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THE USE OF THE FLICKER PHENOMENON IN THE INVESTIGATION OF THE FIELD OF VISION*

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FOLLOWING upon the extensive use of the flicker phenomenon made by Granit in psycho-physiological visual investigations, Phillips[17] attempted to use the same method for recording the visual field defects in cases of intracranial tumour. His paper described only a few cases, and the work was intended purely as a trial of a new clinical method.

As a direct continuation of Phillips's work, further attempts have been made to utilise his method both in its original form and in modifications (see Appendix). These modifications were evolved, and used or rejected from time to time during the course of the regular investigation of the visual fields of suitable cases coming into the Neuro-surgical Department of the London Hospital, so that the whole work may conveniently be considered in two parts. First, the modifications and the reasons for trying them; and secondly, the conclusions to be drawn from the flicker investigation of fifty-eight cases having actual or possible visual field defects.

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I. RATIONALE OF THE METHOD.

If a person views an intermittent light, it may appear to flicker or to be steady, according to the rate of interruption. It is possible to find, for any one set of conditions, a rate of interruption which is only just visible as flicker; and this rate is what is usually meant by the term "fusion frequency," expressed as flashes per second. The fusion frequency may be altered, not always by decrease, in any condition giving decreased visual perception ([2, 5, 22]) and Phillips attempted to make use of this fact in investigating visual fields.

II. DIFFICULTIES IN USING THE METHOD.

The finding of the fusion frequency is not easy, and many people, even those with some experience in forming critical judgments, find great difficulty, at least at first, in deciding upon the presence or absence of flicker when the rate is only two or three flashes per second below the fusion point. In using flicker in field-taking this relatively large error is of little importance in cases of well-marked scotoma; but it was rather in the cases of slight or doubtful field defects that most was expected from the method (Phillips [17]). Usually, though by no means always, practice improves the judgment of flicker; but there is little opportunity to give practice during the investigation of a patient, especially if that patient be sufficiently ill to be exhausted by sitting rigidly in a chair for half an hour. This difficuty in making a critical judgment is not so great at and near the centre of the field as it is 30 degrees or more in the periphery. This no doubt explains why Teräskeli[22] found that patients of all kinds learnt fairly readily to give concordant results, for she was concerned with points no further than 10 degrees from the centre of the field. In the present investigation, concerned as it was for the most part with cases of intracranial tumour, it was necessary to examine as much as possible of the whole visual field. In practice, both Phillips and I were quite unable to obtain reliable readings beyond the forty degrees isopter.

In addition to the difficulty of persuading some people to give an opinion at all, certain curious effects appeared sufficiently often to become recognised as annoying sources of error. Why, for instance, should a person, during the course of an experiment under constant conditions suddenly give readings five or ten flashes per second above or below the previous ones? A fall in the readings may be attributed to persistent local adaptation perhaps (Granit and v. Ammon,[7] Riddell,[18]); but it will be shown later that that factor can largely be eliminated. More probably true fatigue and loss of interest and attention are the cause. But it is more difficult

to explain a sudden rise, a rise that is too sudden to be due to light adaptation. It may be that in some way the visual apparatus becomes more sensitive to flicker. But on the other hand, Granit and Riddell[10] remarked apparently spontaneous flicker waves in the frog's retinal action potential just after cessation of a flicker stimulus; and Granit and Therman,[12] attribute these to synchronised optic nerve discharges. The writer has himself noticed that after repeated observations of flicker the stimulated area may continue to present fine flicker, even when the gaze is directed elsewhere. Such a happening would account for the seeing of flicker at unusually high rates, the flicker waves being due not to the interruptions in the light but to spontaneous synchronised retinal neurone activity left over from a previous stimulus.*

One patient was noteworthy in that he showed suddenly during an experiment an almost exact halving of his fusion frequency; and this is particularly interesting in view of the fact that Granit and Riddell[11] occasionally found a frog's eye to respond to flicker with waves at half the frequency of the stimulus. Granit and Therman[12] have recently confirmed this finding, although they attribute it to the presence of alternate large and small responses rather than to the complete failure of every second response.*

Another big drawback of flicker as an instrument for measuring the visual fields, is its cumbersome nature. The method of recording most often used was the usual one of " sampling," where, by repeated short exposures of about 1·5 seconds' duration, the rate is found at which flicker is just perceptible. Even a practised observer will require on an average six observations to establish a value (*cf.* Lythgoe and Tansley[16]), and that means at least two hundred observations in order to get the bare skeleton of a field from the centre out to 40 degrees. This is quite a heavy task to impose upon even a healthy person at one sitting; and since the values given by the same person appear sometimes to vary a little from hour to hour, due probably to fatigue and perhaps to other factors [20], the field ought obviously to be completed at one sitting if possible. A striking instance of the effects of fatigue was given by one control (K), who, between two sets of readings, had had a sleepless night; the second readings were definitely lowered, and were much more variable.

