Effects of simulated anisometropia and aniseikonia on stereopsis

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Running Title: Anisometropia and aniseikonia effects on stereopsis

Keywords: aniseikonia, anisometropia, meridional, stereopsis, stereoacuity

Number of tables: 1

Number of figures: 2

Word count: ~4400 (without Tables and references)

Conflicts of Interest:

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Abstract

Purpose: Stereopsis depends on horizontally disparate retinal images but otherwise concordance between eyes. Here we investigate the effect of spherical and meridional simulated anisometropia and aniseikonia on stereopsis thresholds. The aims were to determine effects of meridian, magnitude and the relative effects of the two conditions.

Methods: Ten participants with normal binocular vision viewed McGill modified random dot stereograms through synchronised shutter glasses. Stereoacuities were determined using a four-alternative forced-choice procedure. To induce anisometropia, trial lenses of varying power and axes were placed in front of right eyes. Seventeen combinations were used: zero (no lens) and both positive and negative, 1 and 2 D powers, at 45, 90 and 180 axes; spherical lenses were also tested. To induce aniseikonia 17 magnification power and axis combinations were used. This included zero (no lens), and 3%, 6%, 9% and 12% at axes 45, 90 and 180; overall magnifications were also tested.

Results: For induced anisometropia, stereopsis loss increased as cylindrical axis rotated from 180° to 90°, at which the loss was similar to that for spherical blur. For example, for 2D meridional anisometropia threshold increased from 1.53 log sec arc (i.e. 34 sec arc) for x 180 to 1.89 log sec arc (78 sec arc) for x 90. Anisometropia induced with either positive or negative lenses had similar detrimental effects on stereopsis. Unlike anisometropia, the stereopsis loss with induced meridional aniseikonia was not affected by axis and was about 64% of that for overall aniseikonia of the same amount. Approximately, each 1 D of induced anisometropia had the same effect on threshold as did each 6% of induced aniseikonia.

Conclusion: The axes of meridional anisometropia but not aniseikonia affected stereopsis. This suggests differences in the way that monocular blur (anisometropia) and interocular shape differences (aniseikonia) are processed during the production of stereopsis.
Introduction

Stereopsis, the ability to perceive depth in visual space due to the sensory fusion of retinal images from both eyes, is an important advantage of human binocular vision.\textsuperscript{1-4} Lateral displacement of the eyes results in disparate retinal images. The images from the two eyes are combined in the visual cortex, where the disparity is processed to produce awareness of the relative depth of objects. The ability to perceive depth assists functional performance, particularly for judging depth and for assisting visually directed motor activity.\textsuperscript{2, 3} For example, visually guided in-depth hand movements take longer and are less accurate under monocular compared to binocular viewing in visually normal subjects,\textsuperscript{5-7} and walking speed is about 10\% slower under monocular rather than binocular conditions.\textsuperscript{8}

Stereoacuity is reduced when there is degraded information to an eye or abnormal processing along the visual pathway, such as occur with age,\textsuperscript{9, 10} abnormal vision development (amblyopia),\textsuperscript{2, 11} cylinder refractive error,\textsuperscript{12-14} heterophoria,\textsuperscript{15} strabismus, anisometropia\textsuperscript{12-14, 16-28} and aniseikonia.\textsuperscript{24, 29-31} The latter two conditions are investigated in this paper.

Anisometropia refers to a difference in refractive error between eyes. As little as 1 D uncorrected anisometropia early in life can affect normal development of the visual system which can ultimately lead to anisometropic amblyopia. Most studies investigating the effects of anisometropia on stereopsis have simulated it in participants with normal vision. The studies varied in the nature of the stereo test used, whether the blur was optically or electronically implemented, whether blur was monocular or binocular, sign of lenses (positive versus negative), use of spherical or cylinder lenses to create blur and, for the latter, the direction of the cylinder axes. All studies used clinical stereoacuity tests that had few testing levels and no associated measure of variance, with the finest level at or above threshold for at least some participants, and sometimes claimed outcomes were unsupported by statistical analysis.\textsuperscript{13, 16, 21, 25}

