the external rectus in 25 per cent. Between 1908 and 1934 he (May, 1935) found that the incidence of superior oblique palsies doubled and that of the external rectus remained unchanged. In the nine years ending 1934 he had 80 cases of trochlear paralysis and of these 15 resulted from a frontal sinus operation. Of ocular palsies that spontaneously recovered the trochlear form had the highest percentage, 57 per cent., the external rectus 50 per cent. and the others only 28 per cent. The average for all was 38 per cent.

In such operations when the periosteum is cut through the trochlea may recede into the orbit. It should be refixed to its original attachment by exact periosteal sutures, otherwise the function of the superior oblique is weakened.

When we remember the nerve supply and the anatomy of the two muscles it is reasonable to expect paresis of the superior oblique to be more common than that of the superior rectus. Admittedly the latter muscle is exposed to injury during birth, but one would expect to find ptosis as well in the great majority of cases. Apart from this cause it is difficult to understand an isolated palsy occurring without an obvious orbital lesion. In each third nerve the majority of the nerve fibres for the homolateral accompany some for the contralateral superior rectus. The superior branch of this nerve supplies in addition the levator palpebrae superioris. However, the vulnerability of the trochlear nerve and of the superior oblique tendon to operative and other trauma is obvious. This nerve has a long intracranial course; its root, unlike those of the other ocular nerves, decussates in the roof of the aqueduct. As a delicate thread it is very exposed to pressure and inflammation as it winds around the cerebral peduncle.

PART III.—THE INVESTIGATION OF VERTICAL DEVIATIONS.


(a) Unicocular macular projection. Red and green glass test.
(b) Binocular macular projection.

1. The Hess Test.
2. The Projection Test. The Division/Diplopia.
3. The Polaroid Test.


The fundamental problem is to recognise the type of defect presented by any patient. We must ask: Is the error concomitant
or not? Is it paralytic or spastic? If either of the latter, which muscle or muscles is affected? These errors are more stable than those grouped under the title "Dissociation."

It is impossible to take too much care in examining ocular palsies and their sequelae. Errors in diagnosis may underlie faulty treatment. "The non-recognition of the nervous (spastic) component may cause entirely unexpected results if not complete failure." Bielschowsky (August, 1938). The nature of the deviation may be revealed by the various tests which search for the following defects of (1) fixation, (2) tilting, (3) excursion, and (4) projection.

1. Defective positions of eyes and head in central fixation.
2. The presence and influence of head-tilting.
3. Defective excursion of each eye in oblique gaze.
4. Defective projection as revealed by a study of diplopia.

Some of the tests are subjective and some objective and others are combined.

Subjective tests may be delicate but they require a measure of intelligence that is not always available. In addition there are many variables, for example, even the obliquity of one image does not denote a "false" origin, for ocular dominance may determine that the paretic image be erect.

1. The Position of the Eyes and the Head in Central Fixation.

The first task is to study the eyes in the primary position. If the unaffected eye is used for fixation the direction of its fellow will be away from the main action of the paretic muscle. This is shown in illustration No. 8. One must remember that the paretic eye may fix. The normal one will then look in the direction of the main action of the affected muscle. For example, if the right eye fixes when its superior rectus is paralysed, the left eye will be rotated upwards and possibly slightly outwards.

2. The Presence and Influence of Head-tilting.

Very often the head adopts a position characteristic for the affected muscle. The face may be rotated vertically and horizontally and the head tilted towards one or other shoulder. While considering these compensatory postures it is well to study the effect on the ocular deviation of tilting the head first to one shoulder and then to the other. The most typical finding is seen with paresis of the superior oblique in which tilting towards the affected side leads to an upshoot of this eye. Paresis of the superior or of the inferior rectus may lead to little change.
3. The Oblique Excursions of Each Eye.

The position of each eye in the oblique directions of gaze yields much information. The reflection of a bright light on each cornea may make a defect plainer. Spaeth (1944).

The following device is of value. On each side of the examiner, when seated facing his patient, there is a vertical rod on which a globe may be slid up or down. At the top of each rod is a fixed light and the examiner may hold another in his hand. Each light may be of a different colour and may be switched on separately. The examiner studies the corneal reflexes as he asks the patient to look at one of the coloured lights when its fixation necessitates a certain rotation of the eyes.