* In a more recent paper (*Jl. Physiol.*, Vol. LXXXV, p. 421), Raynor Granit has drawn a clear distinction between I-retinae (responding to flicker readily by activity of the negative or inhibition phase of the action potential, and probably always having a preponderance of cones) and E-retinae (responding by a much less active positive excitatory or *b*—component, and being typically rod-containing eyes). He suggests that in the frog's and in the human eye, which have " mixed " retinae, the flicker response may be an algebraic sum of the two types of response, and thus more liable to unexpected changes in values. He mentions in another paper (see footnote, p. 395) that clinical evidence in support of this theory is forthcoming.

This great objection of the time factor and of fatigue led to the trial of the " falling " method, whereby the flicker, starting at a rate that is definitely fused, is slowed steadily and fairly rapidly until it is appreciated as flicker. This method, if reliable, would enable each value to be ascertained in, at the most, three readings. But it leads to trouble from the well-known phenomenon (investigated by Granit and v. Ammon[7] and by Riddell[18]) that steady observation of fast flicker will, especially at the periphery, rapidly lead to its becoming fused. This effect is usually called " local adaptation to flicker," and in using the "falling" method it very often happens that the rate of this local adaptation is faster than any rate of " falling " that is consistent with the patient's reaction time; so that adaptation to the flicker would keep just ahead of actual perception, and the " falling " method would give a reading lower than that obtained by " sampling." The method was therefore abandoned.

Local adaptation to flicker also tends to give trouble with the " sampling method "; for many people cannot give a judgment from an exposure of only 1 to 1·5 seconds, which for physiological reasons is the optimum[7,8,9]. This trouble was, however, finally avoided to a large extent by arranging, by means of a system of mirrors, for parallel beams of light, one steady and the other flickering, but both of an apparent equal brightness (Riddell[18]). The test patch could be illuminated by either beam, and the change from one to the other was made with a minimum of perceptible alteration in the field (Fig. 2B). In this way it was possible to make an area of light of a certain size and brightness suddenly commence flickering at any pre-selected rate. It was found that the preliminary steady light caused no local adaptation to subsequent flicker, so that the observation could usually be made without giving local adaptation time to produce any appreciable drop in the flicker fusion rate; and even when local adaptation to flicker had occurred it could rapidly be abolished, without otherwise altering the appearance of the field of vision, merely by reverting to the steady light for a few seconds.

The special advantages of this mirror method are these: 1. It eliminates some of the difficulty caused by local adaptation to flicker. 2. It allows of modification in the procedure, so that blackness, steady light or flicker can be presented at will without readjustment of the apparatus. This is particularly useful, for instance in cases of low macular acuity (*v. inf.*) 3. It abolishes the need for a shutter, which is noisy and also tends to produce stroboscopic effects. ([16]). 4. If a white test screen is used and the test patch when flickering fast is made to match the screen in brightness, the patient need receive no warning whatever of when flicker should appear. This

state of affairs appears to me particularly important for the following reason. It is easily demonstrated even in the normal subject that the visual field for small movements and small objects can be increased by informing him where to expect the object or movement to appear (*cf.* Grindley[13]). Hence it is not surprising that a slight defect in an otherwise normal field can often be demonstrated only when the patient is given no warning of where and when to concentrate. The defect, in other words, is one of visual attention rather than a definitely scotomatous area.

That the mirror method was likely to be suitable for the purpose was realised first of all during consideration of the probable human retinal potentials evoked under different conditions. The work of Granit and his helpers[3], of Hartline[14], and of Sachs[15,21], has shown that human potentials are similar in behaviour to those of many other vertebrates; so the gaps in our knowledge of the human ones may be filled from the behaviour of those of other animals.

Fig. 1A shows the type of response to a short series of flickers in the frog's light adapted eye (Granit and Riddell[10]). The most marked parts of the whole response are at " on " and " off "; and indeed some patients have apparent difficulty in dissociating the onset and cessation of a short stimulus from the rhythmic stimulus of flicker. If, however, the flicker be made to appear in an area already stimulated by a light of equal brightness (mirror method)

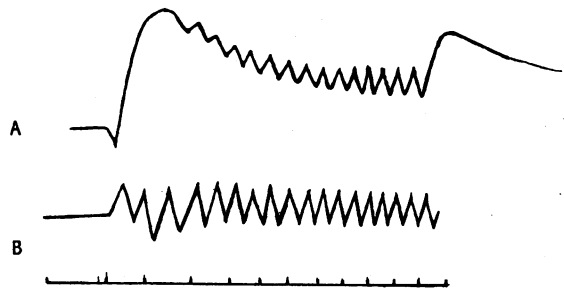

FIG. 1.

A Retinal potentials in response to short series of flickers preceded by darkness. (Slightly diagrammatic for comparison with B). Instrument, string galvanometer. *B* Tracing, under somewhat greater sensitivity, of flicker preceded by steady light. Instrument, oscillograph. Frog. Time, 1/5 secs.