Stereopsis can be appreciated even with a considerable level of monocular blur: Lovasik and Szymkiw\textsuperscript{24} reported mean stereoacuity losses at +2 D and +4 D spherical blur of 3.2 times (0.5 log unit) and 9.4 times (1.0 log unit), respectively. Studies comparing spherical and cylindrical blur found cylinder to have the lesser effect.\textsuperscript{16, 17, 25} As stereopsis is a function of the lateral displacement of the eyes, cylindrical blur along the horizontal meridian would be
expected to have greater effect than along other meridians, but not all studies supported this and there was inconsistency in the influence of cylinder axis. Three studies found greater loss for 45° axis than for 90° axis, which in turn showed greater loss than for 180° 13, 14, 21. Data reported in Oguz25 were not clearly described, but seemed to suggest greater loss for 90° axis than 45° axis, Brooks et al.’s16 data was similarly not clear but seemed to suggest similar losses for 90° and 45° axes, and Jethani22 argued for similar losses for 45°, 90° and 180° axes.

Aniseikonia is a binocular vision disorder where the two eyes’ images are perceived to be of different sizes or shapes. There are retinal, cortical and optical types.32 Retinal aniseikonia may develop due to lateral displacement of retinal elements in one eye with retinal stretching or oedema. Cortical aniseikonia indicates a higher level of dysfunction. Optical aniseikonia is where the two retinal images are different, and may occur due to anisometropia, its correction, or to prisms of different orientations placed in front of the two eyes. This paper is concerned with the simulation of optical aniseikonia.

There have been few studies investigating the impact of lens-induced aniseikonia on stereopsis. Peters30 investigated the effect of adding spherical lenses, of opposite powers in front of the eyes, on the ability to determine when binocularly fused targets no longer appear in a fronto-parallel plane. Reading & Tanlamai31 increased magnification up to 33% to one eye, and found stereoacuity losses of about 1.0 log unit. Lovasik & Szynkiw24 increased magnification to one eye, and found the reduction in stereoacuity for an interocular 12% magnification difference with the “Randot” test was similar to the loss for 2 D monocular spherical blur. Using a novel computer tablet based stereopsis test, Hess et al.33 reported pilot results indicating about 21% (0.08 log unit) increase in stereo-threshold for every 1% difference in image size between eyes.

There have been a few studies of stereopsis in the presence of meridional aniseikonia. Ogle29 investigated the effects of meridional magnifying lenses on the tilt of a vertical plane about a vertical axis necessary to give the appearance of a “fronto-parallel” plane. For lenses with axis 90° (magnification horizontal), tilt was proportional to magnification. Lenses with axis 180° (vertical magnification) produced an “induced” effect on binocular perception in which the perceptual distortion experienced with a x 90° magnifier were reversed (slopes up to the
right now sloped up to the left). When these were placed in front of an eye, a similar linear relationship occurred between tilt and magnification, but only out to about 3% magnification after which the rate of tilt decreased. Other investigators found similar effects.34, 35

There is conflicting information in the literature regarding the impact of induced anisometropia, the relative impact of the axis of cylindrical blur and the “dose-response” relationship, much of which may relate to the lack of threshold-based methods for measuring stereopsis and the limited number of testing levels. Furthermore, there is little information on the impact of induced meridional aniseikonia on stereopsis. Here we report the relationships between blur and magnification with degradation in stereopsis. We used a method that overcomes the previous limitations. Our working hypothesis is, as stereopsis is a function of the lateral displacement of the eyes, optical factors with interocular effects in the horizontal meridian will have greater impact than those with effects in the vertical meridian, with oblique axes having an intermediate effect. Considering some previous work,29, 34, 35 this hypothesis may be rejected for meridional aniseikonia.
Methods

Participants

Participants were recruited from the student and staff population of the Queensland University of Technology. Screening was undertaken to ensure all participants had good baseline habitual visual acuities (< 6/6) and normal corrected stereoacuity thresholds (≤ 40 sec arc). Approval was obtained from the University Human Research Ethics Committee, and informed written consent was obtained from all participants after procedures were explained.