One should study the movements of each eye in binocular gaze and of each separately. In paralysis the affected eye will make the smaller rotation. Towards the end of its movement tell-tale nystagmoid jerks may reveal the affected eye and the weak muscle. Spasm or overaction of one or more muscles will frequently be shown by excessive rotation.

If the difference in rotation is due to a paresis of an oblique muscle it will be found in adduction. The vertical recti cause the greatest vertical deviation in abduction.

Various modifications of the screen test may help to reveal the defective muscle. For example:

The movement of one eye is studied as it begins to fix after a screen is moved from before it to its fellow. This movement may be neutralised by a prism held before it and so the deviation be measured. For a recent description of this test see White (September, 1944). One should also study the movements of the eye behind the screen.

An overshooting of the normal eye is often found when the paretic eye fixes. If the right eye is screened in esotropia it swings inwards behind the screen. If the screen is moved to the left eye the right swings out to fix. Prisms base out should be held before either eye until the outswing is just over-corrected.

The patient may observe the fixation light appear to move during this test. If, for example, the light moves down when the screen is changed from the right to the left eye a right hyperphoria or tropia is present. The prism that neutralises this parallax is the measure of the defect. Occasionally this apparent movement is in the opposite direction to that of the eye as seen by the examiner. Such faulty projection may follow a strabismus operation. A difference between the prisms correcting the movements seen by the patient and by the examiner reveals an anomalous retinal correspondence.

The field of fixation may be measured by moving an object along the arm of a perimeter until the patient just fails clearly to
see it. The corneal reflex may be used also as a guide. The visual line usually makes an angle of four degrees with the anatomical axis. The visual line passes nasal to the centre of the cornea and so if the deviating eye is convergent or divergent we must add or subtract four degrees. Spiegel and Sommer, (1944). The tangent scale may be used if the corneal reflection of a light at the zero point is studied as the patient looks at each graduation successively until the reflection is in the centre of the paralysed eye. A second light is placed at the figure at which the non-paralysed eye is now looking and displaced until its corneal image lies in the centre of the pupil of the normal eye. If one tests heterophoria by moving the patient's head rather than the fixation light one is eliminating the influence of fusional impulses on tone and so faulty measurements may be made.


When relying on diplopia in any investigation it is wise to remember the following points:—
1. A blurred image is sometimes described as a double image.
2. An eye-ball displaced by pressure may cause true diplopia.
3. Patients have discovered their own physiological diplopia.
4. Paralysis of accommodation and of convergence may cause double vision.
5. Unilateral diplopia may be due to lens opacities or subluxation.
6. Diplopia may be found near the end-position in nystagmus in certain organic diseases.

The presence of the two images may be emphasised by placing a Maddox rod before one eye. The distance between the light and the streak reveals the difference in visual alignment. The angle between the two may be measured by placing prisms before one eye.

Von Graefe's pointing test is of value in early paresis. In paresis of the right superior rectus if the right eye looks up and to the right and is then covered the patient will point further up to the right than the object that was fixed.

UNIQUOCULAR MACULAR PROJECTION.

As a rule, however, red and green goggles are used to dissociate the two images formed of a fixation light. The image of the fixing eye will be foveal and therefore central. The other image will be eccentric, as it is due to stimulation of the periphery of the deviating eye. In accordance with the laws of projection the latter will be projected nasally when the temporal retina is stimulated. Such projection requires a reversal in direction when
analysing the findings. An image from the right eye projected to the right means that the eye is rotated to the left for an area on the left of the macula has been stimulated by the object fixed by the left eye. The right eye has failed in abduction.

"To cover one eye with a red glass as the first step in diagnosis is to cover up valuable evidence by making actual deviation or limitation of motion invisible." Bielschowsky insisted on the use of a long horizontal light as object for fixation, as vertical images tend to overlap and fusion may obscure obliquity of either image.

It is wise to aid the patient in his estimation of distance by adding a vertical measure to the side of the torch ophthalmoscope or horizontal light during investigation of diplopia. The simple device of Michaelson (1945) should prove of value.

