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Differences in Tests of Aniseikonia

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The New Aniseikonia Test (NAT), a hand-held direct-comparison test using red/green anaglyphs, has several potential advantages as a screener. We compared the validity of the NAT to that of the Space Eikonometer in three experiments: (1) aniseikonia was induced by calibrated size lenses in a double-blind study of 15 normal subjects; (2) habitual aniseikonia was measured with both instruments in four patients; and (3) eight of the normal subjects were retested with a computer-video simulation of the NAT. The NAT underestimated induced aniseikonia by a factor of 3 in the normal subjects and underestimated habitual aniseikonia in four patients. The Space Eikonometer correctly measured the magnitude of induced aniseikonia in the normal subjects. The simulation test did not show underestimation in the eight normal subjects. We could not attribute the NAT's underestimation of aniseikonia to the red/green anaglyph method, printing error, psychophysical method, or the direct-comparison test format. We speculate that the NAT induces a different sensory fusion response to aniseikonia than do the other tests, and that this altered sensory fusion response diminishes measured aniseikonia. We conclude that the NAT is not a valid measure of aniseikonia. Invest Ophthalmol Vis Sci 33:2063–2067, 1992

More than one million cataract operations are performed annually in the United States[1], with most patients receiving intraocular implants. Of these pseudophakic patients, 41% may have symptoms attributable to aniseikonia,[2] making this condition a significant public health issue. Because symptoms experienced by aniseikonic patients—eg, headache and eyestrain—often are not specific to the condition,[3] the determination of aniseikonia in the patient with fusion and stereopsis must rely on direct measurement of aniseikonia. Because most clinicians who might encounter aniseikonia are not prepared to accurately measure and correct it, screening followed by referral is the logical choice. The current lack of a good screening test affirms the difficulty of constructing a device that is clinically efficient and accurate.

The New Aniseikonia Test (NAT)[4] (Handaya, Tokyo, Japan) is easy to administer and interpret, easily understood by naive patients, fast, and inexpensive. The NAT uses the direct comparison approach[5] to test aniseikonia. The patient views pairs of adjacent half-moon targets—one red, one green—of calibrated size difference. Red/green anaglyph technology separates the right and left eye images. The degree of aniseikonia is determined by the pair that appears most equal in size.

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The NAT has gained some acceptance as a test of pseudophakic aniseikonia. Katsumi et al[6] found 2.8% average aniseikonia in unilateral pseudophakia with the NAT. Lubkin et al[2] obtained similar results in pseudophakic patients with Essilor's stereoscopic eikonometer and a computer-based video direct-comparison test analogous to the NAT. However, the study population differed from that of Katsumi et al.[6] Romano has suggested using the NAT to determine iseikonic corrections.[7]

Awaya and coworkers[4] compared the NAT to the phase-difference haploscope in normal subjects and patients with aniseikonia. When aniseikonia was induced in five normal subjects by known afocal size lenses, the NAT measured less aniseikonia than the phase-difference haploscope, and both devices measured less aniseikonia than expected, based on the value of the inducing lenses. These devices yielded comparable measurements of habitual aniseikonia in some patients with aphakia, but not others.

Given the variable results reported by Awaya and associates[4] and the potential significance of the device, we systematically evaluated the validity of the NAT and found that it significantly underestimated aniseikonia. The apparent mechanism of this underestimation is the rescaling of perceived image size.

Experiment 1: Induced Aniseikonia in Normals

This experiment was designed to determine whether the NAT accurately estimated induced aniseikonia in normal subjects. We used measurements of aniseikonia on the Space Eikonometer (American

Optical Corp., Southbridge, MA) as a basis of comparison. Our hypothesis was that a valid test should measure 1% of aniseikonia for each percent of aniseikonia induced by size lenses.