Table 1 provides participants age and refraction details. There were 10 participants aged 19-64 years, with good general and ocular health including normal binocular vision. Refractions were in the range +1.00 DS to −5.50 DS/−2.50 DC x 180. Apart from participant 4, all participants had 0.50 D differences or less in spherical and cylindrical refraction components of their two eyes.

Table 1. Participant characteristics

| Participant number | Age (years) | Refraction (D)  |
|--------------------|-------------|-----------------|
|                    |             | R               | L               |
| 1                  | 26          | +0.50 DS/−0.50 x 160 | 0.00 DS/−0.75 DC x 170 |
| 2                  | 19          | −5.50 DS        | −5.25 DS        |
| 3                  | 19          | −5.50 DS/−2.50 x 180 | −5.50 DS/−2.50 DC x 180 |
| 4                  | 21          | −1.25 DS        | −0.25 DS        |
| 5                  | 64          | −1.75/−0.50 x 110 | −1.75 DS/−0.25 DC x 150 |
| 6                  | 50          | +0.50/−0.50 DC x 90 | +0.25/−0.50 DC x 90 |
| 7                  | 34          | +0.50/−0.50 x 180 | +0.75 DS/−0.50 DC x 5 |
| 8                  | 21          | Plano           | Plano           |
| 9                  | 24          | Plano           | Plano           |
| 10                 | 34          | 0.00 DS/−0.75 DC x 180 | 0.00 DS/−0.75 DC x 180 |

Random Dot Stereogram threshold measurement

The McGill modified random dot stereogram (McGill Vision Research, McGill University, Montreal, Canada) was used to determine stereoacuity (the stereopsis threshold). Stimuli were displayed on a 24-inch ASUS VG248QE 3D monitor and viewed through synchronised shutter glasses (NVIDIA 3D vision 2 - model P1431) worn over the spectacle correction and blurring/magnifying lenses. Room lights were turned off. The stimuli were spatially bandpass random dots (average luminance 48 cd/m²) on a uniform grey background (luminance 34 cd/m²), and the dots seen by the two eyes were offset to give the perception of a floating
circle with a missing sector (‘Pac-man’ shape). The stimulus subtended an angle of 9° at the 90 cm viewing distance, maintained with a head/chin rest. Initial disparity was set at 320 sec arc. Participants reported the perceived position of the missing sector (up, down, left, right) by selecting a key on a keyboard in a four alternative forced choice procedure without feedback. A staircase method was employed to control the disparity presented for each trial. One staircase was 1-up-1-down and another staircase was 2-up-1-down. Each staircase terminated after 70 trials or 9 reversals, whichever was reached first. Initially the staircases were in ratio steps of 2, but after the first reversal they were in ratio steps of $\sqrt{2}$. Each staircase terminated after 70 trials or 9 reversals, whichever occurred first. The data were fit by a cumulative normal psychometric function. Thresholds were calculated as the disparity required to achieve a 62.5% correct performance level. The repeatability of the test is high. All participants underwent training where the test was explained and data for one complete run with the habitual correction was performed. These data were not used in the analysis but served as confirmation that the participant had normal stereopsis.

Experiment 1 - anisometropia

Five participants were corrected with their own spectacles, one was corrected with contact lenses, two were corrected with trial lenses in a trial frame (Oculus Adult half eye 42580 trial frame with fixed bridge), and two emmetropic participants did not require correction. Two presbyopic participants had +0.75 D additions incorporated to compensate for the 90 cm task distance.

