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MODIFIED MAJOR AMBLYOSCOPE*

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IN the assessment of a patient with comitant strabismus, it is essential to determine the angle between the fixation axes ("objective" angle of squint), the state of the retinal correspondences, the angle of binocular projection ("subjective" angle of squint), and the grade of binocular vision. All methods of determining these factors have their limitations.

Angle between Fixation Axes ("Objective" Angle of Squint)

The most commonly used methods of determining this angle depend on abolishing any ocular movement when fixation changes from one eye to the other. In using the major amblyoscope for this purpose, a fixation object is supplied alternately to each eye, the arms of the instrument being adjusted until no ocular movement takes place. There is thus complete dissociation between the eyes, and the conditions are far from being those obtaining in the normal use of the eyes; moreover, even though the images are optically at infinity, they often appear to be suspended in space at a short distance from the observer. In using Duane's parallax test for measuring the angle, alternate occlusion is again employed, with a prism in front of one or both eyes, so that again the conditions are unusual. It is not surprising that the angle measured by these methods often differs from that suggested by the patient's appearance, by the position of the corneal reflexes, and by the behaviour on cover test.

Methods depending on the corneal reflex may be carried out under more normal conditions of viewing, but are in general either inaccurate or clumsy, and require an independent measurement of the angle gamma. A method which removes some of these disadvantages has been described by Graham and Naylor (1957).

State of the Retinal Correspondences

The three most useful methods of investigating the state of the correspondences (Duke-Elder, 1949) are the after-image test, the congruence test of Tschermak, and the major amblyoscope. The conditions of viewing differ

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greatly from test to test, and in none do they bear a direct relationship to everyday life, so that the state of retinal correspondence elicited may vary from test to test in the same patient, and also from time to time.

Angle of Binocular Projection ("Subjective" Angle of Squint)

If the retinal correspondences are normal, this angle is the same as the angle between the fixation axes; if the retinal correspondences are abnormal, the difference between the two angles is the angle of anomaly. The angle of binocular projection can be measured in several ways, all of which depend on dissociating the images of the two eyes; this may be done by excluding the field of one eye from the other (mechanically as in cover tests, Maddox Wing test, major amblyoscope, etc.; by colour as in the red-green tests; or by polarized light), by displacing one image and so inducing diplopia (*e.g.* prism diplopia test and the various phorometers), or by utilizing after-images. The results again vary from test to test and from time to time, and again, since the fields of vision are dissociated, the conditions are far from being those of everyday life.

Grade of Binocular Vision

This is usually assessed by means of a major amblyoscope, which allows accurate assessment of the binocular vision under its own conditions of viewing, but does not in itself indicate how much use is made of binocular vision in everyday life. Interrupted reading, such as by bar reading or the Bishop Harman diaphragm, gives a very useful indication of binocular function, but even in these tests the vital stimulus is a monocular one; and the colour tests, such as the Friend test and Worth's four-dot test, indicate the use of binocular vision only under the special conditions of each test.

In general, the cover test gives by far the most useful information; although it does not give a direct estimate of the grade of binocular vision, it does indicate directly the position of the eyes under physiological conditions. When it gives an unequivocal result, it is usually sufficient, in combination with major amblyoscope readings, for an adequate assessment to be made. In some circumstances, however, assessment may not be so easy:

(*a*) If the patient's attention wanders, because of youth or slow mental development, fixation may not be maintained sufficiently long for an adequate assessment to be made. This is particularly so in cases with a small angle of squint and with fixation disparity.

(*b*) In some patients with heterophoria, the cover test itself may produce a breakdown of compensation.

(*c*) Since the cover test does not give a direct estimate of the grade of binocular vision present, it may not indicate exactly why the eyes take up a certain position. For example, if the eyes appear to be straight for one distance only, particularly after surgical treatment and in the presence of equivocal major amblyoscope readings, it may be uncertain whether the eyes are straight because of central fusion or of peripheral fusion only, or because of particularly accurate surgery without the help of the patient's binocular vision. The interpretation of small degrees of esotropia and fixation disparity can also be very difficult (Gittoes-Davies, 1952; Jampolsky, 1956).

There appears, therefore, to be a place for an instrument on which the various measurements can be carried out under conditions approaching those of normal life.

Modified Major Amblyoscope

The general construction of the instrument (Fig. 1) is that of the routine major amblyoscope, with all the usual adjustments and provision for an after-image test. The end of each arm nearer to the patient, carrying the reflector and lens and eyepiece, is made so that it is detachable from the main body of the tube (Fig. 2, opposite) by means of a slide having bevelled vertical edges.

Two alternative fittings are provided for each arm: one carries the usual opaque reflector, lens, and eyepiece to provide for routine measurements in the usual way, and the other provides for the modified method of measurement. The transfer from one fitting to the other, consisting only of sliding in one end-piece on each arm in place of another, takes a few seconds only. The fittings not in use may be stored in dovetailed slides on the stand of the instrument (as in Fig. 1) or in a separate box.