I have found the response to as in Fig. 1,B. Here the only result of the altered stimulus is that due to the flicker, and if the flicker is too fast to be perceived, there is no additional stimulus received at all. If then the test light is made to match the surrounding screen, there should be practically nothing perceptible to the

patient on the screen unless flicker appears at a rate below his fusion frequency at the time. Thus full advantage can be taken of any " visual inattention " there may be; and in addition after-images are avoided. It might be thought that the lack of constrast between the flicker and the screen would make it more difficult to see; but this is not so. Contrast has much less influence than might be expected when the surroundings are sufficiently bright to maintain a fair degree of light adaption (Lythgoe and Tansley[16]).

III. ARRANGEMENT OF APPARATUS.

In the appendix are given details of the various modifications of the apparatus. They are denoted in the text by symbols (e.g. A III). Fig. 2A shows the plan of Phillips's set-up (A I); and Fig. 2B shows my final modification (mirror method, C III), which in my hands gave readily the most sure results. Phillips had worked at one metre with the idea of getting more detail, as

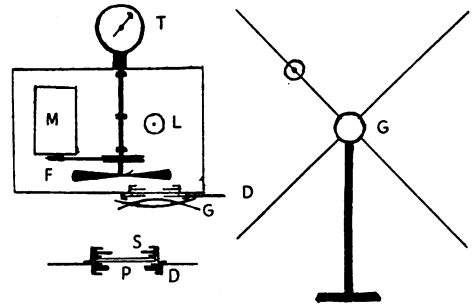

FIG. 2. *A*.

Phillips's Apparatus (AI of the Appendix). T., tachometer; L., single filament lamp; M., motor; F., fan; G., frame for carrying fixation discs out to 40°; S., Luc shutter; D., iris diaphragm; P., milk-glass test patch. S. D. and P. also shown in detail. Used at 1 metre.

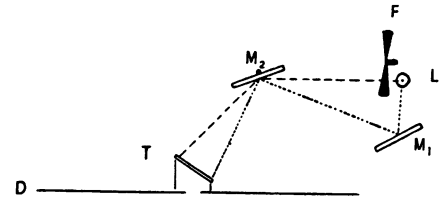

FIG. 2. *B*.

The Mirror Method (CIII of the Appendix). L., single filament lamp; F., fan; M1, fixed plane mirror; M2, plane mirror on vertical axis; T., opal glass test patch; D., white screen of 30° area with central aperture. Used at 0·5 metre.

in campimetry. But, as explained below, fine detail of contours cannot be expected from this method, so there is no disadvantage in using a small screen (as in C III) provided a chin and forehead rest is used. The great advantage of the small screen is that it enables the experimenter to see the patient and to check his fixation, a very necessary feature, as it was almost certain that many of the earlier conflicting readings were due to eye movements. With the small screen, indeed, it became apparent that probably quite 50 per cent. of the patients could not be trusted to use careful fixation unless they were constantly checked.

It may be noted here that Granit[6], and also Teräskeli[22], used short distances and small screens. The principal differences between their arrangements and mine were that they used flicker at a greater intensity than the surroundings, and that they used a shutter.

The Value of Flicker in Investigating Visual Fields

A. FLICKER IN THE NORMAL SUBJECT.

Certain facts about the normal flicker values in different parts of the retina must be understood before a criticism of the results in lesions of the visual pathway can be effective.

Phillips[17] appears to have been the first to attempt to map a considerable part of the visual field by means of flicker. Earlier work for the most part dealt either with readings limited to the fixation point and a point 10 degrees or 20 degrees away (Granit[6,9]), or else to a series of points along one meridian, generally a horizontal one (Lythgoe and Tansley[16]). Observations made in these ways led to the general finding that with fairly high intensities and with areas of flicker of over 1·5 degrees, the values for the fusion frequency at the centre were lower than at 10 degrees in the periphery, and that from the 10 degree mark outwards the values gradually fell (Fig. 5A), cf. Creed and Ruch[4]). This peak value at about 10 degrees is considered to be due to the junction of the macular area and its even number of cones and ganglion cells with the periphery, where there are many rods and cones to each ganglion cell, as well as a profuse synaptic network. The readings obtained from a case of retinitis pigmentosa (with hemeralopia) seem to confirm this idea. They are shown in Fig. 3, compared with similar readings from a control. Although the patient had fields out to 30 degrees for 10/330 white, the flicker-values drop rapidly from the centre owing, presumably, to involvement of the intraretinal