To induce anisometropia, trial lenses were placed in a Keeler Halberg trial clip in front of the spectacles or at the front of the trial frame. There were 17 trial lens powers and cylinder axis combinations, placed in front of the right eye only. This included zero (no lens) and both positive and negative, 1 and 2 D powers, at three axes 45, 90 and 180. Spherical lenses were also tested. The powers were based on pilot investigations. The order of lens use for any participant was randomly generated using the random number generator in Excel. Three measures were taken for each participant/power/axis combination, converted into log seconds of arc, and the mean and standard deviation determined.
Experiment 2 - aniseikonia

Afocal magnification lenses up to 6% were made either of diglycol carbonate (CR39, 1.498) for overall magnifications or a 1.66 material for meridional magnification. Magnification $M$ of spectacle lenses is described by the formula

$$M = \left(1 - \frac{tF_1}{n}\right)^{-1}(1 - hF'_v)^{-1}$$

(1)

where $t$ is lens thickness, $F_1$ is front surface power, $n$ is refractive index, $h$ is distance between the lens back vertex eye entrance pupil and $F'_v$ is back vertex power. As $F'_v = 0$, only the first factor on the right-hand side matters. Overall magnification was achieved by having highly curved spherical surfaces and thick lenses, e.g. the lens providing 6% magnification had +11.5 D front surface power and 7.4 mm centre thickness. Meridional magnification was achieved by having highly curved cylindrical surfaces and thick lenses; considerable care was taken during manufacture to ensure alignment of surfaces, as misalignment of 1° would produce a cylindrical error of 0.4 D for a 6% lens. The axis of a lens was specified by the ophthalmic orientation of the flat meridian of its surfaces. Lenses were edged and fitted into 38 mm diameter trial lens holders.

All ametropic participants were corrected with trial lenses placed in the trial frame. Again, the two presbyopic participants had +0.75 D additions incorporated. The magnification lenses were placed at the front of the trial frame. There were 17 magnification and axis combinations: zero (no lens), and 3%, 6%, 9% and 12% at axes 45, 90 and 180. Overall magnification was also tested. These levels were chosen because, in pilot work, 6% overall magnification gave similar effects on stereocuity as 1 D monocular spherical blur. 3% and 6% magnifications were achieved by placing lenses in front of right eyes. 9% magnifications were achieved by placing 6% magnification lenses in front of right eyes and 3% minification lenses in front of left eyes (the 3% lenses were turned around so that the usual front surfaces were facing eyes), and similarly 12% magnifications were achieved by placing 6% magnification lenses in front of right eye and 6% minification lenses in front of left eyes.

The testing order of magnification lenses for each participant was randomly generated. Three measures were taken for each participant/size lens/axis combination, converted into log seconds of arc, and the mean and standard deviation determined.
Statistical analysis
The outcome of the Shapiro-Wilks test was that 32 of 34 sets of data were normally distributed; on this basis parametric statistics were used. Repeated measures analyses of variance were applied, with inter-subject variables for Experiment 1 being sign of lens, power (positive lens in front of the right eye used to induce anisometropia), magnitude of power (1 D or 2 D) and meridian (x 180, x 45, x 90, overall). Inter-subject variables for Experiment 2 were magnitude of magnification (3%, 6%, 9% or 12% and meridian (x 90, x 45, x 180, overall). The Bonferroni test was used in post-hoc analysis of meridional pair-wise comparisons (i.e. significance for p was set as < 0.008).
Results

Experiment 1 - anisometropia

Figure 1 shows stereoacuity as a function of induced anisometropia. An increase in threshold denotes worse stereoacuity. The main findings were:

1. There was no influence of lens sign with both positive and negative monocular blur reducing stereoacuity ($F_{1,9} = 1.6, p = 0.24$).

2. Threshold at baseline averaged 1.37 log sec arc (i.e. 24 sec arc), and this increased as anisometropia increased ($F_{1,9} = 178, p < 0.001$). For 2 D spherical anisometropia, the threshold was 1.89 log arc sec (78 arc sec), an increase of 0.52 log sec arc (or 3.3 times) and approximately three times the degradation observed with 1 D spherical anisometropia (Figure 1a).