There are three steps in investigating diplopia. (1) The first step is to ascertain if any vertical separation of the images is present. (2) If there is we must find out the direction in which this separation is greatest. The vertical separation is greatest in the direction in which the vertical action of the affected muscle is greatest. This direction gives a clue to the names of the rectus muscle and its fellow that may be affected. For example, if the

![Diagram of ophthalmological tests](http://bjo.bmj.com/BrJOphtalmol first published as 10.1136/bjo.31.Suppl.73 on 1 January 1947. Downloaded from http://bjo.bmj.com/ by guest. Protected by copyright.)
separation is greatest up to the right the affected muscle will be either the "up-right" rectus, R.S.R., or the opposite oblique, L.I.O.  (3) The third step is to find the eye to which the more displaced image belongs.  The more displaced image belongs to the affected eye.  For example, if the furthest image from the primary position of gaze belongs to the right eye the affected muscle is the R.S.R.  Reliance on the lateral displacement and the tilting of the diplopia may lead to an incorrect diagnosis.  The former depends largely on the previous existence of a heterophoria.  For example, a considerable proportion of typical trochlear palsies are without any lateral or even with a divergent deviation because of previously existing esophoria.

Diplopia may be plotted on a tangent screen.  The patient faces the black side and the right eye, through a red glass, fixes a small electric light held centrally and then in the oblique positions of gaze.  White pins are used to mark these places and black ones are inserted where the image from the other eye is seen.

This simple test with red and green glasses as a rule permits an accurate diagnosis of the initial palsy.  See Illustration 33 (1).

If, however, the field of rotation of one eye in the oblique positions of gaze is observed while the other eye fixes in these positions and then the test is reversed so that the former fixes and the rotations of the other eye are examined we will find that there are two components in any visual field showing diplopia.  In other words, we are studying the primary and secondary deviations alternately.

THE DIVISION OF DIPLOPIA.  BINOCULAR MACULAR PROJECTION.

1. The Hess Test.
(See illustrations 13, 15, 18, 20.)

It is essential to separate diplopia into its two components if we are to make full and accurate findings of the muscular state.  It is desirable now not only to separate the images of each eye with red and green glasses but also to ensure that we observe the projection from the macula of the second eye, not from the eccentric area.  Therefore the right eye will first of all fix a red mark, as in the Hess test, or a red light, as in projection tests and the patient will direct towards it either a green knot or green light seen by the macula of the other eye.  So now we measure the degree of ocular displacement by comparing the direction of the visual axes of each eye.  In the simple red and green test we estimate the angle of eccentricity of the displaced eye that is the angle subtended by the visual axis of one eye and the line between the object fixed and the eccentric point in the retina it stimulates.  See Illustration 33 (2).
In the former test one eye has a central image and the other an eccentric image of one light and in the latter each eye has a macular image of different lights and the patient endeavours to project them in an identical direction.

Hess, in 1916, described a method of investigating diplopia that has proved most helpful. He used a special screen with red details seen with one eye and a pointer and green knot seen by the other. He worked at half a metre, which distance is rather short. The examinee is confused sometimes by seeing both the red spots and the knot, though not green, or its shadow, through the red glass. A modification was described by Sattler (1927), who worked at a distance of one metre. On a black wall was painted a graph in green lines. At the zero point and at the intersection of the 20 degree lines were green marks. The examiner pointed to these with a green rod in turn. The patient had a black rod, 1 metre in length, with a red cross at its tip. He was asked to place the rod on the green mark being touched. In these tests, too, it was the foveal images that were used and their distance apart indicated the type and the degree of paresis and overaction.

2. THE PROJECTION TEST.
(Illustrations 3, 23, 24.)

In the projection test the right eye fixes a red light first and then by reversal of the goggles the left eye fixes this light. With the right eye fixing, the field of rotation of the left eye is measured.
and *vice versa*. When this is done it is usually found that in the field showing weakness due to the initial palsy there is also excess movement of the ipsilateral antagonist. In the field of the other eye there is usually found excess movement of the contralateral synergist and defective rotation of the contralateral antagonist. The projection will be direct, that is foveal, and the findings will not require any reversal. For example, a red image from the right eye, seen to the right of the green image from the left eye, means that the axis of the right eye is deviated to the right of that of the left eye and not the reverse. It is simple to record this on a chart as described by Lancaster (1939). In this test the examiner projects a red light to the cardinal positions for the right eye to fix through its red glass. The patient is given a torch projecting a green light, seen only by the left eye and he is asked to place the green on the red light. Each projection will be foveal and the distance between the projected lights a measure of the ocular deviation. The glasses are then reversed and the test repeated. Evidence of the presence of paresis and secondary overaction of antagonist and synergist will then be seen.

Friedenwald (1936) stated that 20 degrees off axis was the maximum deviation we need study. This is approximately the difference in the angle between the reading and the distance visual axes. Beyond this angle fixation is inclined to be unsteady.