Materials and Methods

Fifteen subjects with normal binocular vision wore their habitual farpoint refractive correction for all tests. Subjects, ranging in age from 23–42 yr, had 6/6 or better corrected acuity, 20″ or lower stereoscopic thresholds, and asymptomatic vision. Aniseikonia was induced with afocal overall trial lens magnifiers (−4, −2, −1, 0, 1, 2, or 4%) placed before the right eye. The values of the magnifier lenses were coarsely masked from the examiner by labels with an arbitrary numbering system placed over the size lens magnification markings. Complete masking was difficult because the magnitude of size lenses can be crudely judged from their visible curvature and thickness. The order of magnifier application was randomized as was the order of instrument use. Horizontal and vertical aniseikonia were measured on both devices (horizontal first, as required by Space Eikonometry technique[8]), but the Space Eikonometer declination was ignored. Space Eikonometer technique was otherwise conventional.[8]

The task of selecting matched half-moon targets on the NAT first was demonstrated without added magnification or red/green glasses. The red/green glasses and inducing magnifier then were applied, after which the subject selected the target pair that appeared to be size matched. The search for the best matched half-moon pair began with the 0% pair. The NAT was hand-held by the subject, with free eye movements allowed and no time restriction made on judgments. Informed consent was obtained after the nature of the procedure had been explained fully.

Results

Figure 1 shows that measured horizontal and vertical aniseikonia, plotted as a function of inducing lens power, differed significantly between the devices. The dashed line with a slope of −1.0 represents the locus of points for a valid test if a normal (ie, iseikonic) observer were evaluated. Solid lines show least squares regression to data from each instrument. Error bars are ±1 standard error. Because there was no discernible difference between horizontal and vertical size measurements, these data were combined for statistical analysis.

The slope of the Space Eikonometer data did not differ significantly from −1.0 (t = 0.77, P = 0.455), nor did the Y-intercept (ie, the measured aniseikonia at 0% magnification) differ significantly from zero (t = 0.52, P = 0.61). Thus, the Space Eikonometer data conformed to the expectation for a valid test. The slope of the group NAT data was −0.31, significantly less than the Space Eikonometer data slope (t = 11.8, P = 0.0001). The Y-intercept of the group NAT data, −0.97, deviated significantly from zero (t = 6.98, P = 0.0001).