3. There was a significant effect of axis ($F_{3,27} = 21.9, p < 0.001$). Threshold increased as the axis of meridional anisometropia changed from 180° to 45° and then to 90° (Figure 1b). For example, for 2D meridional anisometropia threshold increased from 1.53 log sec arc (34 sec arc) for x 180 to 1.89 log sec arc (78 sec arc) for x 90. The post-hoc pairwise comparisons between the axes were significant ($p < 0.003$), apart from that between x 90 and x 45 ($p = 0.03$). Cylinders x 90 gave similar effects as spherical lenses ($p = 0.88$).

These findings support our hypothesis. Mean effects of cylinders, relative to spherical lenses, were 29%, 75% and 98% for axes 180°, 45° and 90°, respectively.
Figure 1. Stereoacuity as a function of induced anisometropia. Powered lenses were placed in front of right eyes. A) spherical blur, B) cylindrical blur, with horizontal lines showing values for spherical blur. Data are mean ± standard deviations.
Experiment 2 – aniseikonia

Figure 2 shows stereoacuity as a function of induced aniseikonia. The main findings are:

1. Threshold at baseline averaged 1.37 log sec arc (i.e. 23 sec arc), and increased to 1.93 log sec arc (85 sec arc) with 12% overall aniseikonia.

2. Threshold increased as aniseikonia increased ($F_{3,27} = 63.9$, $p < 0.001$), with the increases, relative to no aniseikonia, being approximately proportional to the square of aniseikonia. The maximum mean increase was 0.56 log sec arc (or 3.6 times) for 12% overall aniseikonia (Figure 2a), similar to that reported by Lovasik & Szymkiw 24.

3. There was a significant effect of meridian ($F_{3,27} = 9.5$, $p < 0.001$). Post-hoc testing showed that threshold was significantly higher for overall aniseikonia than for meridional aniseikonia ($p < 0.004$), but there were no significant pair-wise comparisons between the three axes ($p = 0.77$ to $0.85$). Collectively, the meridional aniseikonias had 64% the effect of overall aniseikonia (Figure 2b). These findings do not support our hypothesis that the direction of the aniseikonia would affect the stereothreshold.

4. Each 1 D induced anisometropia had approximately the same effect on threshold as did each 6% of induced aniseikonia.
Figure 2. Stereoacuity as a function of induced aniseikonia. Magnifying lenses were placed in front of right eyes. To produce interocular magnification differences of 9% and 12%, positive magnification of 6% in front of right eyes was combined with negative magnifications of 3% and 6%, respectively, in front of left eyes. A) overall magnification (OA), B) meridional magnification, with horizontal lines showing values for overall magnification. Data are mean ± standard deviations.
Discussion

This study confirmed that both optically induced anisometropia and aniseikonia degrade stereoacuity, with the reduction in stereoacuity increasing as the interocular difference increased. The anisometropia experiment showed a worsening of stereopsis as the cylindrical axis changed from 180° to 90°; the loss at axis 90° was similar to that for spherical blur. These results partially support the hypothesis in that only some optical factors with interocular effects in the horizontal meridian have greater effect on stereopsis compared with those with effects in the vertical meridian.

The results for anisometropia did not match those of several previous studies, where reported losses for cylindrical blur were always less than those for spherical blur\cite{16, 17, 25} and 45° axes showed greater or similar effects than 90°.\cite{13, 14, 16, 21} Only Oguz & Oguz,\cite{25} who considered 90° and 45° axes, appeared to show greater effects for the 90° axis. We believe that some of the conflicting results may be related to their limited number of testing levels and failure to test stereoacuity to threshold.

