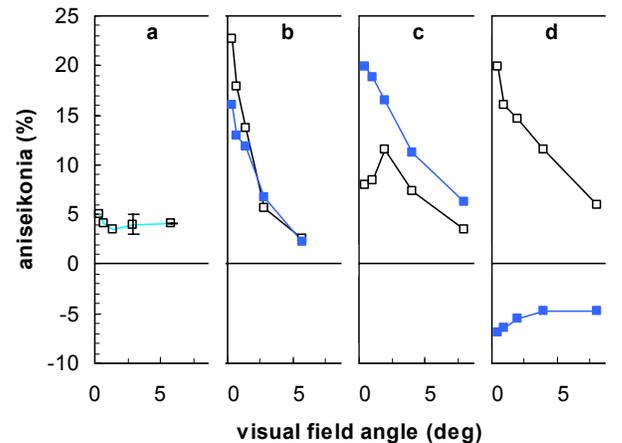

Figure 3: *Aniseikonia as a function of visual field angle in the vertical (open squares) and horizontal direction (filled squares). a) a normal looking with his left eye through a 4% size lens (error bar represents the standard deviation of 4 measurements); b) the epiretinal membrane patient (OS), c) the retinal detachment patient (OD); d) the retinoschisis patient (OS)*

Except for the ERM patient, the aniseikonia was also quite different for the vertical and horizontal direction. Again, this agreed with the observations of the patients. For example, the retinoschisis patient described that with his

affected eye cars looked 'funny' in that they were relatively narrow and high. Also he noted that due to the different aspect ratio, letters looked different in both eyes, as if the font changed depending on which eye he looked through.

Discussion

The results show that the aniseikonia of patients with retinal conditions may be field dependent. This means that the explanation of a uniform stretching or compression of the retinal receptors (as shown in Fig. 2) is in need of a modification. If there are stretching or compression forces close to the fovea, it speaks to reason that this would have little effect on the receptor distribution far away in the periphery. Therefore, a change in the receptor distribution close to the fovea will need to be non-uniform. This is schematically shown in Fig. 4. In this example the receptors are compressed at the center while a little further peripheral they are stretched to finally being unaltered in a position even further out in the periphery. The aniseikonia in this example would be field-dependent with a larger effect for smaller field angles, similar to the aniseikonia of the ERM patient in Fig. 3. Note that, following common practice, the aniseikonia presented in Fig. 3 is the aniseikonia relative to the right eye. This means that a positive aniseikonia value would require an image magnification in the right eye or an image minification in the left eye in order to correct the aniseikonia. Since the ERM was in the left eye, this means that the ERM caused macropsia, which is in accordance with Table 1 and Fig. 4.

Figure 2 shows that the RD-patient also had a positive amount of aniseikonia. Since the retinal detachment was in the right eye, this means that it caused micropsia. The opposite of Fig. 4 seems to happen. Due to the retinal detachment and/or re-attachment, the receptors closest to the fovea have stretched, while further out in the periphery they are compressed (or wrinkled). For small field angles there is a difference in aniseikonia values between the vertical and horizontal direction. This seems to indicate that the forces in play during the detachment and/or re-attachment were not symmetrical around the fovea. The retinoschisis patient shows an even larger asymmetry, because macropsia is caused in the vertical direction and micropsia in the horizontal direction.
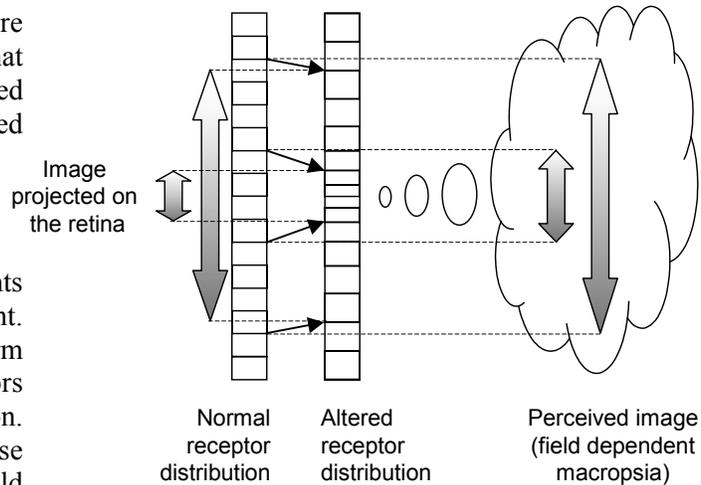

| Normal receptor distribution | Altered receptor distribution | Perceived image (field dependent macropsia) |

Figure 4: *Same as Fig. 2 only now the change in receptor distribution is non-uniform, resulting in a field-dependent dysmetropsia. I.e., in this example, the small arrow is perceived relatively much larger than the big arrow (appr. 80% increase vs. 10% increase).*

