SUBNORMAL BINOCULAR VISION WITH SPECIAL REFERENCE TO PERIPHERAL FUSION*

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IN some cases of unilateral convergent squint the vision of the squinting eye may be suppressed to such an extent that eventually the affected eye appears to be almost blind through suppression-amblyopia, and the patient appears to rely almost entirely on one eye. On the other hand, in the case of a freely alternating squint, the visual acuity of each eye may remain normal throughout life, the patient appearing to change fixation from one eye to the other (depending upon the position of the object of attention) and to suppress to a greater or less extent the central area of the field of vision of the eye which is not being employed for fixation.

In certain cases of convergent squint, however, whether unilateral or alternating, if appropriate treatment is carried out, restoration of the full function of normal binocular vision occurs. In general, it is true to say that the later the onset of a squint and the sooner corrective treatment is undertaken the better the prognosis.

In order to develop normal binocular function in a patient whose binocular reflexes are defective, it is generally held that the first step in the treatment of the squint is to ensure that the visual acuity of the two eyes is equal. Thus occlusion of the fixing eye may be necessary as a preliminary measure. It is however important to realize that equal visual acuity is by no means essential for the enjoyment of binocular single vision if the binocular reflexes have undergone normal early development, as Cases 1 and 2 illustrate:

Case 1, a girl aged 6, had visual acuity as follows:

$$\begin{array}{rcl} \text{Right eye: with glasses} & \frac{-3 \text{ D sph.}}{-6 \text{ D cyl. axis } 150^\circ} & = 6/60 \text{ and J12.} \\ \text{Left eye:} & 6/5 \text{ and J1.} & \end{array}$$

The visual defect of the right eye was due to a partially cataractous and congenitally subluxated lens.

The Maddox rod test showed orthophoria and the cover test showed the presence of binocular fixation. Examination on the major amblyoscope demonstrated the presence of fusion and stereoscopic vision.

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Case 2, a girl aged 10, had visual acuity as follows:

$$\begin{array}{l} \text{Right eye: with glasses } \frac{-0.25 \text{ D sph.}}{-0.50 \text{ D cyl. axis } 90^\circ} = 6/6 \text{ and J1.} \\ \text{Left eye: } 1/60 \text{ not improved with glasses.} \end{array}$$

The visual defect of the left eye was due to a patch of myelinated nerve fibres extending from the optic disc to the macular region and causing a large central scotoma. Orthophoria was present as shown by the Maddox rod test and the cover test showed the presence of binocular fixation. Examination on the major amblyoscope demonstrated the presence of fusion and stereoscopic vision.

On the other hand, there are many cases of squint in which, in spite of adequate surgical and orthoptic treatment producing equal vision in each eye and restoring approximate parallelism of the visual axes, binocular single vision has not been restored in the accepted sense; and yet in many of these cases a fairly strong "binocular union" appears to have developed so that the patient apparently employs his two eyes together with obvious benefit to his visual judgement. Yet examination on the major amblyoscope may show gross central suppression, sometimes absence of fusion, and invariably defective stereopsis.

It has been customary to regard such cases as "non-binocular" and to assess as satisfactory only those in which normal binocular functions can be demonstrated on a major amblyoscope or similar apparatus; but many patients who fail to reach the accepted standard of normal binocularity appear to acquire sufficient binocular function after operation to make them more efficient at the performance of certain visual tasks, including the ability to play fast ball games with skill (*e.g.* Case 3).

Case 3, a boy aged 10, had an alternating convergent squint with visual acuity 6/6 in each eye and an angle of deviation of $+45^\circ$ with gross alternating suppression. Six months after operation (right medial rectus recession and right lateral rectus resection) his angle of deviation was 0° L/R 2° with normal retinal correspondence but no true fusion. He was now playing games at school with considerable skill, whereas previously his ability in that direction had been poor.

In some cases the presence of a fixed anomalous retinal correspondence may explain the patient's apparent ability to employ his two eyes together, but these form a small percentage of the group outlined above. The features of anomalous retinal correspondence are well known, and will not be dealt with in this article.