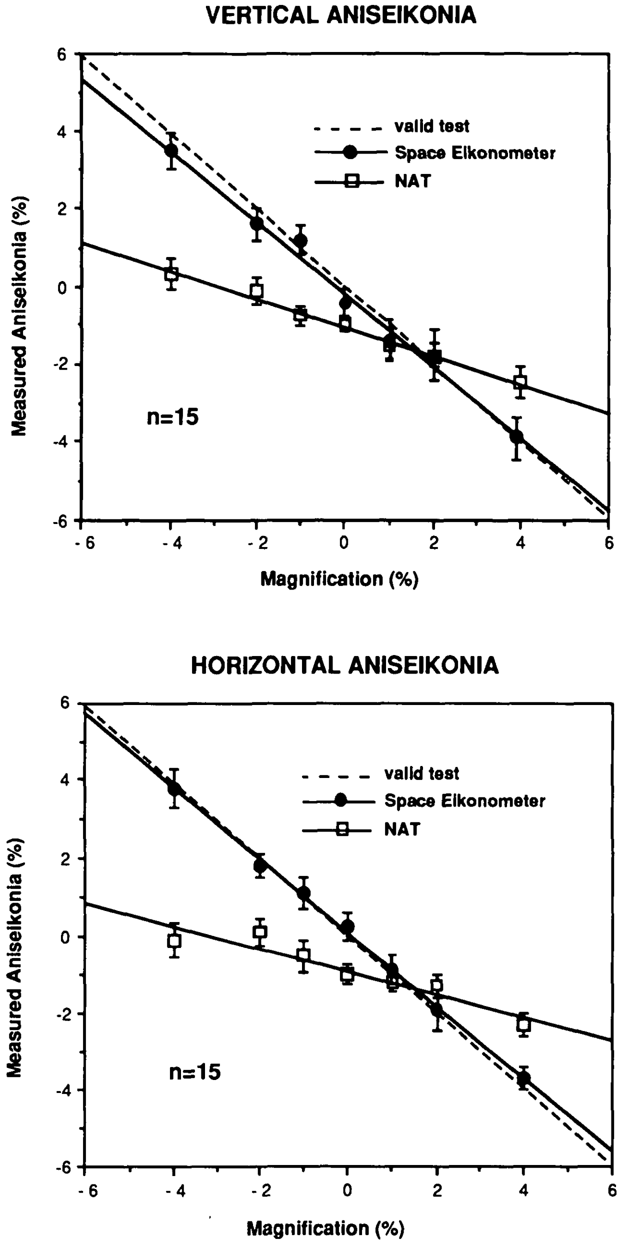

Fig. 1. Induced aniseikonia measured in 15 normal subjects by the New Aniseikonia Test (NAT) and the Space Eikonometer is plotted as a function of inducing lens magnification when tested in the vertical and horizontal retinal meridians. The space eikonometer data do not differ significantly from the valid test criterion, whereas the NAT data show a slope and Y-intercept that are both significantly less than those of a valid test.

Discussion

The difference of the slope between the NAT and Space Eikonometer data indicates that the NAT underestimated induced aniseikonia by a factor of 3 over our range of magnifications. If the NAT test performed similarly on patients, then the test would imply that patients with true image size differences of 2–6% (ie, those with fusible but symptomatic aniseikonia) have insignificant aniseikonia (<2%). These are the very patients for whom a screening test is best suited. The Y-intercept of the NAT population data revealed a bias of nearly −1%, erroneously suggesting that normal subjects require magnification of the left eye image.

Experiment 2: Habitual Aniseikonia in Patients

In this experiment, we determined whether the results obtained from normal subjects were applicable to patients with habitual symptomatic aniseikonia.

Materials and Methods

We evaluated seven patients with symptomatic aniseikonia during the study period. Four of the seven patients provided useful data on both devices. Two patients had stereopsis too poor for the Space Eikonometer, and one had motor fusion too unstable for reliable NAT testing. The four patients with usable data ranged in age from 25–76 yr, had corrected visual acuities of between 6/6 and 6/18 (in the poorer eye), stereoscopic thresholds from 20″–100″, and symptomatic binocular vision. One of the four (JS) had unilateral pseudophakia. Full far-point refractive correction was worn for all tests. Single measurements of habitual aniseikonia were made with the Space Eikonometer and the NAT according to standard clinical practice.

Results

Figure 2 shows that, compared to the Space Eikonometer, the NAT underestimated habitual horizontal and vertical aniseikonia in all four testable patients. Aniseikonia in patient WE probably was below the accuracy threshold of the NAT. When the aniseikonia of the remaining three patients was corrected for the −1% bias of the NAT, the NAT underestimated aniseikonia by a factor of 1.5–2.0. This underestimation was well within the range of that observed in normal subjects when aniseikonia was induced. Thus, the NAT appeared to underestimate habitual aniseikonia in patients just as it underestimated induced aniseikonia in normal subjects.

Discussion

We have been unable to explain this difference in test performance in normal subjects and patients by technical factors. Careful measurement of the NAT plates under magnification indicated they were printed accurately. Moreover, a recent study of chromatic magnification of the ocular images indicated that the red/green anaglyph used for the NAT could account for only a tiny fraction of its underestimation (<0.25%).[9] The NAT failure also cannot be attributed to its direct-comparison format because another direct comparison test and the Space Eikonometer have been shown to provide equivalent measures of aniseikonia.[10] Also, Lubkin et al[2] observed that their video direct-comparison test compared favorably to Essilor's stereoscopic eikonometer. Therefore, the difference in outcome between the two devices must be a result of the visual response to the NAT test target features.