The common way to correct aniseikonia is to change the magnification properties of the auxiliary optics in front of the eyes. This can be done for example by: a) changing the shape of the spectacle lenses, b) changing the vertex distances (including the possibility of contact lenses), c) creating a weak telescope system by using spectacle lenses together with contact lenses, d) changing the power of one of the spectacle lenses (reducing also the visual acuity), or e) a combination of the above. With the advent of computer software (e.g., the Aniseikonia Inspector) the task of determining a prescription to correct a certain amount of aniseikonia has become relatively simple and easy for the practitioner. However, the problem with correcting field-dependent aniseikonia through optical means is that the correction will almost not vary with field angle. This means that effectively the graphs of Fig. 2 can be shifted up or down. Therefore, not all of the field-dependent aniseikonia can be corrected at the same time by standard optical corrections. Nevertheless, both the ERM and RD patient have gained considerably improved visual comfort by correcting between 5 and 10% of the aniseikonia. Unfortunately, the retinoschisis patient could not be provided with an optical correction because any overall correction would reduce the aniseikonia in one direction, but at the same time increase the aniseikonia in the other direction.

Subjective experiments with size lenses did seem to reveal though that corrections in the vertical direction would give slightly better improvement than corrections in the horizontal direction. An optical solution that would correct different amounts of aniseikonia in different directions could be considered, but this would need to be accomplished with bitoric lenses (difficult to make, expensive, and can only provide limited amounts of correction) or with cylinder contact lens – glasses combination. The retinoschisis patient did not pursue this last option. The RD patient did try a contact lens – glasses combination, but with limited success. Even though it clearly did provide the intended (static) aniseikonic correction, it also introduced a different kind of visual discomfort: dynamic aniseikonia (i.e., induced anisophoria). Dynamic aniseikonia is defined as a heterophoria whose magnitude varies with the direction of gaze due to a glasses-induced varying prismatic effect as the eyes deviate from the optical axes of the spectacle lenses[19]. The tolerance level for dynamic aniseikonia will depend on the fusional reserves of the patient. When designing a prescription to correct aniseikonia, it is therefore also important to look at the induced prismatic effect of the spectacle lenses.

If an optical correction does not improve the binocular vision comfort enough, a (partial) occlusion may also be tried. A full unilateral occlusion should be a last resort. Patients are usually not too happy when a full occlusion option is proposed, especially after just having had surgery to fix a retinal problem. Also, fully occluding one eye may not be the solution if the patient is especially troubled by a lack of binocular depth perception due to the aniseikonia as this by definition makes vision monocular and no longer binocular. A less drastic approach that also proved beneficial for some field-dependent aniseikonia patients is to blur or block just part (a section) of the visual field. For example, the RD and retinoschisis patient both gained some relief by blocking only the central field in one eye by placing an opaque spot at the center of one of their spectacle lenses (even though the eyes could gaze beside the spot). The RD patient also performed subjective experiments with blocking only the peripheral view in one eye and this also seemed to help some. Therefore, it might be that the difference in aniseikonia values between the central vision and more peripheral vision is especially aggravating for field-dependent aniseikonia patients. Instead of blocking (part of) the visual field of one eye, an even better solution might be to reduce the vision in one eye by applying a partial occlusion foil on one spectacle lens[20] or by changing the refraction correction to sub-acuity-optimum in one eye. This way also (some of) the stereovision is left, but now the solution not only applies for viewing in one direction only. The RD patient also discovered a totally different 'solution' that seemed to help. He intermittently blocked the vision in one eye (e.g. by moving a finger quickly up and down before one eye or with modified shutter glasses), which resulted in less strain on the binocular vision and giving comfortable depth perception.

Conclusion

Under the assumption that retinally-induced aniseikonia is caused by a change in the receptor distribution, the aniseikonia is most likely field dependent. That is, far away from the retinal location where forces exist(ed) to change the receptor distribution, the receptors are likely not to have changed (or changed less) in position. It is important to realize that one cannot speak of 'the' (specific amount of) aniseikonia in these patients. When studying and reporting aniseikonia in these patients, one would need to specify also at what field angle the aniseikonia was measured. Better yet, the aniseikonia should be graphed as a function of field angle.

Because many of the retinally-induced aniseikonia patients are isometropes or near-isometropes, the aniseikonia is mostly static. It is therefore important that the aniseikonia test does not measure (also) dynamic aniseikonia, as may happen in direct-comparison tests with long viewing times where the gaze can roam around to compare the two targets[19]. In the measurements for this article this was accomplished by limiting the viewing time of the targets to only 0.5 seconds.

The field dependency of retinally-induced aniseikonia makes it more difficult to correct. Normal optical solutions are not field dependent and can therefore only provide a partial

correction. Nevertheless, a partial correction can often provide the patient with a significant improvement in their binocular vision comfort. If necessary, an optical solution could be augmented with a partial occlusion to reduce the visual acuity in one eye or even blocking (or partial occluding) just a part of the visual field.

Even though retinally-induced aniseikonia patients are relatively difficult to correct, they might also be the aniseikonia group with the most severe symptoms. It is therefore important that further research be performed on, for example, the incidence of retinally-induced aniseikonia, if there are any surgical procedures that reduce or limit the amount of aniseikonia, and what the most effective optical correction method is (for example what field angles and what direction to target in the correction).

Acknowledgements

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