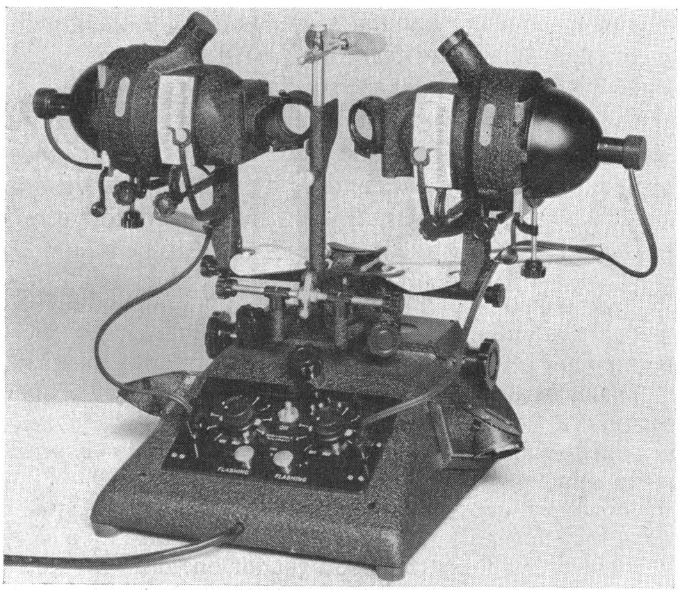

FIG. 1.—General view of modified major amblyoscope.

FIG. 2.—Interchangeable fittings for routine and modified methods of examination.

The principle of the modified instrument is shown in Fig. 3. The opaque mirrors incorporated in each arm of the routine major amblyoscope are replaced by transparent mirrors M, so that the patient can see through them with both eyes simultaneously to a target T at a distance, thus providing a natural binocular stimulus. At the same time pictures can be projected on to each retina from the slide-holders H in each arm, the face of the transparent mirror M nearer to the patient acting as the main reflecting surface. A fainter reflection is also produced by the back surface of the mirror, but trouble from this is avoided by inclining this surface relative to the front one, so that the two images virtually coincide; the prismatic effect thus introduced is far too small to interfere in any way with the measurements. The lens

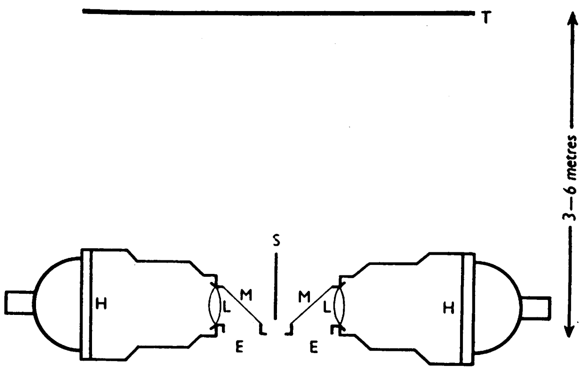

FIG. 3.—Principle of modified major amblyoscope (for lettering see text).

which is normally incorporated in the eyepiece E, and which serves to put the image of the slide optically at infinity, is replaced by a +8D lens L placed between the slide and the mirror, serving the same purpose but not obstructing the patient's view of the target. A septum S prevents troublesome reflections of the light from the opposite arm of the instrument. The patient's subjective impression is of an uninterrupted wide-angle (35°) view of a distant target, superimposed on which he sees the images of the slides. The conditions of viewing approximate closely to those of everyday life.

The target T used in most measurements is a patterned wall or screen (wallpaper is very convenient) executed preferably in greys or fawns so that it does not make the images of the amblyoscope slides too difficult to distinguish when they are superimposed upon it, but with a sufficiently bold and well-defined design to give adequate stimulus to fusion. It is best placed at 6 metres from the instrument for routine use, but may be nearer when it is desired to assess visual functions for shorter distances. If the space for the full 6 metres is not available, perfectly satisfactory results can be obtained at shorter distances, and most of the patients described in this paper have been measured at 3 metres; at these shorter distances it must be remembered that the eyes will be slightly convergent when they are being used normally, and this must be allowed for; at 3 metres, the normal scale reading on the amblyoscope will be +1°. This difference will not be of great importance in most patients, unless measurements of fixation disparity are being made (see below). When the eye is focused for these shorter distances, the image of the slides, which are optically at infinity, will not be perfectly in focus, and theoretically the power of the lens L should be changed; if the working distance is fixed, this can easily be done during the construction of the instrument, but in any case the slight fuzziness at 3 metres ($\frac{1}{3}$ dioptre error) produced by an instrument designed for 6 metres does not interfere in any way with its use.

The slides are identical in nature with those used routinely with the major amblyoscope, except in two respects; in the first place, the pictures are executed on a black background, so that, when projected in the instrument, only the picture itself is seen superimposed on the target. Secondly, the change in the position of the lens L results in a greater magnification than in the usual major amblyoscope, so that the pictures have to be made correspondingly smaller if they are to correspond with the routine slides.

MEASUREMENT OF OBJECTIVE AND SUBJECTIVE ANGLES.—Since the slides used with the modified instrument are largely black and allow only a little light to reach the eye, the corneal reflections cannot be seen and are therefore no guide to the objective angle of squint. Measurement of this angle must therefore depend on abolition of movement of the eye as fixation changes from one eye to the other, and can therefore only be carried out if monocular fixation is central in both eyes.

Using slides similar to the routine S.P. or S.M.P. slides, the flashing buttons are operated so that only one eye (the fixing eye) is presented with a picture from the slide; the arm of the instrument is adjusted so that the image is seen roughly in the centre of the distant target which is, of course, seen by both eyes. The second arm of the instrument is then adjusted until a change of fixation to the second eye (produced by operating the flashing buttons so that only the second eye sees the image of a slide) produces no movement of this eye. During the measurements it is essential to make sure that the patient's eyes are close to the eyepiece; if the head is allowed to move from this position, the view of the target is restricted and does not provide an adequate stimulus. This may make it difficult to watch the eyes over the top of the eyepieces as with the routine instrument, but they can still be seen by looking through the upper part of the transparent mirror; this can easily be done without obstructing the patient's view of the distant target.