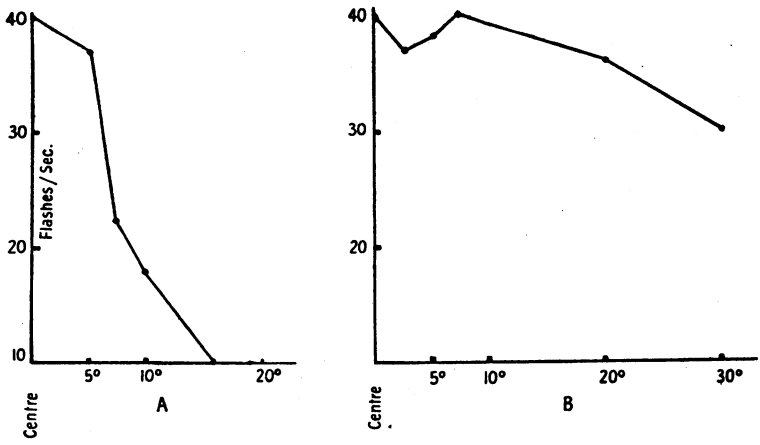

FIG. 3.

A Case of retinitis pigmentosa, with retention of fields for 1/330 white out to about 30°. Flicker conditions B V ; aperture 2°.
B Normal control (K) with full fields to 1/330 white. Flicker conditions similar. Unusual detail of values near the fixation point obtainable with this observer.

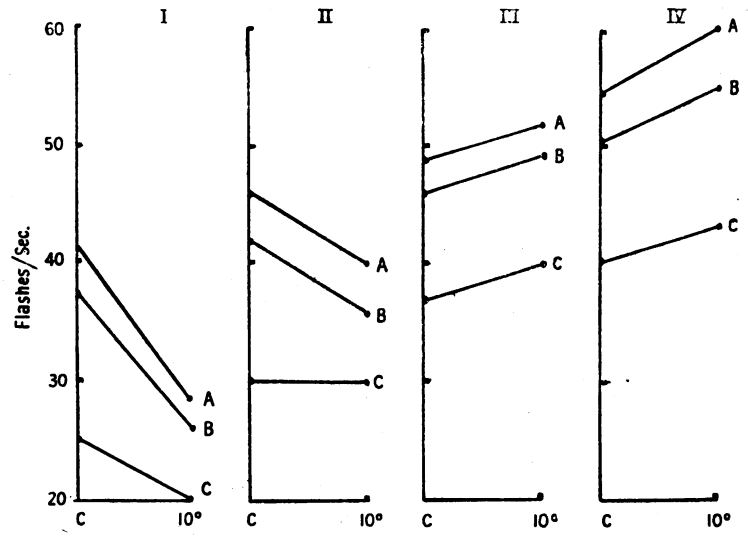

FIG. 4.

Condition AIII. Normal subject R. In each set the letters A, B and C denote values with the flicker at 14 equiv.f.c., 5 equiv. f.c., and 1 eqiv. f.c. respectively. I is with aperture 30 min., II is with 1°, III with 2°, IV with 3°.

synapses (But *cf.* inf. and [5]). However, the degree of development of this " peak " necessarily varies, as already stated, with the intensity and area used. Fig. 4 shows a series of actual values from the same normal subject under different conditions. From this it will be realised that flicker readings are essentially relative, and that external conditions must be rigidly controlled. The values shown were obtained with a black background; if this were white and subjected to varying degrees of illumination, the changes in the values would be still more involved.

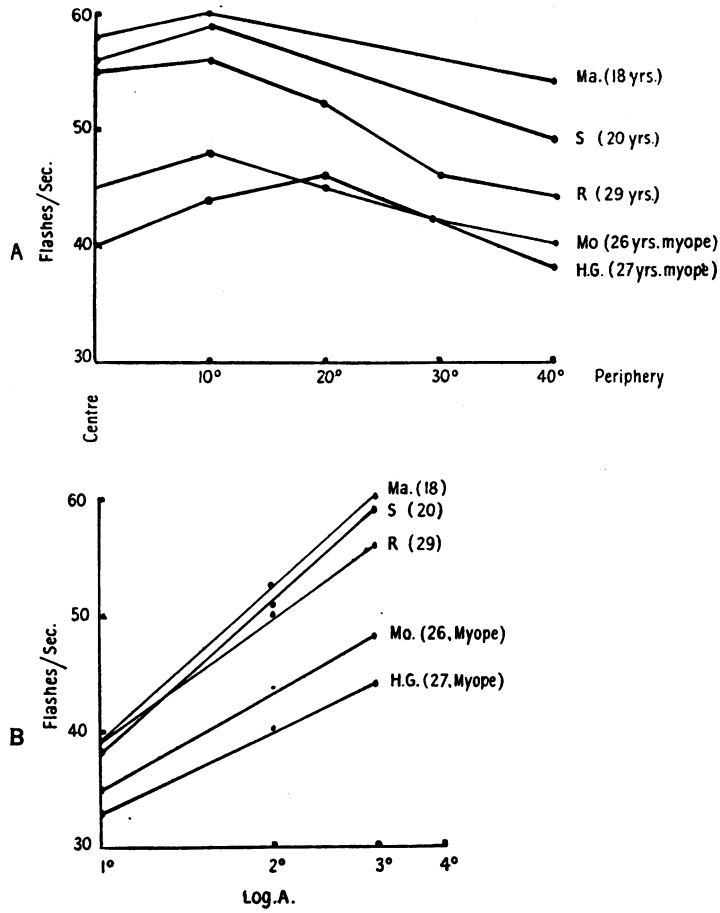

FIG. 5.