The group of cases in which we have been particularly interested are those in which there is good vision in each eye (the "better-seeing eye" having a degree of acuity not more than 2 or 3 lines better than the other eye as measured with Snellen's test types at 6 m.), normal retinal correspondence, symmetrical binocular movements, an angle of deviation between 0° and 10° as measured on the major amblyoscope, simultaneous perception, and usually the ability to "join" fusion slides. In these cases there is no subsequent deterioration in the state of the binocular functions, the angle of deviation appears to remain stationary, and there appears to be some form

of "binocular union" between the two eyes. Most of the patients had reached this stage as a result of operation, correction of the refractive error, or both. In some cases orthoptic treatment and also occlusion had been necessary.

Burian (1947) has suggested that in these cases a fusion mechanism unites the peripheral fields of the retinae.

The recognition of this group of cases is important, for time spent in striving to achieve normal binocular functions by orthoptic treatment appears to be wasted. A good prognosis can be given as far as the cosmetic appearance is concerned, and, moreover, it seems that subsequent consecutive divergence is unlikely to occur. Douglas (1952) questioned whether patients with convergent squint in whom the full function of binocular vision has been restored have any real advantage functionally over those in whom only a satisfactory cosmetic result has been achieved. In raising such a question it should be borne in mind that the so-called "cosmetically satisfactory cases" are not all of the same type. For instance, a review of two hundred consecutive cases of non-paralytic convergent strabismus treated at this hospital during the period 1950 to 1952 showed that they could be divided into three well-defined groups:

- (1) *Functionally Satisfactory* (patients in whom binocular single vision had been fully restored) ... 39 (20 per cent.)
- (2) *Cosmetically Satisfactory*
 - (a) Subnormal binocular vision (equal or nearly equal visual acuity, normal retinal correspondence, and doubtful fusion) ... 88 (44 per cent.)
 - (b) Grossly defective binocular vision (intractable amblyopia, abnormal and lack of normal, retinal correspondence) ... 73 (36 per cent.)

THREE-PIN TEST FOR STEREOPSIS.—Assuming that patients comprising Group 2a would have better visual judgement than those in Group 2b, twenty patients from each of these two groups were examined on the Livingston rotating depth perception apparatus.

A control series of twenty patients with binocular single vision from Group 1 was also examined for comparison.

This apparatus, described by Livingston (1942), has a working distance of 15 ft. from the head-rest to the centre of the recording system. The subject looks through an aperture at three black pins which can be rotated through a horizontal axis. The pins are contained in a compartment in which the illumination is evenly distributed. Thus such factors as perspective, shadows, etc., can give no useful help to the patient. This compartment is connected to the head rest by means of a metal rod supported by vertical uprights, and the rod is connected to a wheel accessible to the patient. By turning the wheel the patient can alter the position of the centre pin.

To carry out the test, the aperture is first closed, and the examiner sets the middle pin so that it stands in front of or behind the two stationary pins. When the aperture is opened, the subject is instructed to position the centre pin (by turning the wheel) so that all three appear to be in the same horizontal plane. The performance of the subject in aligning the centre pin is recorded on a self-recording chart.

The method of carrying out the test was as follows:

(1) Each patient was given five tests to position the middle pin (the pins being used in the vertical position only).

(2) The time the patient took to adjust the middle pin was recorded in each test.

(3) The "error" in each instance was recorded (*i.e.* the distance of the middle pin from its correct position.)

The results are shown in Table I.

TABLE I

Group	Number of Patients	Average error (cm.)	Average Time for Adjustment (sec.)
1 Binocular single vision	20	0.76	12.56
2(a) "Subnormal" binocular vision	20	10.40	22.46
2(b) Defective binocular vision ...	20	7.07	23.2

To determine the point at which the middle pin was level with the other two, patients with defective binocular vision noticed that the middle pin appeared to move to one side as it was pushed backwards and to the other side as it was brought forward in front of the stationary pins. Thus the pins were judged to be level when the distances between all three appeared to be the same. Fig. 1 shows how the pins appear to a patient who has a right convergent squint.

Thus the alignment of the pins was carried out by using one eye only—the dominant or fixing eye. This probably explains why patients with a definite squint and defective binocular vision (especially those in which one eye was usually preferred for fixation) were somewhat more accurate in aligning the pins than patients who had subnormal binocular vision.