The subjective angle is also measured with S.P. or S.M.P. slides, one of which is presented as before to the fixing eye with the arm adjusted so that it is seen in the centre of the target. The patient is then asked to move the second arm of the instrument until the images of the slides are superimposed.

In both these measurements, the distant target is seen continuously by both eyes, which therefore take up the positions occupied in everyday life; the images of the slides act merely as markers which indicate the objective and subjective angles and do not influence the positions of the eyes. This is particularly obvious in patients with esophoria, who give readings indicating no deviation of the eyes on the modified instrument.

In all these measurements, it is essential to have the target well illuminated, and to adjust the illumination of each slide individually so that there is only just sufficient light to make the picture visible against the target background and the strongest visual stimulus is still the distant target; if the slide illumination is too high or the target illumination too low, the slide pictures become the predominant stimulus and tend to be seen in front of the target. In this way the whole principle of the method is lost, as in the following example:

Case 1, a boy aged 10 years, had had a right convergent comitant squint with equal visual acuity since the age of 6 years, with some fusion and weak ductions but a marked tendency to right eye suppression.

Examination.—The cover test showed a manifest right convergent squint with and without glasses most of the time, but occasionally he appeared to be straight for distance with glasses. A recession of the right medial rectus muscle had been performed at age of 8 years.

When he was seen for assessment, routine major amblyoscope readings showed S.P. and fusion at $+20^\circ$, with ductions from $+16^\circ$ to $+30^\circ$; the eyes looked quite straight, but binocular vision broke down rapidly on cover testing to show a convergent squint. The modified amblyoscope gave an angle of $+20^\circ$ with S.P. slides when the slide illumination was relatively high and the light in the room (and therefore the target illumination) rather dim, but he showed no deviation when the room light was increased and the slide illumination reduced to a minimum.

Similarly, the slides carrying small pictures (S.M.P. type) often give more reliable information than larger pictures (S.P. type), since the larger image of the latter may tend to be dominant over the peripheral fusion stimulus given by the background target, so that the readings approximate more closely to those of the routine method, as in Cases 2 and 3.

Case 2, a girl aged 5 years, had an intermittent divergent squint of the divergence excess type.

Examination.—Routine amblyoscope measurements showed S.M.P. and fusion at $-10°$, with ductions to $+5°$; the modified instrument showed S.M.P., fusion, and S.V. at 0°, but S.P. slides were superimposed at $-8°$.

Case 3, a girl aged 7 years, had had a left accommodative convergent squint with partial left amblyopia since the age of 3 years; after occlusion, the visual acuity was 6/9 in each eye. A cover test with glasses showed a variable degree of squint, sometimes definitely straight for distance and near; without glasses, she had a manifest left convergent squint for distance, but no deviation for near.

Examination.—Routine major amblyoscope readings showed fusion at $+5°$ with suppression on ductions. The modified instrument at 3 metres consistently gave readings indicating no deviation with S.M.P. slides, but $+8°$ to $+12°$ with S.P. slides.

S.M.P. slides or the smallest practicable slides should therefore always be used.

Measurements of the objective and subjective angles may give results comparable with those obtained with the routine major amblyoscope, but in a number of patients the angle on the modified instrument was appreciably different, as in the following example:

Case 4, a boy aged 7 years, had had an alternating convergent comitant squint, with a rather variable angle, since the age of 6 months. He had had a resection of the right lateral rectus and recession of the right medial rectus muscles 3 months previously.

Examination.—The post-operative objective angle on the routine major amblyoscope was $+20°$, but on the modified instrument only $+13°$. No subjective angle could be obtained on either instrument.

Since a different amount of surgery is indicated for angles of $+20°$ and $+13°$, this difference is obviously of significance.

A limitation of this modified method of examination is that measurements of angles of more than 25° cannot be taken accurately; this is because the arm of the instrument corresponding to the fixing eye must remain stationary in such a position that this eye sees the image of the slide in the centre of the target, and as the second arm is moved inwards it gradually cuts off the view of the target by the non-fixing eye. This is probably of relatively little importance; in the first place, the angle between the two eyes in such patients is probably determined mainly by the conditions presented to the fixing eye rather than to the non-fixing eye, and the field of vision of the fixing eye is not affected by the movement of the other arm of the instrument; in the second place, differences in the readings given by the modified and routine methods of measurement are of little practical importance with large angles of squint, since they are unlikely to influence the amount of surgery to be performed.

STATE OF THE RETINAL CORRESPONDENCES

If the subjective and objective angles are equal, the retinal correspondences are normal; if they are unequal, the difference is the angle of anomaly. It has already been pointed out that the apparent state of the retinal correspondences may depend on the type of test employed, and the presence or absence of abnormal retinal correspondences (A.R.C.) on routine testing on the major amblyoscope does not necessarily indicate that the same result would be obtained under normal viewing conditions. This is indicated by the following example; in this patient the modified instrument indicated abnormal retinal correspondence long before it was detected on the routine instrument:

Case 5, a boy aged 7 years, had had a left convergent squint with marked amblyopia since the age of 1 year; occlusion had restored equal visual acuity.

Examination.—On routine testing in the orthoptic department, he showed an angle of +35° with S.P. only, and A.R.C. had not been suspected at any time. The modified instrument at 6 metres showed an objective angle of about +30°, but a subjective angle of 0° with S.P. slides. Resection of the left lateral rectus and recession of the left medial rectus muscles were then performed; after this no binocular vision could be demonstrated on routine testing for 12 months, but 2 years later the routine tests on the major amblyoscope showed A.R.C., with an objective angle of +2° and subjective angle of −5°.

