A Stereoacuity Test for Detecting Aniseikonia

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Abstract

Thresholds of stereopsis were measured bilaterally using two vertical pins, one nearer than the other to the subject. In the majority of cases, the threshold when the left pin was nearer was different from the threshold when the right pin was nearer. This inequality was thought to be caused by aniseikonia. When calculated from bilateral inequalities, aniseikonia was found to be of small amount. The effect of inequalities on the measurement of stereoacuity was also investigated by comparing bilateral and unilateral arrangements of the same data. Stereoacuity calculated from bilateral data was found to be more precise than that calculated conventionally (i.e. unilaterally).

Abrégé

Nous avons mesure le seuil de la stereoscopie bilateralement en presentant deux aiguilles verticales dont une plus rapprochee que l'autre. Dans la plupart des cas, le seuil differait selon que l'aiguille de gauche ou de droit etait la plus rapprochee. On croyait que cette difference pouvait provenir d'une aniseconie mais un calcul base sur ces inegalites bilaterales ne soutenait pas cette hypothese.

Les effets des inegalites sur la mesure de l'acuite stereoscopique ont etes examines en comparant les memes donnees sous un aspect bilateral ou unilateral. L'acuite stereoscopique est plus precis, base sur un calcul bilateral qu'unilateral.

It may be possible to detect and measure aniseikonia by measuring thresholds of stereopsis bilaterally. This idea came to me after completing an investigation of the relationship between induced errors of refraction and stereoacuity.[1] A reduction in stereoacuity occurred when lenses of unequal power were before the eyes and this might have been due, in part, to differences in retinal image size caused by the lenses used. If this were so, there might be a relationship between aniseikonia and stereoacuity which could be detected by the test used for the investigation.

To study this possibility, the test[2] was revised so that thresholds of stereopsis could be measured bilaterally. This was possible because test disparities were presented by means of two adjacent pins which were parallel and in the vertical plane. One pin was nearer to the observer than the other pin by the amount of the disparity. Two pairs of pins were provided for each disparity, one with the left pin nearer and the other with the right pin nearer. Therefore, one threshold of stereopsis could be found for left-nearer and another for right-nearer pin arrangements. The word bilateral is used to differentiate such thresholds from those found by pooling data together so that the identity of the nearer side is lost.

The apparent position of objects in space can be altered when retinal images differ in size (aniseikonia). This distortion is due to stereopsis and cannot be perceived without it. An observer with aniseikonia in the horizontal meridian will not see the test's disparities as they really are because the plane of the pins will appear to have been rotated about a vertical axis. The amount of this rotation will be the same as that which occurs when a frontoparallel plane is seen with aniseikonia, as Ogle has shown.[3] As a consequence of this apparent rotation, the same disparity will appear to be bigger when one side is nearer and smaller when the other side is nearer. Some disparity other than zero will appear to lie in a frontoparallel plane.

The smallest disparity at which the nearer pin can be identified establishes the threshold of stereopsis. With aniseikonia, the left-nearer and right-nearer thresholds will not be numerically equal. It can be assumed that these disparities are at equal and opposite angles with respect to the apparent frontoparallel plane. The disparity which lies in the apparent frontoparallel plane is then half-way

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between the threshold disparities. The amount of aniseikonia can be calculated from this information.

To test this hypothesis and to investigate the prevalence of aniseikonia as well as to discover its effects on stereoacuity, bilateral thresholds of stereopsis were measured using a group of 42 people. From these data, stereoacuity and aniseikonia were calculated according to threshold criteria as described in the following section. The results of this study are reported here.

Method

The apparatus has already been described in detail.[2] The test distance was 0.6m. A head rest was used. Disparities were concealed from view by a metal screen with a window that could be closed by a shutter. The disparity to be viewed was positioned behind the window and the shutter was opened. The subject saw two vertical pins and identified the nearer by depressing one of two microswitches located under the left and right hands. The left hand switch was actuated when the left pin was nearer; the right switch when the right pin was nearer. If neither pin were perceived to be nearer, both switches were actuated at the same time.

The 11 disparities shown in Table 1 were presented 3 times in random order. After each presentation had been identified, the shutter was closed for 2.4 sec while the disparity was changed. When the test was completed, the results were presented on a display terminal in a format similar to that shown in Table 1.

Each subject performed the test at least twice, usually on different days. When the test was failed, it was repeated with disparities of 256, 128, 64, 32 and 16 sec.

The data from each test were arranged in two ways. In the *bilateral* arrangement, disparities were treated as if they formed part of a descending sequence. The left-nearer sequence was -24, -16, -12, -8, -4, 0, 4, 8, 12, 16 and 24 sec. The right-nearer sequence was 24, 16, 12, 8, 4, 0, -4, -8, -12, -16 and -24 sec. In the *unilateral* arrangement, the data of the left and right nearer disparities were combined by adding them together. The resulting sequence was 24, 16, 12, 8 and 4 sec. In this arrangement, zero disparity had no significance.