In addition to the test already mentioned ten of the patients in Group 2b were allowed to move their heads to see if the use of parallax improved their visual judgement, but no improvement resulted.

Also ten patients in Group 1 (binocular single vision) were tested with one eye covered. This gave similar results to those obtained in Group 2b.

An analysis was also made of the position of the middle pin as determined by each patient. For this examination the patients were divided into four groups:

- I. Those with binocular single vision.
- II. Those with normal retinal correspondence.
- III. Those with lack of normal retinal correspondence.
- IV. Those with abnormal retinal correspondence.

FIG. 1.—Appearance of pins to a patient with right convergent squint.

With the exception of patients with binocular single vision and those with abnormal retinal correspondence the majority positioned the middle pin too far forwards (Table II).

TABLE II

Group					Percentage		
					0	+	—
I	Binocular single vision	...	...	...	15	23	62
II	Normal retinal correspondence	...	...	...		78	22
III	Lack of normal retinal correspondence	...	...	...		72	28
IV	Abnormal retinal correspondence	...	...	...		15	85

Peripheral Fusion

The significance of peripheral fusion was first brought to the notice of one of us (T.K.L.) in 1940 in the case of a soldier who had received a closed head injury and who subsequently complained of diplopia. As the visual acuity of his right eye was reduced to 6/60 and J12 (due to a traumatic macular lesion with a resulting central scotoma) whereas that of his left eye was 6/5 and J1, his medical officer had suspected that the diplopia was spurious. However, examination showed the presence of a right superior oblique palsy. The presence of fusion (using large test slides) could be demonstrated at 0° R/L 10° on the major amblyoscope. After restoration of the visual axes to parallelism by means of operation (recession left inferior rectus) the diplopia disappeared and binocular single vision was restored, although the visual acuity of the affected eye remained 6/60 and J12 and the scotoma was unchanged.

Evidence that peripheral fusion has a stabilizing influence upon binocular vision in the normal subject is sometimes afforded by patients who suffer from progressive loss of the temporal field of each eye, so that finally practically no part of the total visual field is common to the two eyes. In such circumstances if the patient happens to suffer from heterophoria he may experience diplopia especially when viewing distant objects.

Case 4, a man aged 50, had a bitemporal hemianopia due to a chiasmal lesion (Fig. 2, opposite). Apart from the defective vision the patient complained of diplopia for distant objects. On investigation this was found to be crossed and with a slight vertical element, which was consistent with the fact that the Maddox rod test (at 6 metres) showed 7° of exophoria and 1.5° of right hyperphoria. There was no demonstrable defect of ocular movement and the diplopia was approximately the same in extent, except for physiological variations, in the various cardinal directions of the gaze. There was no diplopia when viewing near objects and convergence was normal. His visual acuity was 6/6 in each eye.

The possibility that the existence of peripheral fusion may enable a patient to maintain parallelism of the visual axes in spite of central suppression, may account for the infrequency of consecutive divergence in certain cases of squint.

FIG. 2.—Bitemporal hemianopic field defects due to a lesion of the optic chiasma.

Posner and Schlossmann (1951) state that peripheral vision being orientational in function and more primitive in origin than central vision, it is more stable and more likely to remain intact after central suppression has developed to a relatively high degree.

Panum (1858) first established that images falling on slightly disparate points of the retinae can be fused, and that these areas of fusion, now known as Panum's areas, increase in size towards the extreme periphery. It would seem feasible therefore, that in cases of strabismus of small degree in which a central suppression scotoma exists, fusion of images formed on disparate points of the periphery may occur provided the images fall within the limits of Panum's fusional areas.

Burian (1947) discovered that the displacement of images stimulating corresponding points in an area around 12° from the macula can cause disruption of fused macular images. In a number of tests, he established that peripheral fusion was present in patients with a central sensory disturbance if stimulation of the central area was avoided, while patients with no central sensory disturbance could not appreciate peripheral fusion stimuli, but either suppressed one image or experienced diplopia.

These views are confirmed by Ogle (1950), whose experiments revealed that peripheral stimuli subtending a visual angle of 0.5° at an angular distance of 12° from the fovea produced definite fusional movements.