Occasionally patients who have no binocular vision on routine major amblyoscope measurements can be shown by the modified method to have abnormal retinal correspondence:

Case 6, a girl aged 12 years, had had a left convergent squint with paresis of the left superior oblique muscle and bilateral overaction of the inferior oblique muscles since the age of 2 years. Intermittent occlusion had been required for partial left amblyopia, the final visual acuity being 6/5 in the right and 6/12 in the left. When she was 11 years old, a bilateral myectomy of the inferior oblique muscle was performed, followed by lateral rectus resection and medial rectus recession in both eyes.

Examination.—When she was seen post-operatively for assessment, the cover test showed a small manifest left convergent squint for near and distance. Routine major amblyoscope readings showed an objective angle of +7°, and measurements on many occasions had failed to demonstrate S.P. On the modified instrument, the objective angle was +6°, and the subjective angle was −2° with large S.P. slides and 0° with S.M.P. slides, though the latter showed a marked tendency to left eye suppression.

Case 7, a boy aged 14 years, had had a left convergent squint with partial left amblyopia since the age of 5 years. After occlusion, the final visual acuity was 6/6 part in the right eye and 6/9 in the left. When he was 13 years old, a bilateral resection of the lateral recti had been performed.

Examination.—When he was seen for final assessment, glasses were not worn; the routine major amblyoscope showed no S.P., though on previous occasions attempts at S.P. had been made; the modified instrument showed an objective angle of +9° and a subjective angle of 0° with both S.P. and S.M.P. slides.

Similarly, a non-harmonious A.R.C. found on routine testing may be shown to be harmonious in normal viewing conditions:

Case 8, a girl aged 9 years, had had a manifest right convergent squint and paresis of the right lateral rectus muscle since the age of 4 years, with partial amblyopia (R.V. 6/36. L.V. 6/9), and nystagmoid movements of the right eye on abduction. On routine testing, the objective angle fixing right was +20° L/R 9△, and fixing left +20° L/R 3△, and she attempted S.P. at +5° L/R 4△ when fixing with the right eye. With the modified instrument, the subjective angle was 0° with no height, the objective angle fixing right and fixing left being +10°/+15°. A resection of the right lateral rectus muscle was performed; 2 months later the objective angle on the modified instrument was 0°, the subjective angle being −5° with S.P. slides and −10° R/L 3△ with S.M.P. slides.

Harmonious A.R.C. may occasionally be demonstrated in patients who are incapable of doing subjective tests on the routine instrument:

Case 9, a girl aged 5 years, had had a right convergent comitant squint for 1 year for near and distance, with and without glasses, with partial amblyopia (visual acuity 6/18, in the right eye and 6/12 in the left, after occlusion).

Examination.—The angle of squint was very variable, but appeared to be between +10° and +30°; she was too young for subjective readings on the routine major amblyoscope, but gave consistently a subjective angle of 0° on the modified instrument.

It is noteworthy that, in all these patients, the abnormal correspondence under normal viewing conditions was harmonious at the original tests, though in Case 8 it became unharmonious immediately after operation. There appears to be a definite tendency for A.R.C. to be harmonious in normal viewing conditions more commonly than would be expected from the routine readings on the major amblyoscope; this was also found to be the case by Halldén (1952) and Levinge (1953). Nevertheless, some patients have unharmonious A.R.C. even on the modified instrument:

Case 10, a boy aged 7 years, had had a manifest alternating convergent comitant squint since the age of 2 years; the onset was associated with four or five mild epileptic fits.

Examination.—The objective angle before operation was +20° with glasses, +40° without glasses, with marked alternating suppression. A bilateral resection of the lateral recti had been performed 3 months before he was seen for assessment. On examination, the objective angle was +14° both on the routine major amblyoscope and on the modified instrument; no subjective reading was possible on the routine instrument, but on the modified instrument the subjective angle with S.P. slides was consistently +5°.

In this patient, the recent operation may again be responsible for the failure of the A.R.C. to be harmonious; if that were the case and the A.R.C. had been present before operation, however, it would be expected that the angle of anomaly after the operation would have been greater rather than less than the angle of squint.

Grade of Binocular Vision

The binocular vision being used under normal viewing conditions can be assessed in several ways:

(*a*) Unless the readings with the modified instrument indicate no objective or subjective deviation of the eyes, the patient cannot be exercising normal binocular vision. If there is no objective or subjective deviation, this may be the result of central fusion, peripheral fusion, or possibly of accurate surgery without useful binocular vision.

(*b*) When using S.P. or S.M.P. slides, central suppression is manifest in the same way as on the routine instrument.

(*c*) In patients with no deviation, or with only a small angle of squint, fusion is best tested as follows:

The arms of the instrument are locked in the position indicating no ocular deviation (*i.e.* at 0° for a distant target, +1° for a target at 3 metres). S.P. or S.M.P. slides are used, depending on the amount of central suppression present; if no deviation is present, the patient will of course see them superimposed on the target, but if a squint is present and the retinal correspondences are normal, the pictures will appear separated. In the latter case, prisms are introduced in the eyepiece usually of the non-fixing eye, until the pictures are superimposed; prisms of both greater and less power than this are then introduced, using both eyepieces if necessary, and the range of powers over which the slides remain superimposed is the measure of the amplitude of fusion. The principle of this method is shown in Fig. 4. The image of the distant target, and the images of the slides from the arms set in the position corresponding to no deviation, are all affected equally by the prisms P in the eyepieces; provided the eyes converge or diverge to compensate for the effect of the prisms, the distant target is seen singly (though apparently at a nearer or farther distance), and the images of the slides remain superimposed. If however the eyes fail to compensate for the prisms, the images fall off the fovea of the non-fixing eye, and the slides are no longer seen superimposed.