A further modification of these tests will now be described. A lantern projects on to the wall a black chart consisting of white lines forming 100 squares each seven centimetres square. The lantern and the patient are situated two metres from the wall, and at this angle each square subtends an angle of two degrees. As an alternative, of course, the squares may be painted on the wall. In the centre of the chart a short horizontal red line is projected. This can be seen by only one eye of the patient, who wears complementary red and green glasses. The red glass is placed before the right eye first. In his hand he holds a torch which projects a green line identical in shape with but complementary in colour to the red line. He is instructed to place the green line on the red line when looking in front and also in the positions of oblique gaze. The green line must be tilted the same way as the red one. The chart is projected up and to the right and left and down and to the right and left in succession. The distances separating the images and the obliquity of the line are observed. While the green light is being projected obliquely the left field of fixation is being explored. Any deficiency or excess will be revealed. If, for example, the left superior oblique is paralysed a failure in rotation of this eye down and to the right will be found and also a defect up and to the right due to poorly
opposed contraction of the ipsilateral antagonist. The results are entered on ordinary graph paper as seen in diagrams. The goggles are then reversed so that the green glass is before the right eye. Any deficiency or excess of the right eye will be revealed. As a rule in paralysis of the left superior oblique we will find the contralateral synergist, R.I.R., overacting down and to the right and the contralateral antagonist, R.S.R., failing up and to the right. With the red glass before the right eye the primary angle of squint is measured if the left eye is affected and the secondary angle when the goggles are reversed. It is most important to fix the head securely on a chin rest with frontal bandage. A rheostat is supplied so that the light seen by one eye may be intensified. This is sometimes desirable if the vision of one eye is defective from suppression, amblyopia, or other causes. See Illustration 33 (3).

3. The Use of Polaroid Lenses.

These lenses provide us with a useful alternative to red and green glasses for separating the images seen by each eye.

The author uses a plastic slide with a design on each surface, one alone being seen by each eye. One design is of two cross lines, the other is of a series of a hundred squares. A The designs are polarized at right angles to each other. Numbers and letters

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ILLUSTRATION 36.

The Polaroid Test. Miss McC. The right field is the smaller and the overaction of the R.I.O. is greater than that of L.I.R. This suggests that—R S O was initial loss but in absence of influence of head tilting, diagnosis of — L.S.R. was made. The projected squares and the vertical line are shown in only one direction. They are seen with one eye and the cross lines with the other. ("A").
along the edges of the squares enable the examinee to describe the position of the cross-lines, seen by one eye, as they lie across the squares seen by the other eye. The slide is projected on to an aluminised screen at a distance of two metres. The screen is viewed through polaroid lenses that are polarized at right angles to each other. The slide is projected directly in front at first and then obliquely to each corner. The results are entered on graph paper as in Illustration 36.

The polaroid lenses must be in a reversible frame so that only either the cross lines can be seen with one eye and the squares with the other, or vice versa. One must be careful always to place the slide in the lantern with the same surface forwards. Otherwise the squares will sometimes be seen by one eye and sometimes by the other.

It may be desirable to project a slide that will cover an area of the wall 6 or 7 feet square. This will require a specially constructed lantern. Or the squares could be printed on a special screen illuminated from behind.

If one wishes to work at one metre, allowance must be made for the distortion due to projection on to a plane surface.

The measurements used by Sattler (1927) for his tangential table were:

-0° 10° 15° 20° 25° 30° 35°
87 mm. 176 mm. 268 mm. 364 mm. 466 mm. 577 mm. 701 mm.
-40° -45° -50°
839 mm. 1,000 mm. 1,192 mm.

For the interpretation of diplopia the rule to remember is this, whether we rely on the simple red and green or on a projection test:—Up and to the right we find R.S.R. and L.I.O. at fault, whether it be a weakness or overaction. In the simple test as one image is eccentric the more displaced image belongs to the paretic eye the findings must be reversed. In the projection tests as both images are central this is not so, and the less displaced image is that of the paretic eye.

The Advantages of Charting the Diplopia.

It is claimed that no examination of an ocular deviation is complete and no diagnosis sound unless one makes a screen-recording by the method of Hess or one of its modifications. Accurate measurements are of particular value for—

1. the early diagnosis of a partial palsy,
2. observing progress, and
3. the diagnosis of compensated and of complicated palsies.

It is extraordinary that, despite the works of J. Ohm and W. R. Hess, the measurement and graphic registration of
disturbances of ocular movements have not yet received sufficient attention." Sattler, (1927).