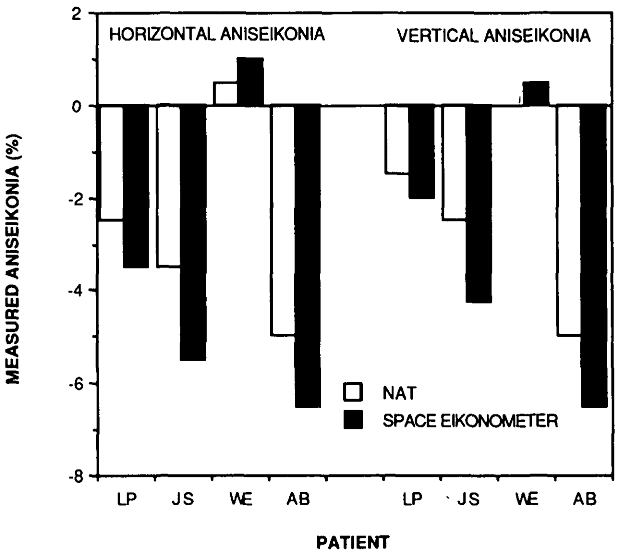

Fig. 2. Habitual aniseikonia measured in four aniseikonia patients is shown for the horizontal and vertical retinal meridians. The New Aniseikonia Test (NAT) underestimated aniseikonia, compared with the Space Eikonometer, in all four patients.

Experiment 3: Test Structure and Induced Aniseikonia in Eight Normal Subjects

To explore target features that might account for the difference in results between the NAT and the Space Eikonometer, we constructed a computer-video simulation of the NAT test that could be compared to the printed NAT, anticipating that our initial simulation also would underestimate aniseikonia. Our simulation did not underestimate aniseikonia like the NAT.

Materials and Methods

Eight of the 15 normal subjects tested previously were retested with targets created on a Macintosh II computer (Apple Computer Co., Cupertino, CA) using a 256 color video board. The red and green colors were chosen carefully to achieve complete extinction of the complementary color target when viewed through the NAT's anaglyph glasses. The shape and angular subtense of the video targets were matched to that of the NAT, except that only one target pair was presented per video screen, whereas six target pairs were printed on each page of the NAT. This test difference was necessary to assure adequate target resolution on the computer video screen. Key strokes allowed the observer to flip through a range of target size comparisons on the computer until the best match was found. Because the NAT and our video simulation used one fixation point centered between each target pair, there were six such binocularly fusible points per NAT page but one such point per video screen. Induced aniseikonia was measured with the same procedures described above. Because Experiment 1 indicated that the underestimation behavior was not characteristic of one retinal meridian, only vertical aniseikonia was tested.

Results

Figure 3 shows that measured vertical aniseikonia differed between the NAT and its computer simulation. The slope of the best-fit linear regression on the video test data (−0.84) did not differ significantly from the valid test criterion [$F(1,7) = 4.75$, $P = 0.066$], whereas the slope of the best fit linear regression on the NAT test data (−0.31) was significantly less than that of the video test [$F(1,7) = 43.6$, $P = 0.0003$]. Moreover, the Y-intercept of the video test result was virtually zero, unlike the NAT.

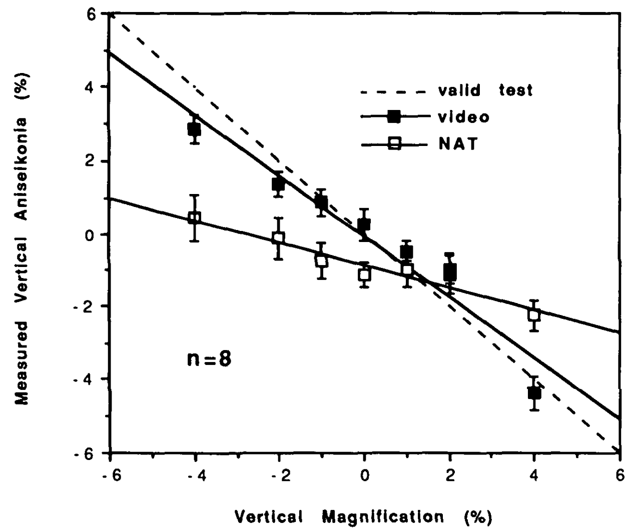

Fig. 3. Induced aniseikonia measured in eight normal subjects by the New Aniseikonia Test (NAT) and a computer-video direct-comparison test is plotted as a function of inducing lens magnification for the vertical retinal meridian. The video test data do not differ significantly from the valid test criterion, whereas the NAT data show a slope and Y-intercept both significantly less than those of a valid test.