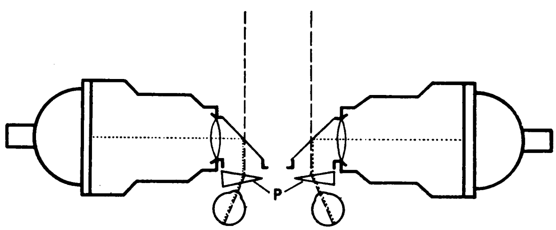

FIG. 4.—Principle of method used for measurement of fusion.

If the target used is the usual one with the overall pattern, the stimulus to fusion is both central and peripheral, and is the maximal one available for the patient; if central suppression is present, the effective stimulus will, of course, be peripheral only. If reproduceable measurements of fusion are required, the illumination of the target and the slides must be standardized.

(*d*) Interrupted reading can be carried out by using slides such as those shown in Fig. 5 (overleaf). In the "friend" test (Fig. 5*a*), the capitals on one of the slides are angled so as to discourage fusional movements which, with Roman capitals, may superimpose F on R, I on E, and N on D with consequent difficulty in interpretation.

(*e*) Stereoscopic vision can be tested in the usual way, using slides with a black background.

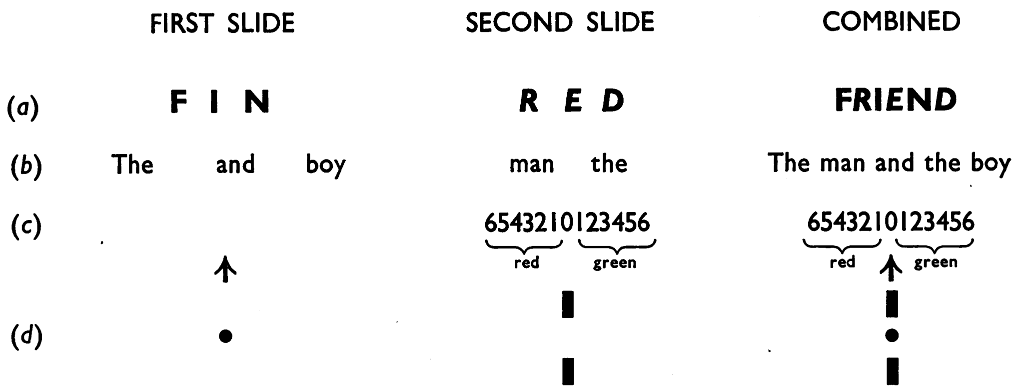

FIG. 5.—Special slides.
a, b.—Interrupted reading.
c.—Fixation disparity.
d.—Accurate measurement of subjective angle.
All slides are white on a black background, except *c*, in which the left-hand set of figures 654321 is red, and the right-hand set of figures 123456 is green.

By a suitable combination of these tests on the modified instrument, the binocular vision used under normal viewing conditions can be assessed. In most patients, of course, the findings confirm the impression given by the cover test and major amblyoscope readings; in such cases the modified instrument performs a similar function to say, Worth's four-dot test, with the advantage of being carried out under much more physiological conditions. When the impression given by the routine instrument differs from that given by the cover test, as in the following examples, the modified instrument usually confirms the cover test:

Case 11, a boy aged 6 years, had had a right accommodative convergent squint since the age of 4 years. Ten orthoptic treatments had been given.

Examination.—The cover test with glasses showed no deviation for near or distance; without glasses, the eyes were straight for distance, with occasional manifest squint for near. Routine major amblyoscope readings with glasses showed fusion at +10° with ductions from +5° to +20° only, but the modified instrument showed S.M.P. and fusion at 0°.

Case 12, a girl aged 7 years, had had a right accommodative convergent squint since the age of 4½ years.

Examination.—The cover test with glasses showed esophoria with rapid recovery for near and distance; without glasses, she had esophoria with rapid recovery for distance, but occasionally manifest squint for near. Routine major amblyoscope readings had always shown a convergent angle of +12° to +15°, with abduction only to +2°; on the modified instrument, she had S.P., fusion, and S.V. at 0°, and carried out interrupted reading without difficulty.

In some patients, however, additional information may be obtained, particularly those in whom the cover test is difficult to interpret:

Case 13, a girl aged 8 years, had had a right convergent comitant squint since the age of 4 years; it had appeared to be largely accommodative, and three short courses of orthoptic treatment had been given at approximately yearly intervals since the age of 6 years, after which routine examination on the major amblyoscope showed S.M.P. at +6° with fusion from −2° to +15°, and stereopsis. Worth's four-dot test indicated binocular single vision. The child was thought on many occasions to be controlling the deviation well.

Examination.—When she was seen for assessment her eyes sometimes appeared quite straight for distance and near with glasses, but occasionally a minute flick was seen indicating right convergent squint; without glasses, she had a manifest convergent squint for near and distance. The cover test, however, was made difficult by a strong habit of nodding the head, which was particularly marked during the cover test and also when the glasses were removed; she was also very fidgety, and was being treated with bromide by her own doctor. Examination on the modified major amblyoscope with glasses showed S.M.P. at +4° (*i.e.* a convergent angle of 3° for testing at 3 metres), indicating that she was not, in fact, using bifoveal fixation under normal conditions. The measurements on the modified instrument were done quite easily and repeatedly.