The superiority of recording the projection over the ordinary red and green test is seen in the following summary:—

Shirley L., aged 18 years, had had a left concomitant convergent strabismus for nine years. A left recession and resection reduced the angle to ten degrees but overaction of the left inferior oblique persisted. The red and green goggles showed that the vertical separation of images was greatest up to the right, and that the more displaced image belonged to the right eye. A diagnosis of - R.S.R. and + L.I.O. was made. The screen test, however, showed that not only the R.S.R. but also the L.S.O. was weak. Then it was found that the head was usually tilted towards the right shoulder and that tilting towards the left caused discomfort. In addition rotation of the left eye downwards was an effort. A more probable diagnosis therefore was a partially recovered initial paralysis of the left superior oblique with inhibitional palsy of the right superior rectus and overaction of the left inferior oblique.

There are two other tests which are of particular value in palsies that have recovered partially or completely and are survived by an overaction of an antagonist or synergist.

They are—

(1) the Bite-tilting test of Hofman and Bielschowsky,
(2) the After-image test.

1. THE BITE-tilting TEST OF HOFMAN (1900).

This was described clearly by Bielschowsky (January, 1935, and August, 1938). As rotation of the head leads to an alteration in position of the two images even if all the muscles are intact because they do not fall on corresponding retinal points it is desirable that the test object should rotate to the same degree as the head. Therefore one end of a 25 centimetre rod is gripped between the teeth. At the other end there is a white board with a horizontal black line on it. The patient sees this double and is asked to describe the effects of head-tilting to either shoulder. The vertical separation of the images will increase when the head approaches the right shoulder if the R.S.O. is paralysed, for when the head tilts this way the superior muscles of the right eye are stimulated. The action of the R.S.R. is unopposed because the other muscle stimulated, R.S.O., is paralysed. The right eye will rotate up while the left merely rotates to the left. The R.S.O. is not called on if the head is tilted to the left. If the L.S.O. is paralysed and the head is tilted to the left the vertical separation increases, because this tilting stimulates the superior muscles of the left eye.
ILLUSTRATION 37.

Bite-tilting or Head-tilting Test of Hofman and Bielschowsky.

1. The appearance of the two images when left superior oblique is weak and head is erect.
2. On tilting the head to the left the image of the left eye rises and tilts more.
3. On tilting the head to the right the images tend to fuse.
4. The test being made with head to left.
2. The After-image Test.

The patient, in a dark room, looks through a monocular tube at a glowing filament which can be rotated to the left or the right until it appears exactly vertical. If the filament deviates more than one or two degrees from the vertical position one may infer a corresponding deviation of the vertical meridian of the eye, especially if, when the other eye is tested, the patient declares the filament to be vertical when it really is vertical.

SIMPLIFIED ROUTINE.

For those not equipped with a Hess or a projection apparatus the following routine is useful:

1. Primary Deviation.—Observe relative positions of eyes in forward gaze. The affected eye when not fixing tends to look away from the direction of its vertical and horizontal actions.

2. Excursion.—Study relative positions of eyes in the diagonal directions. Defective movement of the affected eye and over-action of its fellow are greatest in the direction of the maximum vertical pull of the affected muscle. This direction gives a clue to the defect, for if most marked “up to right” the affected muscle will be the right “up” rectus or opposite muscle, left inferior oblique, and so on.

3. Recovery.—Watch the recovery movements in these directions as fixation is changed by covering one and then the other eye.

4. Diplopia.—If vertical separation of the two images is present, find the direction in which this is greatest, using red and green goggles. Again apply the rule. If greatest up to the right the affected muscle is right “up” rectus or opposite muscle. The image of affected eye is the more displaced one.

5. Division of Diplopia.—Measure the vertical separation in the diagonal directions with one eye fixing through the red glass and then, after reversing the goggles, with the other eye. Insist if possible that the red image is fixed. It is convenient to attach vertically a portion of a measure one foot long, to the holder of the fixation light. This aids the patient in estimating height-difference. To lessen the risk of fusion a short horizontal strip-light or illuminated plastic is better for fixation than the ordinary electric globe. The height of the fixation object in the four diagonal positions should be standardised. A study of these measurements transferred to graph paper will reveal the paretic and the overacting muscles.

6. Torticollis.—The presence of head-tilting and its effect on the deviation and the diplopia may clinch the diagnosis.