The aniseikonia experiment gave similar stereoacuity loss with overall magnification as that reported by Lovasik & Szymkiw\cite{24} using a Randot test book, and the losses were in similar proportion to the loss with anisometropia reported by these authors (each 1 D induced anisometropia had approximately the same effect as 6% overall image size difference). Aniseikonia did not provide a meridional related loss of stereopsis, with the mean loss with meridional aniseikonia being 64% of that for overall aniseikonia.

That the axis for meridional anisometropia, but not aniseikonia, affected stereoacuity, suggests differences in the way that monocular blur (in particular induced meridional anisometropia) and interocular shape differences (as a consequence of meridional aniseikonia) interact with disparity cues for the processing of stereopsis. Welchman\cite{37} reviewed the cortical processing of binocular disparity and the interaction with other depth cues. For example, the overall depth perception results from image disparity, shading, shape factors and other monocular depth cues (i.e. depth information is extracted based on blur and other image properties).
The effects we find may be better understood by considering how the lenses we use affect the retinal image. Monocular blur along the horizontal meridian will interfere with horizontal disparity coding. We would therefore expect a large impact on stereoacuity. Blurring along the vertical meridian will primarily affect vertical disparity. We therefore expect a lesser effect. Before extracting disparity, a correspondence between the features in the two eyes’ retinal images must be found. Meridional aniseikonia will impact this correspondence process no matter its direction. It is perhaps unsurprising then that we find a greater impact for size differences in all meridians than in one meridian alone. One may expect these size differences to disrupt the mechanisms that fuse the images from the two eyes, leading to reduced stereoacuity and eventually suppression or double vision.

From our aniseikonia results, we expect that some of the observed effect on stereopsis of the lenses in the anisometropia experiment would be due to magnification. However, by far the greater component was due to monocular blur. The largest vertex distance for any subject was 20 mm. This would have produced magnifications to ±4%, but for most participants the magnification range would have been about ±3% for the 2 D lens. According to the 1 D/6% equivalence mentioned above, the magnification effect on stereopsis was similar to that produced by 0.5 D blur. As the magnification effect did not have a meridional component, the influence of cylinder axis on stereoacuity may have been more distinct without this confound.

Clinical stereopsis tests include Randot, TNO, Frisby and Titmus tests. The McGill modified random dot stereogram test used here is close in approach to the Randot (a vectograph random dot stereotest utilising polarizing lenses) and TNO (a random dot anaglyph utilising red green lenses) tests, except that the disparate stimuli are presented in different time intervals and shutter goggles are used. The Frisby test is a real depth test (one of four plates has detail painted on the back surface and the plates vary in thickness; motion parallax, a monocular depth cue is able to be used), and the Titmus test contains monocularly visible contours. Lovasik & Szynkiw found that anisometropia and aniseikonia affected Titmus results more than Randot results, presumably because the Titmus test is the more difficult task. The results reported here using the McGill test for spherical anisometropia and overall aniseikonia are similar to their findings with the Randot test. The computer-based test can measure to threshold and thus allows for the assessment of subtle factors affecting stereopsis. In a natural situation when both monocular and binocular depth cues are present (e.g. interposition, motion parallax, texture, light and shade) the effects of interocular
variables on depth perception may be less. For example, the Frisby test, which has real depth cues, is less affected by monocular blur induced by Bangerter filters than the Randot test.\textsuperscript{40}

Uncorrected refractive errors are common,\textsuperscript{41} and even if refractive errors are accurately corrected when spectacles are first dispensed, changes in refraction occur during the wearable life of a pair of spectacles and sometimes prescriptions are dispensed incorrectly.\textsuperscript{42} Refractive changes can occur due to myopia progression,\textsuperscript{43} crystalline lens age changes,\textsuperscript{44} during pregnancy,\textsuperscript{45} due to ocular (eg uveitis\textsuperscript{46}) or systemic disease (eg diabetes\textsuperscript{44,47}), ocular surgery (eg scleral buckles\textsuperscript{48}), and as a side-effect of some medications (eg \textsuperscript{49}); these changes could occur at different rates in each eye and may be asymmetric. Cylinder is common, with a meta-analysis reporting 15\% of children having greater than 0.50 D,\textsuperscript{50} and it could also be inaccurately corrected for many reasons. Although the axis of cylinder is reported to be mostly stable, it changes in direction in 23\% of people aged over 49 years.\textsuperscript{51} Here we show that cylinder of 1 D that induces defocus along the horizontal meridian (x 90) has a large effect on stereopsis with effects similar for spherical anisometropia of 1 D. These errors thus have the potential to affect the depth perception of many individuals; difficulty in judging depth and eye hand coordination tasks involving small objects would be common.