Case 14, a girl aged 6 years, had had an alternating convergent squint since the age of 3 years with slight overaction of the right inferior oblique muscle but no definite muscle paresis. The angle of squint had always been greater for near than for distance, and she had at various times been thought to show no deviation for distance, a slight alternating deviation, or an esophoria. She had never needed occlusion, though the visual acuity in the right eye had tended on occasion to be slightly less than that in the left. The angle on the major amblyoscope had always been about 15°, with S.P. and fusion with weak ductions, but with a marked tendency to central suppression.

Examination.—When she was seen for assessment, the cover test with glasses for distance appeared to show esophoria of about 10° with a very slow recovery, but it was uncertain if the eye did in fact recover to the straight position, giving the impression of right convergent squint with a fixation disparity that was not fully established. Examination on the modified instrument with foveal slides showed an angle of +5° with a tendency to central suppression, showing that the condition was not an esophoria (in which case the reading would have been +1° at 3 metres).

Occasionally, both the routine major amblyoscope readings and the cover test may agree in indicating a good functional result, whereas the modified method indicates that this is not so:

Case 15, a girl aged 10 years, had had a left convergent accommodative squint since the age of 4 years.

Examination.—The visual acuity was 6/6 in the right eye and 6/6 partly in the left. The cover test with glasses showed no deviation for near or distance: without glasses, she showed esophoria with rapid recovery for near and distance. Routine major amblyoscope readings with glasses showed fusion at +2° with ductions from −8° to +15°, and some stereopsis; Worth's four-dot test with and without glasses indicated binocular single vision at all distances. On the modified instrument, however, she showed S.M.P. at −1° with glasses, and at −2° without glasses, at 3 metres, and definite alternation on attempting interrupted reading.

Further examples of small-angle squints, in which more detailed examination was carried out to elucidate the exact conditions present, are given below (Cases 16 and 17). In all these patients the reproduceability of the readings is noteworthy; if binocular vision (whether as bifoveal fixation, heterophoria, or fixation disparity) is being used under normal conditions, the fusion produced by the distance fixation target maintains a steady position of the eyes relative to each other, so that readings with suitable slides are consistently reproduced to 0·5 prism dioptre.

SPECIAL INVESTIGATIONS

Peripheral Fusion.—This can be tested separately, even in the presence of central fusion, by covering the central part of the distant target by a matt grey square or circle of stiff paper or board (Fig. 6); the arms of the modified instrument are set so that the images of the slides are superimposed in the centre of this circle. The power of fusion is then measured as already described, the stimulus to fusion now being entirely paramacúlar or peripheral. Different sizes of circles can be used to eliminate greater or lesser

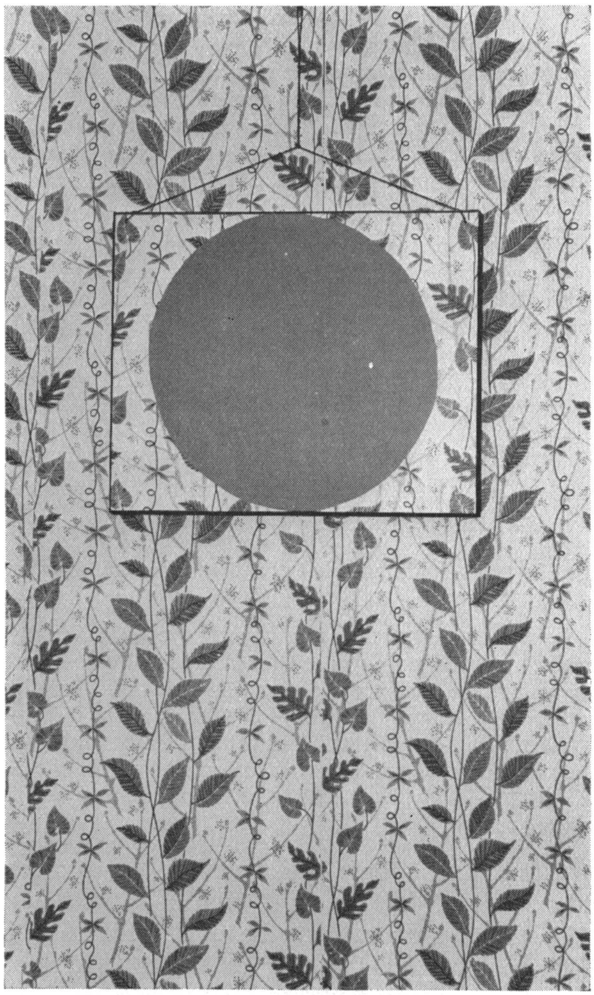

FIG. 6.—Distant target for measurement of peripheral fusion.

areas of central fusion. It is convenient to hang the circle by an adjustable cord from a hook placed at the top of the target, so that its height can be altered to correspond with the most convenient position of the instrument for the particular patient being tested.

The effectiveness of the method is well illustrated by a patient with visual acuity of 6/36 in each eye due to myopia; the corrected visual acuity was 6/6 in each eye; peripheral fusion, measured with a central grey area 10° in diameter, produced adduction of 8Δ without glasses and 14Δ with glasses; with prisms just stronger than these, so that the images of the slides were seen separated, removal of the central grey area provided immediate superimposition, due to the extra ductions produced by central fusional stimuli. In most people, however, peripheral fusion appears to be approximately as strong as that produced by the whole target.