Discussion

Our video simulation of the NAT showed neither the underestimation nor the bias of the NAT. Thus, it is more comparable to the direct-comparison device of Ames[10] and the video eikonometer of Lubkin et al[2] than it is to the NAT. It is surprising that the small differences in test design between the NAT and our simulation made such a large difference in outcome.

General Discussion

Awaya et al[4] attributed NAT underestimation in normal subjects to the vertex distance of the size lenses, a conclusion difficult to reconcile with the fact that the magnification of afocal size lenses is not determined by vertex distance but by the front surface curvature and thickness. They obtained equivalent measurements of aniseikonia from the NAT and the phase-difference haploscope in young patients with anisometropia (aged 7–10 yr). However, this outcome is difficult to interpret because some of those patients undoubtedly had varying degrees of amblyopia, and, therefore, probably were incapable of reliable interocular image size comparisons. Awaya et al[4] speculated that aniseikonia underestimation by the NAT in patients with unilateral aphakia may have been a result of fusional effect evoked by the binocularly visible letters and crosses on the NAT, which might have reduced the measured aniseikonia.

We cannot yet explain the difference in results between the NAT and the other two tests, but offer the following speculations.

First, the psychophysical method may explain the Y-axis offset of the NAT data but probably not their slope. The layout of the NAT begins with the 0% target, followed by the left eye magnification targets (negative magnifications in this study) and the right eye magnification targets. This target order may have caused the left eye magnification bias in the averaged data. That bias did not appear in the Space Eikonometer data or the video simulation data indicates that our subjects did not have −1.0% aniseikonia, our lenses were not in error, and our testing procedure did not introduce bias.

Second, the angle of gaze differed slightly between the NAT (minimal down gaze) and the other tasks (straight ahead gaze). While down gaze may create a vertical vergence stimulus in spectacle-corrected anisometropic individuals,[11] there is no evidence that down gaze per se induces aniseikonia. Moreover, our size lenses could not have induced aniseikonia because the magnification of size lenses does not vary significantly as a function of angle of gaze.

Third, we suggest that sensory fusional response to binocular textures, as proposed by Awaya and coworkers,[4] is the dominant factor leading to NAT underestimation of aniseikonia. Moreover, we propose that this fusional response is present in varying degrees in all binocular observers. The effect is undoubtedly much stronger than observed by Awaya et al[4] because their reference test, the phase-difference haploscope, contained background fusional texture that would have diminished measured aniseikonia. Accordingly, they measured significantly less aniseikonia on the phase-difference haploscope than was induced in normal subjects. This underestimation was not quite as large as that of the NAT. The Space Eikonometer exhibited no such underestimation in our tests. It is noteworthy that the direct comparison eikonometer designed by Ames scrupulously eliminated peripheral fusion[5] and produced measurements of aniseikonia equivalent to those found with the Space Eikonometer.[10]

Rescaling of binocular correspondence could be the mechanism by which fusion leads to aniseikonia underestimation. This rescaling is probably a different mechanism than true adaptation to aniseikonia, which requires several days.[12–14] The effects we observed required no more than a few seconds; the underestimations were evident when the subject began to view the NAT. Moreover, there was no aniseikonia underestimation by the Space Eikonometer in this study, whereas adaptation was revealed by others with the Space Eikonometer.[13,14] The rescaling might begin with fusion textures adjacent to the half-moon targets and then spread to the targets, altering their apparent size. Kertesz and Lee proposed such a mechanism to explain the difference between subjective and objective fixation disparity measurements during forced vergence.[15] However, rescaling due to forced vergence would only require that a constant be added to perceived directions, whereas rescaling due to aniseikonia would require that a multiplicative scaling factor be applied to perceived directions. Experiments are needed to test this hypothesis and to determine how significant such rescaling might be in maintaining normal binocular vision in the face of optical image size differences.

We conclude that the NAT in its present form is not a good screening test for aniseikonia. Individual measurements on the NAT also cannot be rescaled to true size difference (eg, by multiplying the results by 3), because the amount of perceptual rescaling varied significantly between normals. A more useful approach would be a redesign of the instrument to reduce the bias and underestimation.

Key words: aniseikonia, eikonometer, pseudophakia, binocular vision

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