A Variations in fusion frequency for a 3° aperture under AIII conditions in five normal controls. The abscissae represent points in the field.

B Values for the same five controls at 10° in the periphery, showing the summation due to replacing a 1° aperture by a 2° and a 3° aperture (n = a log A plus b.).

Another effect noticed by all observers was that the larger the area of flicker the higher the fusion frequency (*see* Fig. 4); and Granit and Harper[9] proved this to be due to a process of retinal summation mediated by the horizontal synaptic paths in the retina. As mentioned above, these path are most numerous out in the periphery, and occur not at all at the fovea. Summation is therefore greater in the periphery. It conforms to a law like the Ferry-Porter Law, *viz.*, n = a log A + B, where n = fusion frequency in flashes per second, A = area of flicker, and a and b are constants (Granit and Harper[9]). Fusion frequency values at any one point, therefore, when plotted against log area, lie upon a straight line (Fig. 5B).

Several workers have noted that flicker values may vary in the different quadrants. Weymouth and his co-workers[24] quote Alex. Duane (in Fuchs' Textbook of Ophthalmology, 8th ed.) as having found that flicker was perceived best in the temporal and nasal inferior quadrants. Phillips also found that the lower temporal values were higher than the upper temporal, and he evidently considered this a constant finding; for he thought that all normal values for corresponding points in the corresponding quadrants of different people were very much the same. He used, however, only three controls. My experience is that there is no constant value. The investigation of fifteen normal subjects of different ages shows that there is considerable variation from one subject to another, both in absolute values and in degree of summation, and both these tend to be influenced by such diverse

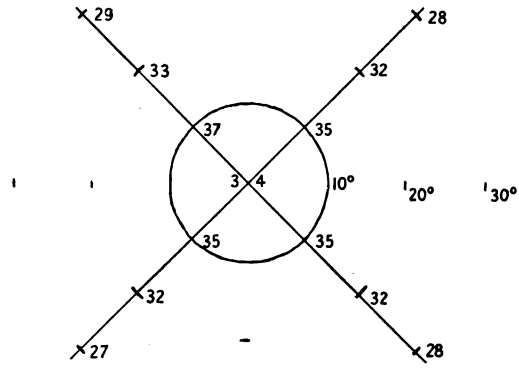

FIG. 6.

Raised values in one quadrant in a normal control (N). Conditions C III, aperture 2°. In this and subsequent diagrams the numbers represent the fusion frequency in flashes/sec.

conditions as age, myopia (Fig. 5), time of year and pulmonary ventilation ([20]). Variations between quadrants in any one eye (Fig. 6) are by no means constant in distribution, and may be absent; they are not large (1 or 2 flashes per second), and may even vary slightly in the same eye from day to day. There is, except for this, quite a close correspondence between the values in the two eyes of the same person. The greatest individual variations were noted when using the black screen; but with the small white screen the values tended to approximate more, though still being far from identical from person to person. Whatever the cause of this improvement, it would seem that in my hands at any rate the small apparatus with white background makes for greater accuracy.

Teräskeli[22], from the investigation of fusion frequencies at the centre and at 10 degrees in the periphery in twenty-nine controls, also concluded that the two eyes of normal people closely agree, but that there is considerable variation in the values from person to person. She decided that comparisons were possible only between corresponding points of the two eyes of the same person. It is obvious that in field defects comparisons between the two eyes are not always possible; so that it is necessary to compare different quadrants in the same eye. There must therefore be some sort of average normal values decided upon for use in such cases; and it is essential that all the control values should have been taken under exactly similar conditions of lighting and arrangement of apparatus; and in addition to that, the influence of the age and general condition of the patient must be remembered.*

Hence the flicker phenomenon requires very careful use, accurate control and some degree of special knowledge. In my opinion no conclusions in cases of field defect due to cerebral conditions should be based on differences of less than three flashes per second.

B. OBSERVATIONS IN THE ABNORMAL.

A noteworthy feature of all the results in pathological cases was the fact that even with defective fields the Granit-Harper Law tended to be obeyed at all parts of the field; with such constancy was this so that it was possible to use obedience to the law as a test of the accuracy of the readings at any one point (Fig. 7A).

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*A useful summary on the known facts on flicker, physiological and pathological, has just been published by Ragnar Granit. *Acta Ophthal.*, Supplement VIII, Vol. XIV.