Fixation Disparity.—To measure significant amounts of fixation disparity, slides more accurate than the usual S.M.P. slides are required. Those shown in Fig. 5(*c*) are convenient; if the arms of the instrument are locked in the position corresponding to no deviation and bifoveal fixation is perfect, the arrow points to the figure 0, but if fixation disparity is present the arrow will point to one of the figures to the right or left of 0, depending on the direction of the fixation disparity. It is convenient to colour the figures on one side red, and on the other side green, and to space them so that they give a direct reading of the amount of fixation disparity in prism dioptres or degrees. The principle of this method is fundamentally the same as that of the Maddox rod and tangent scale, or Maddox wing; with the arms of the instrument locked at 0° for distance fixation, the images of the arrow and of the figure 0 fall on the fixation points of the two eyes (Fig. 7); in fixation disparity, one of these points will be non-foveal. If the numbers are seen by the eye with non-foveal fixation (Fig. 7*a*) the fovea F will receive the image of one of the numbers other than 0; since the retinal correspondence in true fixation disparity is normal (all subjective methods of measuring fixation disparity depend on

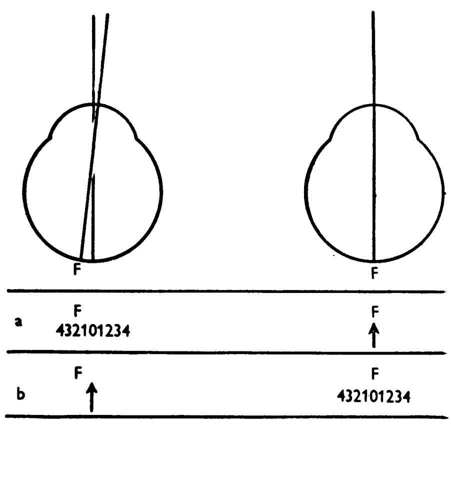

FIG. 7.—Principle of slides for measurement of fixation disparity, showing relative positions of fovea and image of slide in each eye, in a patient with left fixation disparity of 2Δ

(*a*) Arrow opposite eye with foveal fixation.

(*b*) Arrow opposite eye with non-foveal fixation.

this), the arrow, seen foveally by the other eye, will therefore be seen to lie opposite this number. Similarly, if the arrow is seen by the eye with non-foveal fixation (Fig. 7*b*), its image will fall on a non-foveal point and will be seen to lie opposite the number which lies on the corresponding non-foveal point on the retina of the other eye. It is immaterial, therefore, which eye sees the arrow and which one the number (neglecting aniseikonia, which is of no significant magnitude in this connexion).

An alternative method of measuring fixation disparity depends on the accurate determination of the subjective angle, since, in the presence of normal correspondence, this gives directly the angle between the two foveal visual directions. For this purpose, ordinary S.P. or S.M.P. slides are not sufficiently accurate, and are better replaced by slides depending on vernier alignment (Fig. 5*d*) analogous to those described by Jampolsky (1951). Such measurements can be made with remarkable accuracy and reproduceability by patients with fixation disparity.

The presence of fixation disparity may be easier to demonstrate if the central area of the distant target is occluded by the grey circle as in measurements of peripheral fusion, since it has been shown (Jampolsky, Flom, and Freid, 1957) that absence of central details in the binocular target allows greater fixation disparity to occur; most measurements of fixation disparity (such as those of Ogle, 1950) have indeed used a small central blacked-out area.

All these measurements require precise centring of the slides, which must not wobble in the holders, and accurate setting for the interpupillary distance; the adjustment of the arms of the instrument should be checked subjectively by the operator to ensure that it corresponds to the position of no deviation for the particular target distance used.

The value of these measurements in the accurate diagnosis of small-angle squints is shown by the following patients:

Case 16, a man aged 42 years, was first seen in the orthoptic department at the age of 40 years with a history of left convergent squint for 4 years only, following a blow on the left eyebrow, and intermittent diplopia which was increasing in frequency and severity.

Examination.—He had a negligible degree of hypermetropic astigmatism, the corrected visual acuity being 6/6 in each eye; the cover test showed a constant left convergent squint for near and distance; the ocular movements were full; the major amblyoscope showed S.M.P. and fusion at +32°, with ductions from 30° to 35°, and doubtful stereopsis.

Recession of the left medial rectus and resection of the left lateral rectus were performed at the age of 42 years, and he was seen for assessment 6 months later. The cover test showed esophoria with rapid recovery to a position which often appeared straight, but which occasionally gave the impression of very slight fixation disparity of the left eye. He had slight limitation of adduction in the left eye.

Routine major amblyoscope readings showed S.M.P. (unsteady) at +5°, and fusion at +4° with adduction to +20° and abduction to 0° with a tendency to left suppression; weak stereoscopic vision was present. On the modified instrument, the subjective angle was +1·5 to +2° (a convergent angle of 0·5 to 1° at 3 metres) depending on the relative levels of illumination of the target and the slides; using the fixation disparity slides, he showed disparity with a convergent angle of 0·5 to 1°. When the target illumination was high, this could only be elicited with the grey circle over the central area of the target, showing the dependence of the magnitude of the fixation disparity on the conditions present.

Case 17, a boy aged 6 years, had had a right convergent comitant squint since the age of 18 months, with only a slight hypermetropic astigmatism, which was not worth correcting.

Examination.—The visual acuity was 6/12 in the right eye and 6/6 in the left. The cover test showed a slight but definite manifest right convergent squint for near and distance with no recovery.

