RETINAL IMAGE SIZES*† A PILOT STUDY IN STRABISMUS

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As a result of investigations into anisometropia and its importance in strabismus (Phillips, 1959, 1966), the possibility was suggested that, in spite of the presence of equal refraction in the two eyes, unequal axial lengths might exist and give rise to optical aniseikonia; if the inequality in size of the retinal images were great enough, the patient might adopt squinting as a means of escape from his difficulty in achieving binocular single vision.

Hughes (1935, 1937) suggested that aniseikonia might be a factor in the cause of concomitant strabismus in spite of symmetrical refraction. Bannon (1952) found that approximately 3 per cent. of his series had an aniseikonia that was clinically significant, but Alajmo (1954), who found that 5 per cent. of 327 subjects had some aniseikonia, considered its clinical significance to be slight or negligible because it was equally frequent in orthophoric and heterophoric subjects. Toselli (1953) reached the same negative conclusion from a study of 100 orthophoric, emmetropic, and isometropic patients. Hosaka (1954) found no evidence that asthenopia was caused by aniseikonia though in some cases the possibility might exist. A case report (Dowler, 1955) records the value of isekonic lenses in preventing the recurrence of amblyopia in an anisometropic child. Berens and Bannon (1963) found a greater frequency of aniseikonia in 166 asthenopes than in 140 non-asthenopes, and suggested that the condition should be considered as a possible factor which disturbs binocular vision.

Gillott (1956a, b, 1957) has studied the problem of aniseikonia in detail and provides many references to the literature. Although the commonest cause of aniseikonic errors was found to be anisometropic refractive error (Gillott, 1957), 40 per cent. of refractively emmetropic subjects had errors in size of more than 0.8 per cent., and significant aniseikonic errors with suppression were found in two of seventeen emmetropic subjects. Normal binocular single vision was not present if the difference in size between the retinal images was 3 per cent. or more in any one meridian, and at a level of discrepancy of 1 to 3 per cent. visual disturbance or symptoms might be found. As possible causes of aniseikonia in bilaterally emmetropic subjects, differences in axial lengths or in concentration of retinal receptors were suggested.

Material

From the records of the Orthoptic Department at Moorfields Eye Hospital, High Holborn Branch, patients were selected with the following characteristics:

- (a) homes within fairly easy reach of central London;

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- (b) presence of squint, some manifest and some latent;
- (c) either equal refraction in the two eyes or an inequality up to a maximum of 0.5 D sph. or its equivalent (a cylinder being regarded as equivalent to half its power in terms of sphere).

A few of the patients who were asked to attend for examination were unable to do so; in some who did attend, phakometry was found to be impossible because of difficulty in co-operation on account of age, etc. In a very few the photographs were not good enough to allow satisfactory measurements.

Methods

In patients without binocular vision, an objective method is required for estimating the sizes of retinal images. From a knowledge of axial length of the eye and of the powers of the refracting surfaces with the distances between them, it is possible to calculate fairly accurately the size of retinal image produced by an arbitrary object at an arbitrary distance from the eye. (Because of difficulty in applying the method to children, ultrasonography was not used.)

Refraction was done 30 min. after the instillation of cycloplegic drops, gutt. Mydrilate (cyclopentolate). By ophthalmometry and phakometry, measurements were made of corneal curvature, depth of anterior chamber, thickness of crystalline lens, and curvature of the lens surfaces, from which data the total power of the eye was calculated. The refractive indices of the media are assumed to be 1.333 for aqueous and vitreous and 1.416 for crystalline lens. Details of the methods of phakometry are given by Sorsby, Benjamin, Davey, Sheridan, and Tanner (1957) and Sorsby, Benjamin, Sheridan, Stone, and Leary (1961).

The refractive error of an eye being known, it is possible from keratometry, phakometry, etc., to calculate its axial length, *i.e.* in this context the distance between the anterior surface of the cornea and the level of tissue in the region of the macula responsible for the red reflex which is considered to be approximately the level of the rods and cones: at least it is probably a standard level for all cases.