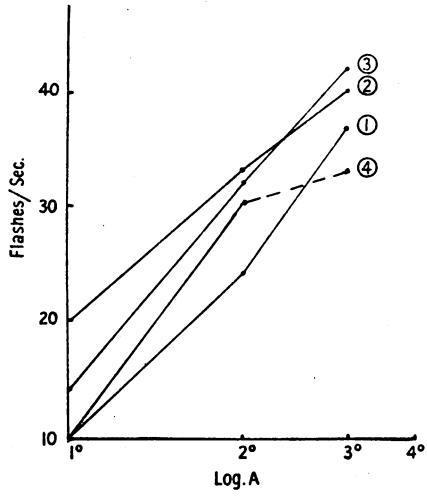

FIG. 7. *A*.

Values showing obedience to Granit-Harper law in a case (J.S.) of aneurysm of the circle of Willis producing complete left homonymous hemianopia and considerable depression of the temporal field of the right eye. All values are for 1° aperture taken at 20° from fixation point in the right temporal field. (1) Meridian 30° to right of vertical. ' (2) Meridian 45°. (3) Meridian 90°. (4) Meridian 135°.

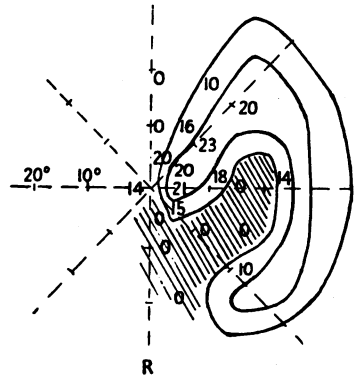

FIG. 7. *B*.

The right field of this case (J.S.) shows that the reduced value for 3° aperture in Fig. 7A (4) is due to the fact that the area tested probably overlapped the area of a dense scotoma. Isopters to 10/2000 and 50/2000. V.A. 6/36. Flicker conditions A III, aperture 1°.

There were only two apparent exceptions to be allowed for. First, where the values were all very low, the readings for small areas of flicker (30 min. to 1 degree) were often lower than the law would indicate. This, however, is quite in keeping with Granit's observation that the law is observed best with flicker fusion values of 30 to 50 per second. The other exception was that sometimes the largest areas failed to give a high enough reading; but in such cases comparison with the fields obtained with the Bjerrum screen usually showed that the area used must have overlapped into a steep-edged scotoma, and thus have had its apparent size reduced ([4] in Fig. 7A). Enlargement of the blind spot can produce a similar error, so that when only a few values can be obtained there may be the erroneous suggestion of a quadrantic defect on the tempora side.

(1) *Cases of Intracranial Lesions.*

The main object of this investigation was a further testing of Phillips's conclusion[17] that in cases of intracranial lesions of the optic pathways flicker fusion values were affected earlier and recovered more quickly than form perception. Riddoch[19] had previously concluded that there was a similar dissociation between form and movement perception in occipital injuries. If then the results of these two observers were correct, both flicker and movement should provide useful tests in early diagnosis and in post-operative prognosis; and of the two, flicker at first sight seems the better to use since it can readily be measured in definite units. The present investigation has led to the conclusion that, in general, flicker and ordinary perimetry, in which movement may form an element in the test[23], agree in their findings; but in my hands neither seems as a rule more sensitive than the other.

The work of Granit and his co-workers[10,12] upon the retinal action potentials and optic nerve potentials in flicker makes it obvious that flicker perception is distinct from steady light perception, and the two might therefore be dissociated in disease of the retina. It is possible that a similar study of potentials with vibratory movement of a light would also show a distinct difference. But it must be noted that the differences appear to arise in the retina and not in the pathways beyond. Hence there is the less reason for expecting a dissociation in cases of cerebral tumour and of occipital injury such as was described by Phillips and by Riddoch.

With the well-known dissociation of pain sense from touch, the lesions are in the spinal cord, and the syndrome occurs because the pathways are there distinct. There is no basis of comparison between the two sets of conditions.

Indeed, granted that flicker of a light or vibration of a test object produced greater stimuli than a steady light or a stationary object, there seems no reason why either should not provide as ready a means as the other of detecting small defects in the field when these are due to intracranial conditions. When they are due to retinal conditions, on the other hand, dissociation may

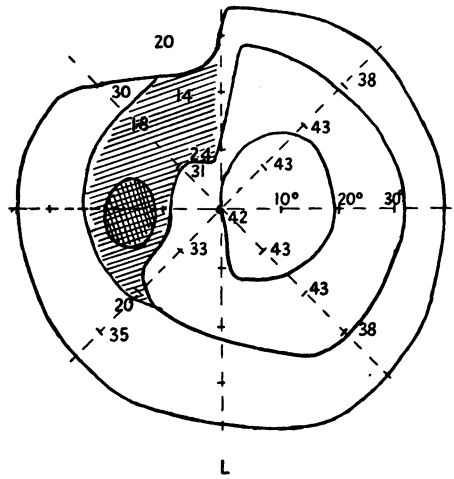

FIG. 8. *A*.