Routine major amblyoscope readings showed S.M.P. at 0° with fusion with ductions from $-5°$ to $+12°$ and S.V., but there was definite movement of the right eye on flashing when fixing with the left eye; it was thought that fixation disparity might be present. Examination on the modified instrument showed an objective angle of $+3°$, but a subjective angle of $+1°$ (*i.e.* harmonious A.R.C. for examination at 3 metres). The fixation disparity slides showed no fixation disparity. There was no suppression on either the routine or the modified instruments. Peripheral fusion was almost as strong as central fusion, abduction being 8△ with the complete target and 6△ with a central occluded area of 10°.

The condition appeared to be a small degree of esotropia (2° at 3 metres) with abnormal retinal correspondence of the type described by Jampolsky (1951), though it is doubtful if this type of A.R.C. is of the same nature as that seen in the large-angle squints.

Discussion

The modified method of examination obviously is not intended to replace accurate cover testing and examination on the routine major amblyoscope as the basis of assessment of patients with squint. It does, however, provide some additional information; it is not intended in the present paper to assess its value fully, since this can only be done over a long period of time, but several points of interest emerge from this preliminary survey.

(1) In those patients in whom the modified instrument confirms in general the findings of the cover test and routine major amblyoscope readings, but in whom it indicates an appreciably different angle from that found on the major amblyoscope, the significance of the measurements in relation to the surgery to be performed can only be assessed over a long period. The readings on both the modified and routine instruments have to be taken into account, those with the modified instrument indicating the normal position of the eyes, and those with the major amblyoscope the fully dissociated position. It is possible that the readings with the modified instrument may help to elucidate cases in which surgery gives an unexpectedly large or unexpectedly small change in the apparent angle of squint.

(2) The information obtained from the modified instrument regarding the state of the retinal correspondences may be of considerable importance. It is obviously of importance to know as soon as possible when abnormal retinal correspondence is present, and the modified instrument may reveal this condition long before it is detected on the routine major amblyoscope (*e.g.* Case 8); in such patients, as Halldén (1952) has suggested, the presence of

harmonious A.R.C. before operation may be responsible for a tendency to revert after operation to the original angle of squint. On the other hand, the presence of A.R.C. which is harmonious under normal viewing conditions may be of value in stabilizing the position of the eyes and preventing subsequent divergence. Further experience will also show whether or not the presence of A.R.C. which is detectable only by the modified method has the same gloomy prognosis for the subsequent development of normal binocular vision as has A.R.C. on the routine major amblyoscope.

The findings on the modified instrument are also of considerable interest regarding the aetiology of this condition; the fact that the A.R.C. in normal viewing conditions is commonly harmonious lends support to the theory that it is a purposive reaction, and the instrument lends itself to the investigation of purposive fusional movements in such patients in ordinary clinical practice without the use of projectors such as were used by Halldén (1952). It is not surprising that A.R.C. is more easily and consistently demonstrated on the modified instrument than on the routine major amblyoscope, since the distant target forms a strong stimulus to purposive adaptive phenomena.

(3) Since the instrument measures the binocular use of the eyes under normal viewing conditions, it has obvious advantages over the Worth four-dot test and similar devices. It may help to elucidate those patients who, in spite of an apparently excellent result as judged on cover test and routine major amblyoscope readings, have poor depth perception (Naylor, Shannon, and Stanworth, 1956); Case 15 may well come into this category.

(4) The measurement of peripheral fusion (in small-angle squints) is brought within the range of clinical practice without the use of complicated apparatus unfamiliar to the orthoptist, such as that used by Burian (1941) and Winkelman (1951). The patient also finds these measurements much easier than by the use of special slides in the routine major amblyoscope, such as were used by Swan and Laughlin (1944) and Stanworth (1952, 1955). The measurement of peripheral fusion may be of particular interest (Stanworth, 1949; Cashell, 1950) in those patients who, having no appreciable binocular vision before operation, somewhat unexpectedly develop binocular vision after operation, as assessed on the major amblyoscope; the stages by which this result is achieved cannot be elucidated by the cover test and routine amblyoscope readings alone, but the modified instrument may permit investigation of the suggestion (Stanworth, 1952) that peripheral fusion is an important factor.

(5) The measurement of fixation disparity is also brought within the range of clinical practice. The method is analogous to that used by Ogle (1950), but is not, of course, so accurate, and will not measure the minute amounts of fixation disparity (in fractions of a degree) found in heterophoria. It is designed to measure degrees of fixation disparity which may be of clinical importance; the cover test will only definitely diagnose those patients who have fixation disparity combined with a greater amount of heterophoria, so

that the affected eye shows partial recovery when uncovered; it appears probable, however, that fixation disparity may occur without extra heterophoria, and so would not be detectable by the cover test. The instrument will thus facilitate the diagnosis of small-angle squints, as in Cases 16 and 17, and help to elucidate the frequency of fixation disparity and anomalous correspondence in such patients.

Summary

A modified major amblyoscope is described in which measurements are made in a similar manner to those with the routine instrument, but in which the conditions for the patient approximate to those of everyday life. The changeover from routine to modified method of examination is rapid and easy.

It makes possible an assessment of the angle of squint and the use made of the patient's binocular vision under normal conditions. It is also of particular value in the detection of abnormal retinal correspondence, in small-angle squints, and in patients in whom the cover test is difficult to interpret. The measurement of peripheral fusion (in small-angle squints) and of fixation disparity in normal viewing conditions is brought within the range of ordinary clinical practice.

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