For each eye of each patient a calculation was done in order to estimate the height of the images in focus on the retinae. The refraction was converted to its equivalent air distance by the use of reciprocals, and from this number the vertex distance was then subtracted. The new vergence was obtained using the reciprocal tables once more. To this the corneal power was then added to give L'_1 and the reciprocal was taken of the sum. The "reduced" depth of the anterior chamber, obtained by dividing the measured value by the refractive index of aqueous humour (assumed to be 1.333), was subtracted from this value to give a resultant, the reciprocal of which was the reduced vergence at the first surface of the lens (L_2). The power at this surface (F_3) was added to give L'_2 and from its reciprocal was subtracted the reduced lens thickness (obtained by dividing the measured value by the refractive index of the lens, assumed to be 1.416) to give L_3 . The reciprocal of L_3 was added to the posterior lens power (F_4) to give the reduced vergence of the light reaching the retina (L'_3). To obtain the total power of the eye, the appropriate values were substituted in the formula:

$$F = \frac{L'_1 \cdot L'_2 \cdot L'_3}{L_2 \cdot L_3}$$

The height of the retinal image can then be determined (for a standard arbitrary angle in each case) by multiplying the tangent of the angle by the focal length of the eye.

Results

These are presented in the Table (opposite).

Discussion

Only a small number of cases was examined, partly because it was decided not to ask patients to travel long distances and also because of the exclusion of some inaccurate observations which were due to difficulty in patient co-operation, but mainly because of the

TABLE
DIFFERENCES IN SIZES OF RIGHT AND LEFT RETINAL IMAGES

Eleven patients with latent squint
and some binocular vision

Patient No.	Sex	Age (yrs)	Image Height		Per cent. Difference
			Right	Left	
1	F	5 $\frac{1}{3}$	1.406	1.405	0.071
2	M	5 $\frac{1}{3}$	1.418	1.419	0.070
3	M	5 $\frac{5}{12}$	1.393	1.415	1.555
4	F	4 $\frac{4}{12}$	1.498	1.451	2.804
5	F	6 $\frac{8}{12}$	1.573	1.526	2.988
6	F	7	1.469	1.484	1.011
7	M	9 $\frac{1}{12}$	1.486	1.472	0.942
8	M	14	1.445	1.441	0.277
9	M	21	1.356	1.388	2.3
10	F	27	1.537	1.538	0.1
11	F	22	1.447	1.435	0.8

Six patients with manifest squint
and without binocular single vision

Patient No.	Sex	Age (yrs)	Image Height		Per cent. Difference
			Right	Left	
12	M	5 $\frac{7}{12}$	1.467	1.441	1.8
13	M	5 $\frac{8}{12}$	1.402	1.418	1.2
14	F	10	1.486	1.480	0.3
15	F	6	1.431	1.442	0.7
16	M	6	1.430	1.463	2.3
17	F	27	1.529	1.546	1.2

The statistical analysis excluded the adult cases. A comparison was made between the two groups in the Table (with latent squint versus manifest squint) in respect of the percentage differences in height of images between R and L eyes ($\text{larger} \div \text{smaller} \times 100$); the Mann-Whitney U test was used and revealed no significant difference ($P = 0.362$).

departure from London of Mr. G. A. Leary and the author. The negative result obtained on the patients so far examined does not seem to warrant increasing the size of the samples.

It would be possible to retain the "optical aniseikonia" hypothesis in spite of the above negative findings on two grounds. One possibility is that unequal growth of the two eyes caused aniseikonia, with or without anisometropia, when the squint started but that subsequently the inequality disappeared. A second possibility is that the sensory pathways are in some way abnormal, including an unequal concentration of cones in the two eyes, so that "aniseikonia" exists at a higher level than the optical one. However, these are to be regarded as very unlikely explanations for the difficult problem presented by the cause of strabismus.

Summary

Anisometropia is probably a factor in the causation of at least some cases of squint. Optical aniseikonia might exist in spite of isometropia or iso-ametropia, if eyeballs had differing axial lengths but appropriately differing lens systems to compensate. Two short series of patients ((a) with latent squint and (b) with manifest squint) were examined by phakometry, keratometry, etc., and calculations were made to determine the heights of optical images on their retinæ; the percentage difference between right and left eyes was calculated for each patient in the two groups. The percentage differences in the two groups were compared and no support was found for the hypothesis that the two groups belong to different parent populations, indicating rejection of the hypothesis on the evidence obtained. It seems unlikely, though possible, that optical aniseikonia, with or without anisometropia, precipitated the onset of squint and later disappeared.

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