Two typical cases of agreement of perimetry and flicker. Subject J.O.H., pituitary adenoma. Isopters to 1/2000, 3/2000 and 9.5/2000. Relative scotoma to 9.5/2000. Blind spot: 50/2000. Flicker values for 4° aperture, conditions C III. V.A. 6/9 left eye.

be produced by interference with the action of the synapses and the neurones, for this interference may be selective[5].

In campimetry, vibration of a test object[22] has the advantage of requiring no special apparatus, and no special knowledge. On the other hand, flicker is capable, in a good subject, of much more accurate measurement; but this appears to be its only advantage in lesions situated beyond the retina, unless certain special aspects of it prove to have significance (v. inf.).

In the present work it has indeed been found quite exceptional for flicker to show a defect not found on the screen.

From a total of fifty-eight cases the following results were obtained:—

In forty-four there was substantial agreement between the fields by flicker and by perimetry. Two examples are given in Fig. 8.

TABLE I

Patient	Age and Sex	Date	Method	Lesion	Vision	Comparison of methods
E. B. -	33 F.	Pre-op.	B V	Probably cerebellar tumour	6/6 6/6	*Perimetry* showed only slight concentric constriction and large B.S. *Flicker* gave homonymous upper left defect. This is not a likely finding.
W. C. -	32 F.	No op.	A I	Chiasmal (? pituitary)	6/12 6/12	*Perimetry:* bitemporal restriction to small visual angles. *Flicker*: no defects. Probably wrong, and therefore less sensitive.
M. F. -	28 M.	4 years post-op.	B V	L. occip. glioma	6/6 6/6	*Perimetry:* homonymous upper right defect (very slight). *Flicker:* suggestion of upper left defect. Obviously wrong.
H. C. -	33 F.	18 mths. post-op.	B IV	Pituitary adenoma	6/9 6/9	*Perimetry:* upper bitemporal defect to 3/2000 white and to red. *Flicker:* no defect. Definitely less sensitive.
M. H. -	35 F.	Pre-op.	A II	L. olfact. groove meningioma	6/18 6/6	*Perimetry:* left shows slight upper temporal defect. *Flicker:* lower nasal defect on left. Probably wrong, though not necessarily.
M. H. -	28 F.	No op.	B V	I.C.T. suspect	6/36 6/12	*Perimetry;* upper nasal defect, left; right—both upper quadrants restricted. *Flicker:* upper bitemporal defects. This patient had no papilloedema, and there is the possibility that flicker was right, though no clinical signs to suggest a chiasmal lesion.
G. H. -	11 M.	No op.	B III	I.C.T. suspect	6/9 6/6	*Perimetry:* suggestion of upper field defects. *Flicker:* normal; there were no definite signs of a tumour, so flicker was probably right.

TABLE I—*continued*

Patient	Age and Sex	Date	Method	Lesion	Vision	Comparison of methods
J. H. -	48 M.	No op.	B IV	Headaches (origin unknown)	6/18 6/18	*Perimetry:* suggestion of upper and lower temporal defect. *Flicker:* negative (probably right).
D. J. -	40 M.	No op.	B IV	Gliosis after contusion	6/18 6/18 (not corrected)	*Perimetry:* suggestion of central relative scotomata. *Flicker:* central values normal. Flicker probably right (no central changes).
I. A. L.	51 F.	No op.	B III	? arteriosclerosis	6/60 6/24 (not corrected)	*Perimetry:* upper nasal defect in right eye only. *Flicker:* homonymous upper left decrease. This is the more attractive finding; but other investigations failed either to substantiate or to disprove it.
M. M.*	59 F.	Pre-op.	A III	Right parietal meningioma	6/9 6/18	*Perimetry:* no definite findings beyond scotoma from old retinal haemorrhage, left. *Flicker:* slight homonymous left defect. It is tempting to believe that flicker was the more sensitive here.
J. M.*	34 M.	1 year post-op.	B V	Right parietal meningioma	6/6 6/6	*Perimetry:* normal. *Flicker:* suggestion of upper left homonymous defect. Here flicker seemed definitely more sensitive.
H. P. -	48 M.	No op.	C III	I.C.T. suspect	6/6 6/8	*Perimetry:* variable. Confrontation gave "inattention in right homonymous fields." *Flicker:* right homonymous defect. Flicker seems more sensitive here.
T. W. -	65 M.	Pre-op.	C II	Carcinoma of base of skull	6/24 6/36 (not corrected)	*Perimetry:* full fields. *Flicker:* defect in upper left temporal at 20°. Due perhaps to blind spot?