At a distance of 5° from the macula, visual acuity decreases to 6/60 or less. With the constant demands of central vision, peripheral fusion can only exist in a rudimentary form, but it is now believed that its presence may be of some value in certain cases of strabismus in which surgical or other treatment has failed to achieve the accurate alignment of the visual axes necessary for the development of bi-macular correspondence, or in which in spite of alignment of the visual axes, bi-foveal fixation has not developed on account of central suppression.

The investigations carried out by Burian and Ogle were based on the theory

that peripheral fusion can cause disruption of central fusion, peripheral fusion being, as it were, stronger than central fusion. The test described below which has been carried out in our cases is based on the same principle:

SCREEN TEST FOR PERIPHERAL FUSION.—The patient sits in a dark room 5 metres from a screen which is marked out by a series of vertical lines placed at 10-cm. intervals on each side of the fixation point. The patient's eyes are dissociated by means of polaroid spectacles, the plane of the polaroid being horizontal in front of one eye and vertical in front of the other.

Two squares of equal brightness, subtending a visual angle of 0.5° , are projected on to the centre of the screen, one square being bisected by a horizontal line and the other by a vertical line. These squares are polarized to correspond with the patient's glasses, so that he sees the square with the horizontal line with one eye and the square with the vertical line with the other eye. The lines in the squares act as controls, so that when correctly fused they should appear as a cross (Fig. 3).

The position of the squares is adjusted according to the angle of deviation, and the patient is instructed to fix on the fused square.

FIG. 3.—Screen test for peripheral fusion.

P.H. Polaroid horizontal
P.V. Polaroid vertical

M, M₁ Maculae
A, A₁ Corresponding points

The peripheral targets consist of two similar squares polarized in the same manner as the central targets, and containing similar controls. These are projected on to the screen 25° from the fixation point, and positioned so that the images fall on corresponding points of the periphery of the patient's retinae (Fig. 3). These squares are moved slowly inwards towards the area of central vision until the

patient observes that they are fused. They are then separated until disparity becomes too great for fusion to be maintained and the patient notices diplopia or suppression of the peripheral and/or central targets. This procedure is repeated until the peripheral squares have been brought into the area of central vision.

Three sets of peripheral targets were used, subtending a visual angle of 10° , 5° , and 2.5° respectively.

By way of variation, the test was also carried out with the patient wearing red and green goggles for dissociation instead of polaroid spectacles and with red and green filters placed in front of the slides instead of the polaroid material. The patient therefore saw the red square (containing the vertical line) with one eye, and the green square (containing the horizontal line) with the other eye.

In cases of amblyopia, the beam of the projectors containing the slides seen by the non-amblyopic eye is dimmed so that the squares appear to the patient to be of equal brightness.

The disadvantages of these methods are obvious because, the test being entirely subjective, the patient must be of an age to understand what is required. Our results have been inconsistent and depend to a large extent on the patient's alertness, powers of concentration, and ability to comment on his own observations.

Owing to the variability of the results obtained when examining patients with convergent strabismus, it was thought advisable to find out the reaction to these tests of subjects whose binocular vision was normal. Of a total of seventy patients examined, fifty had binocular single vision, and twenty had a convergent strabismus of less than 10° .

Results.—The distance from the macula at which the patient first noticed peripheral fusion varied according to the size of the peripheral squares. In most cases, fusion first became apparent at an angular distance of about 9° , 12° , and 15° from the macula with peripheral squares subtending a visual angle of 2.5° , 5° , and 10° respectively (Table III, overleaf).

In cases in which peripheral fusion could be demonstrated, there was generally some intermittent peripheral suppression, *i.e.* the patient noticed the disappearance of one or other control from time to time. In some cases, however, alternating suppression was so rapid that fusion of the squares was rarely noticed, a situation best described by one patient's remark:

I can see one square, but only one line at a time, sometimes the vertical and sometimes the horizontal. Occasionally I see a cross in the square, but only for a moment.

Suppression tended to become less intense as the peripheral squares approached the area of central vision; this was not invariable, for in a few cases the situation was reversed and suppression became more intense in the central area.

The incidence and intensity of suppression in the periphery did not appear to vary according to the dimensions of the peripheral squares (Table III, *a*, *b*).

In thirteen patients with convergent strabismus, the angle of deviation increased under cover, and, although on removing the cover there appeared to be a recovery to parallelism of the visual axes and binocular fixation, the presence of fusion could not be demonstrated on the major amblyoscope (Table III, *c*).