Each sequence was analysed to find the *perfect* and the *absolute* thresholds of stereopsis. The perfect threshold was defined as the least disparity

Table 1. Data of 4 subjects arranged bilaterally and unilaterally
Disparity (arc sec)

	Bilateral arrangement	Left rod nearer						Right rod nearer					Unilateral arrangement					
Subject	Response	-24	-16	-12	-8	-4	0	4	8	12	16	24	Response	24	16	12	8	4
	Left	3	3	3	3	2	2	0	0	0	0	0	correct	6	6	6	5	4
L.R.	Right	0	0	0	0	0	1	2	2	3	3	3	opposite	0	0	0	0	0
	Equal	0	0	0	0	1	0	1	1	0	0	0	equal	0	0	0	1	2
	Left	3	3	2	0	0	0	0	0	0	0	0	correct	6	6	5	3	3
N.T.	Right	0	0	0	0	2	2	3	3	3	3	3	opposite	0	0	0	0	2
	Equal	0	0	1	3	1	1	0	0	0	0	0	equal	0	0	1	3	1
	Left	3	3	3	2	3	2	0	1	0	0	0	correct	6	6	5	4	4
D.M.	Right	0	0	0	0	0	0	1	2	2	3	3	opposite	0	0	0	1	0
	Equal	0	0	0	1	0	1	2	0	1	0	0	equal	0	0	1	1	2
	Left	12	12	12	12	12	3	2	1	0	0	0	correct	24	23	24	21	19
M.L.	Right	0	0	0	0	0	2	7	9	12	11	12	opposite	0	0	0	1	2
	Equal	0	0	0	0	0	7	3	2	0	1	0	equal	0	1	0	2	3

Table 2. Thresholds of stereopsis, stereoacuity and aniseikonia from Table 1 data.

Arrangement	Threshold	Result (arc sec)	Subjects L.R.	N.T.	D.M.	M.L.
Bilateral	Perfect	left-nearer	-8	-16	-4	-4
		right-nearer	12	4	16	12
		stereoacuity	10	10	10	8
		aniseikonia	2	-6	6	4
	Absolute	left-nearer	-4	-12	0	-4
		right-nearer	4	-4	12	8
		stereoacuity	4	4	6	6
		aniseikonia	0	-8	6	2
Unilateral	Perfect	stereoacuity	12	16	16	12
	Absolute	stereoacuity	4	12	4	4

at which all responses were correct. The absolute threshold was the least disparity at which stereopsis was in evidence. In the bilateral arrangement, this was defined as the final disparity in a sequence of 3 correct or 2 correct and 1 equal. In the unilateral arrangement, this was defined as the final disparity in a sequence of 4 or more correct. If a bilateral sequence contained a disparity with 2 correct and 1 equal flanked by disparities with all 3 correct, this disparity was counted as if all had been correct. In the unilateral sequence, 5 correct and 1 equal was treated in the same way.

Stereoacuity was found from these thresholds. For the unilateral arrangement, threshold and stereoacuity were the same. For the bilateral arrangement, the stereoacuity was one-half of the algebraic sum of the left and right-nearer thresholds.

Aniseikonia was obtainable only with the bilateral arrangement. This was found by subtracting the stereoacuity from the right-nearer threshold of stereopsis. This gave aniseikonia in terms of disparity rather than in terms of the relative size difference of retinal images.

Aniseikonia in terms of disparity was converted into a retinal image size difference by the following formula:

$$M=A/(36(\arctan((2a+d)/2b)-\arctan(2a-d)/2b)))$$

where A is the aniseikonia in arc sec, 2a is the interocular separation, d is the pin separation, b is the distance from the eye's base-line to the pins and M is the % retinal image size difference. All distances are in mm and a positive A means that the right eye image is bigger than the left. For this apparatus, d=3.8 mm and b=600 mm.