In terms of aniseikonia, the induced 3\% size difference, which is roughly equivalent to the image size difference that occurs with a 2 D anisometropic spectacle lens correction, had little impact on stereoacuity. Anisometropia of this degree occurs in about 2\% of children\textsuperscript{52} and age changes in the eye increase the prevalence to 6\% in people aged over 60 years.\textsuperscript{53} 2 D of spherical blur increased the threshold by about 2 times. This indicates that aniseikonia is much less of an issue concerning stereopsis than is anisometropia.

Anisohyperopia of > 1.00D and anisomyopia of > 3.00D early in life can interfere with the neurodevelopment of vision and result in amblyopia that is characterized by reduced best corrected visual acuity and degraded stereo acuity.\textsuperscript{54} Initial treatment for anisometropic amblyopia is correction of refractive error, followed by periods of penalization of the dominant eye or activities to promote binocular perception.\textsuperscript{55} Changes in visual acuity and stereoacuity are the usual clinical measures to document treatment effect. However, our findings confirm that stereoacuity can be limited by the image size difference resulting from the correction of the refractive error by spectacles and that this places a ceiling on stereoacuity improvement. To avoid image size changes that occur with spherical and
meridional anisometropia corrected with spectacle lenses, contact lens correction could be considered.56

Some limitations should be mentioned. Firstly, participants were not cyclopleged and the eight young adults could have compensated for negative lens induced hyperopic blur by accommodating. We did not assess which eye (with the negative, positive or no lens) was used to guide the accommodation response to the near target. However, as accommodation between the two eyes is linked the intraocular difference would have been maintained. Also, the relative stereoacuity data for added positive and negative lenses were similar for the older presbyopic participants and the younger participants. Related to this issue is that any residual imbalance in habitual correction of the two eyes of participants may have had small effects. Secondly, the visual system is capable of considerable adaptation, especially during childhood and to changes occurring gradually, so that it is possible that responses to the sudden imposition of anisometropia or aniseikonia in normal adult observers may not be representative of the visual system's capacity to achieve a high level of stereopsis in the real world after many years of adaptation. Thirdly, several participants had astigmatic corrections, and in particular participant 3. There is evidence that people adapt to their uncorrected astigmatism so that blurring (corrected) vision with cylindrical lenses has the minimum effect on visual acuity if the cylindrical axis matches that of the uncorrected astigmatism state57; it is possible that there may be some similar influence on stereopsis.

Conclusion
Meridional patterns of loss of stereopsis were dissimilar for anisometropia and aniseikonia. The former, but not the latter, support a hypothesis that optical factors with interocular effects in the horizontal meridian will have greater impact than those with effects in the vertical meridian. Approximately, each 1 D induced anisometropia had the same effect on threshold as did each 6% of induced aniseikonia.

Acknowledgements
Jianing Lu and Jeongmin Lee were supported by QUT Vacation Research Experience Scholarships. Afocal magnifying lenses were provided by Carl Zeiss Vision; we thank Philipp Jester for arranging their manufacture. Harry Grzes and Shamir edged and fitted the magnifying lenses. Robert Hess and Alex Baldwin are inventors on a US Provisional Patent,
US 62/793,632, entitled “System and Method for Digital Measurement of Stereo Vision”, filed January 17th, 2019, which has been commercially licensed by McGill University.
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