It is interesting to note the response to peripheral fusion stimuli in cases of lack of normal retinal correspondence. Here, difficulty arose over the correct positioning of the peripheral squares, since subjective bi-macular superimposition was not possible, but in five of a total of twelve cases, peripheral fusion could be demon-

TABLE III
RESULTS OF SCREEN TEST

Patients	Test				Polaroid			Red and Green		
	Visual Angle subtended by Peripheral Squares (°)				10	5	2.5	10	5	2.5
(a) 50 with Binocular Single Vision	Peripheral Fusion	Without suppression			11	13	10	14	10	9
		With intermittent suppression ...			33	31	29	19	20	19
		With momentary suppression only			5	5	11	15	16	14
		None ...			1	1	—	2	4	8
	Total	...	...	...	50	50	50	50	50	50
(b) 20 with Convergent Strabismus (average angle of deviation on major amblyoscope 5°)	Peripheral Fusion	Without suppression			4	4	1	2	1	1
		With intermittent suppression ...			10	9	8	5	5	5
		With momentary suppression only			1	1	2	1	1	2
		None ...			5	6	9	12	13	12
	Total	...	...	...	20	20	20	20	20	20
(c) 13 with "Binocular Fixation" but no Fusion	Peripheral Fusion	Without suppression			4	4	1	1	1	1
		With intermittent suppression ...			6	5	4	4	3	3
		With momentary suppression only			1	1	2	1	1	2
		None ...			2	3	6	7	8	7
	Total	...	...	...	13	13	13	13	13	13

strated, although its presence was fleeting. In all these cases, the deviation was manifest only on dissociation by the cover test, with an apparent fusional effort to regain binocular fixation on removal of the cover. This recovery also occurred in the four cases in which peripheral fusion was not demonstrable.

Response to Central Targets.—Since, according to Burian and Ogle, peripheral fusion can cause disruption of central fusion, it was to be expected that, in the event of peripheral fusion being maintained, central diplopia would occur on separation of the peripheral squares. But of the fifty patients with binocular single vision, central diplopia occurred in only ten with the polaroid test, and in only eighteen with the red and green test. Diplopia was momentary, central fusion being re-established immediately the peripheral squares were re-positioned so that the images fell on corresponding points of the periphery of the retina. Of the twenty patients with convergent squint, central diplopia occurred in only one with the polaroid test and in two with the red and green test.

Amplitude.—It was not expected that peripheral fusion amplitude would amount to more than a few degrees, *i.e.* according to the dimensions of Panum's area where

the separation of the peripheral squares occurred. Of the fifty patients with binocular single vision, peripheral fusion amplitude varying between 2° and 6° was elicited in twelve, whereas of the remaining 38 patients, 32 noticed peripheral diplopia immediately on separation of the peripheral squares and six suppressed the vision of one eye.

Of the twenty patients with convergent squint, peripheral fusion amplitude was elicited in three, immediate peripheral diplopia in eight, and suppression in eleven.

It would seem, therefore, that despite varied results due to the difficulties involved in testing in the periphery, peripheral fusion can be demonstrated in patients with normal binocular single vision, and also in patients with convergent strabismus with central suppression, although in the latter peripheral suppression may be more intense.

STEREOSCOPE TEST FOR PERIPHERAL FUSION.—Further investigation of peripheral fusion has been carried out using a stereoscope of the Pigeon-Cantonnet type, as it was thought that such a method would more closely represent the state of affairs normally obtaining in the binocular panorama.

The stereoscope used consisted of an enlarged version of the Pigeon-Cantonnet instrument having a black wooden base divided by a septum on which was mounted a mirror (Fig. 4). The septum measured 33 cm. making a working distance of one-third of a metre. Thus an apparent displacement of an object by 1 cm. represented a deviation of three prism dioptres. The base of the stereoscope was marked in centimetres so that the angle of deviation and range of fusion could be measured in prism dioptres. The instrument was at first used with the flaps of the base forming an angle of 130° , this angle being bisected by the septum. It was found, however, that with the flaps in this position, a notable reduction of the peripheral field occurred, and the small difference in the size of the images caused by using the instrument with the base in a flat position was negligible.