Results

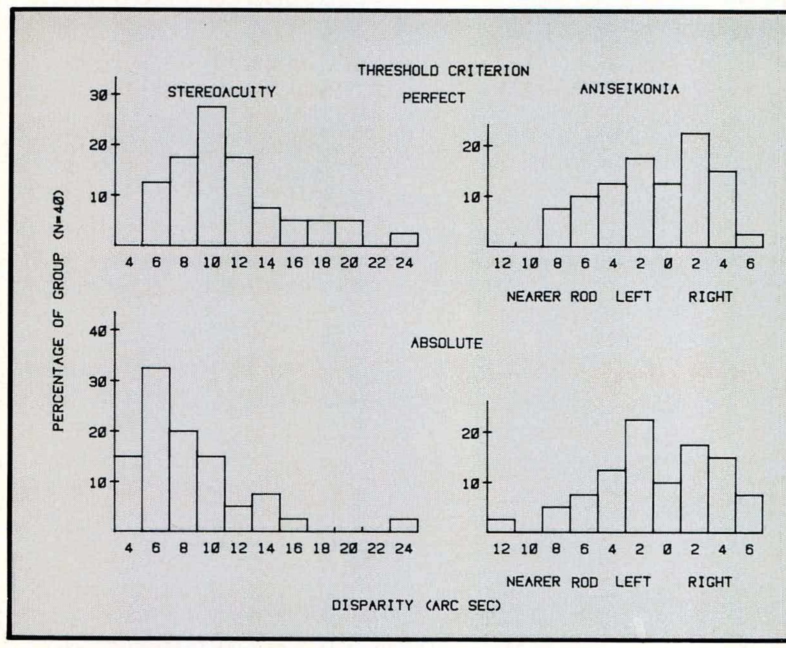
All 42 subjects were university students in their early twenties. Apart from this, the group was selected at random. Data from the initial test were discarded because all subjects were unfamiliar with the apparatus. Two subjects had stereoacuities greater than 24 sec which excluded them from the group. Therefore, the group was comprised of 40 subjects whose stereoacuities ranged from 4 to 24 sec.

Examples of test data are shown in Table 1. These were selected as representative of negligible aniseikonia (L.R.), left-nearer aniseikonia (N.T.) and right-nearer aniseikonia (D.M.). An amalgamation of data from 4 tests is also shown (M.L.). This provides 12 and 24 responses at each disparity for the bilateral and unilateral arrangements respectively. The disparities are for an interocular separation of 60 mm.

The bilateral data of Table 1 were analysed to find the left-nearer and right-nearer thresholds of stereopsis, the stereoacuity and the aniseikonia of each subject. The results are shown in Table 2 along with stereoacuities from the unilateral data. The absolute threshold criteria for the amalgamated data (M.L.) were 9 and 18 correct for the bilateral and unilateral arrangements respectively. This 75% correct threshold was chosen because Howard used it for his pioneering study.[4]

Results for the whole group are summarized by the histograms in Fig. 1. These show how members of the group were distributed with respect to stereoacuity and aniseikonia for perfect and absolute threshold criteria.

With the perfect threshold criterion, over half (57.5%) of the group had a stereoacuity of 10 sec or better. With the absolute threshold criterion, almost half (47.5%) had a stereoacuity of 6 sec or better. This supports Howard's observation that the absolute threshold of good stereopsis is 8 sec of arc or less.[4] The distribution of aniseikonia was slightly biased toward left-nearer. This may have been due to a small calibration error or else to a bias in the relatively small sample. With one exception, aniseikonia did not exceed 8 sec. An aniseikonia of 8 sec corresponds to a retinal image size difference of 0.6%.



Histograms showing the group's distribution with respect to stereoacuity and aniseikonia for the perfect and absolute threshold criteria. N=40.

Discussion

Asymmetrical thresholds of stereopsis were found for 88% of the group. The asymmetries were small with half being less than 4 sec. An examination of the data in Table 1 and in particular those of subject M.L. (who repeated the test 4 times) suggests that asymmetries were real and not just an artifact of the test.

The idea that aniseikonia can be calculated from these asymmetries is probably original. Nevertheless, it has not been demonstrated that the asymmetries measured here have been caused by aniseikonia. Aniseikonia of such small amounts (i.e. 0.6% or less) is probably of no clinical significance and may be typical of residual aniseikonia.

When bilateral thresholds of stereopsis lose their identity in a unilateral arrangement, stereoacuity is less certain. At first, I thought that a unilateral arrangement would always give an underestimate of stereoacuity. After examining these results I find that overestimates are possible also. The results of subjects M.L. show an underestimate with the perfect threshold and a slight overestimate with the absolute threshold. On the other hand, subject N.T.'s stereoacuity was underestimated with both threshold criteria.

Head position changes during the test might have caused unequal thresholds. To investigate this possibility, an experienced subject (whose thresholds were invariably equal) performed the test with the head rotated 6 deg to the left and again with it rotated 6 deg to the right. In both positions, the absolute thresholds remained equal and unchanged. Therefore, it is unlikely that small differences in head position (which were never as great as 6 deg) caused thresholds to be unequal.

Among other things, the results of this study have demonstrated the versatility of the test system and have shown that bilateral thresholds of stereopsis are often unequal. In addition, it has been demonstrated that estimates of stereoacuity are more precise when the bilateral nature of the data is recognised. It has also been shown that zero disparity is not different from other disparities. In some instances, it is above the threshold of stereopsis (subject N.T., Table 1).

Aniseikonia was calculated from threshold asymmetries with the assumption that retinal image size differences caused these asymmetries. Nothing in this study has demonstrated that assumption to be true. To demonstrate this, another study is required in which retinal image size differences are induced artificially by means of afocal size lenses. Aniseikonia will have been found measurable, if threshold inequalities vary in accordance with apparent rotations of the frontoparallel plane.

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