FIG. 4.—Stereoscope test for peripheral fusion.

Method of Testing.—Two fusible pictures are placed on either side of the septum. The patient fixes the object on the non-mirror side; the object on the mirror side is projected to the opposite side so that the two images can be superimposed. The pictures consist of two houses (Fig. 5) subtending a visual angle of 25° , with controls (chimneys and cross lines on windows) at 10° and 23° from the fixation point (the door knob). While maintaining fixation on the door knob, the patient comments on suppression or diplopia experienced in the periphery. When the patient has positioned the two pictures so that they appear fused, the picture on the mirror side of the septum can be moved towards or away from the septum causing divergence or convergence, and the fusion range can be measured on the scale.

FIG. 5.—Pictures used in stereoscope test for peripheral fusion.

Investigation of peripheral fusion by the stereoscope differs from that by the screen test in that here the entire picture is separated, whereas in the screen test the peripheral targets are separated independently of the central targets, so that one set of corresponding points opposes the other, and either peripheral or central diplopia must inevitably occur. Thus, with this test there is no means of determining whether peripheral fusion can cause disruption of central fusion, and the examination must be regarded *merely as a means of establishing that peripheral fusion can be demonstrated*.

Fifty patients were tested with the stereoscope. Twenty of these had binocular single vision, and the results corresponded roughly with those of the screen test (*i.e.* all could obtain peripheral fusion), but in most cases there was intermittent suppression of the peripheral controls.

The remaining thirty patients were divided into three groups of ten:

(1) Ten who, like the thirteen mentioned in the screen test, were unable to maintain fusion on the major amblyoscope, but appeared to have binocular fixation when examined by the cover test.

Peripheral fusion could be demonstrated in eight cases. (The two in which peripheral

fusion could not be demonstrated are interesting in that they probably indicate that the test is too sensitive).

(2) Ten patients with fixation disparity*, *i.e.* a condition of binocular single vision in the absence of bi-foveal fixation.

As was to be expected, peripheral fusion could be demonstrated in all the ten patients when tested with the stereoscope. There was intermittent peripheral suppression in most cases, approximately in the same proportion as that found in the patients with binocular single vision. Tests with the special stereoscope revealed central suppression to a greater extent than could be demonstrated by the usual test on the major amblyoscope, but the range of fusion averaged about 15° with both tests.

Jampolsky (1951) believes that fixation disparity is due to abnormal retinal correspondence with anomalous peripheral fusion. Swan (1950), on the other hand, states that in amblyopia Panum's area may become enlarged, so that with a disparity of 5°, binocular single vision may be maintained.

(3) Ten patients with convergent squint, who had been treated surgically and whose post-operative condition suggested that the spontaneous development of peripheral fusion, or possibly the spontaneous development of binocular single vision, was likely. All these patients had been discharged with a manifest angle of deviation of less than 5° horizontally, and less than 2△ vertically as measured on the major amblyoscope, equal or nearly equal visual acuity, and normal retinal correspondence, but no fusion.

The average age at onset of squint was 2½ years, and none of the patients had been operated upon before the age of 5 years. On re-examination, after a minimum interval of 3 years, peripheral fusion could be demonstrated in all cases, and one patient had developed binocular single vision with intermittent deviation and a good range of fusion; a second patient (Case 5) had developed fixation disparity in which the angle of deviation was partly esotropic and partly hypertropic.

Case 5, a boy aged 5, had a right convergent squint first noticed by the parents when he was 3 years old.

Visual Acuity (with glasses).—Right eye $\frac{+3.75 \text{ D sph.}}{+1.50 \text{ D cyl. axis } 90^\circ} = 6/36$
Left eye $\frac{+1.25 \text{ D sph.}}{+0.75 \text{ D cyl. axis } 90^\circ} = 6/9$

Major Amblyoscope.—Angle (with glasses) +25° R/L 25△ to 40 (objective measurements).

Pre-operative Treatment.—Occlusion of the left eye resulting in equal vision, *i.e.* vision with glasses, right eye 6/9, left eye 6/9.

Operation.—At the age of 9 years (Right inferior oblique myectomy. Right medial rectus recession).

A course of orthoptic treatment was given post-operatively.

Visual Acuity (with glasses).—Right eye 6/6 pt. Left eye 6/6.

Cover Test.—Small degree of right convergent strabismus for near and for distance, with slight right hypertropia.

Major Amblyoscope.—Angle (with glasses) +1°, R/L 2△.

Simultaneous macular perception was present with foveal suppression of the right eye. No fusion. No stereoscopic vision.

At the age of 12 years he was re-examined:

Visual Acuity (with glasses).—Right eye 6/9 pt. Left eye 6/5.

Cover Test.—Right eye becomes hypertropic under cover.

Major Amblyoscope.—Angle (with glasses) 0° R/L 2△. No change in the binocular vision.

*Since controversy exists over the characteristics of fixation disparity in strabismus, these are outlined below:

(a) Constant slight unocular esotropia (the angle of deviation may increase under cover).
(b) Amblyopia of the esotropic eye amounting to not more than three lines difference between the squinting and non-squinting eye, the visual acuity for near being usually equal and normal in each eye.
(c) Angle of deviation 5° or less as measured on the major amblyoscope with an angle of anomaly of 3° or less.
(d) Fusion, with a fusional range of about 15°.
(e) Appreciation of physiological diplopia in most cases.
(f) Stereopsis in some cases.

He was unable to appreciate physiological diplopia.

Examination on the large Pigeon-Cantonnnet stereoscope showed that there was considerable right central suppression, but he could superimpose the pictures and had developed fusion with a horizontal range of about 10°.

When tested on the Livingston rotating depth perception apparatus, he positioned the middle pin within 7.5 cm. of zero, averaging 3.2 cm.

This phenomenon occurred in only one case in the group of ten. In the remaining patients, the angle of deviation and the state of binocular vision were approximately the same as at the previous examination 3 years before.

Conclusion

Although many patients with convergent squint who have normal visual acuity in each eye do not attain normal binocular function after treatment by operation and/or orthoptic treatment (and occlusion if indicated) a considerable number of these cases show an improvement of binocular function which gives rise to a condition of sub-normal binocular vision. In these cases consecutive divergence is rare. It appears likely that a "binocular union" is brought about by a fusion mechanism which links the visual fields of the two eyes in the area of "field overlap".

Peripheral fusion can be demonstrated in these cases, but as the tests are subjective in nature the results are varied and somewhat inconclusive.

Ideally such tests should reproduce as nearly as possible the natural conditions of life. This lack of normality and the difficulty which patients, particularly children, experienced in commenting accurately on their own observations, may account for our failure to demonstrate peripheral fusion in all cases in which it may have been present. The screen test in particular presents difficulties, because isolated peripheral targets are presented to the eyes without the background which makes up the normal panorama of vision.

That peripheral fusion exists and plays some part in the establishment of an unrefined form of binocular single vision is evident from the clinical findings in some cases of squint. Whether the stabilizing effects of peripheral fusion can have lasting results, or whether it can eventually lead (in some cases) to the development of normal fusion and stereoscopic vision, remains to be seen when numerous cases have been followed up for many years.

Summary

An analysis has been made of the state of binocular vision of 200 consecutive and unselected patients with convergent squint treated during the period 1950/54 by operation and/or orthoptic treatment and occlusion. The patients were divided into three groups:

- (1) Those with binocular single vision.
- (2a) Those with subnormal binocular vision.
- (2b) Those with grossly defective binocular vision.

To discover whether visual judgement was better in patients with "subnormal binocular vision" than in those with a gross defect of binocular

vision, twenty patients from each group were examined on the Livingston rotating depth perception apparatus. All the patients in Groups 2a and 2b gave a poor performance as compared with those in Group 1, and, if anything, the performance of those in Group 2a was slightly worse than that of those in Group 2b.

A series of the patients with subnormal binocular vision was examined to determine the presence of peripheral fusion.

Twenty patients with subnormal binocular vision (and fifty controls with binocular single vision) were examined by the screen test, and thirty patients with subnormal binocular vision (and twenty controls with binocular single vision) were examined by the stereoscopic test.

The results are varied and inconclusive owing to the subjective nature of the tests, but peripheral fusion with a varying intensity of peripheral suppression could be demonstrated in all cases in which normal retinal correspondence was present.

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