*** Flicker, but not campimetry, in agreement with operative findings.**

In fourteen there was a disagreement between the two methods; the lesion was verified histologically in six of these cases and not verified in eight. In five of them the flicker fields were almost certainly wrong, giving very improbable defects in three cases and missing defects in two. In nine cases, however, flicker may have been the more correct, but in only two of these were the flicker findings able to be substantiated by operative findings.

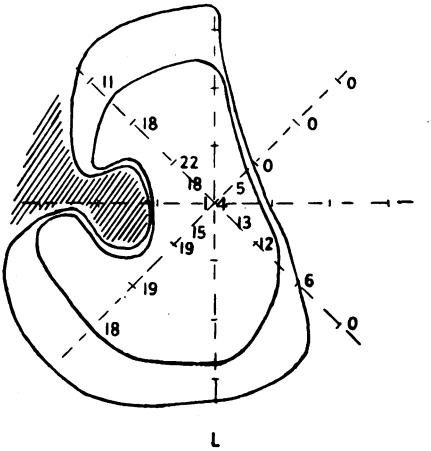

FIG. 8. *B*.

Subject A.M., temporo-occipital meningioma. Isopters to 4.5/2000 and 9.5/2000. Flicker for 4° aperture, conditions C III. V.A. (corrected) 6/9 left eye.

Table I gives a summary of the cases where there was disagreement between the methods.

In the other forty-four cases the flicker tests and perimetry gave substantial agreement. By this it is meant that flicker, in the areas of retina where it was measured, gave similar indications of normality or of defects to those which were obtained by campimetry; but in no case was it possible to do nearly so complete a field with flicker, and in some cases only a very few values could be obtained. The flicker field was always poor in contours (Fig. 8) and was never measurable beyond 40 degrees in the periphery.

As a general conclusion it may be stated then that for intracranial lesions the flicker method cannot replace perimetry in the mapping of a field. It is as a rule no more sensitive to slight defects, and it is more difficult to use. There is, however, one way in which the method may be of use in investigating field defects, and that is to employ it for more accurate measurement of the density of relative scotomata. Though it can show

their boundaries only roughly, it can give in arithmetical units a more definite value for such relative blindness. With the screen it may be found, for instance, that a scotoma on one occasion is at its centre quite blind to white 5/2000, while on another occasion this size of object can be seen if it is agitated. This is only a very indefinite measure, and flicker can do better; for the change may be expressed as an improvement from a fusion frequency of, say, 30 flashes per second, to one of 36 flashes per second.

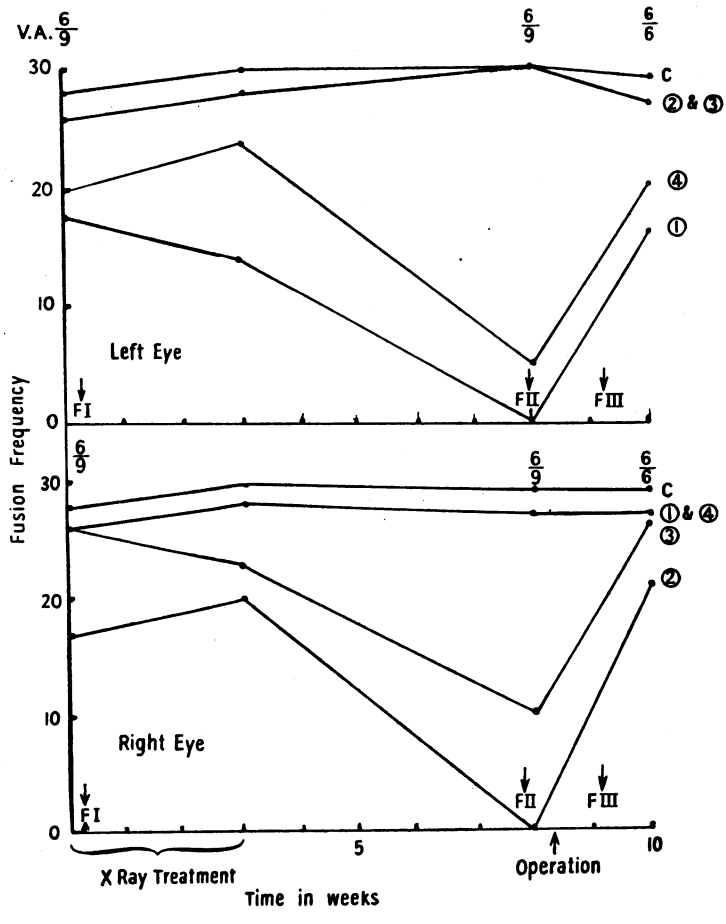

FIG. 9.

Subject P.M., pituitary adenoma with bitemporal hemianopia. Variation in values at 20° in periphery during 10 weeks. Conditions B.V. C = values at centre.
(1) Upper left quadrant (2) upper right quadrant (3) lower right quadrant (4) lower left quadrant.

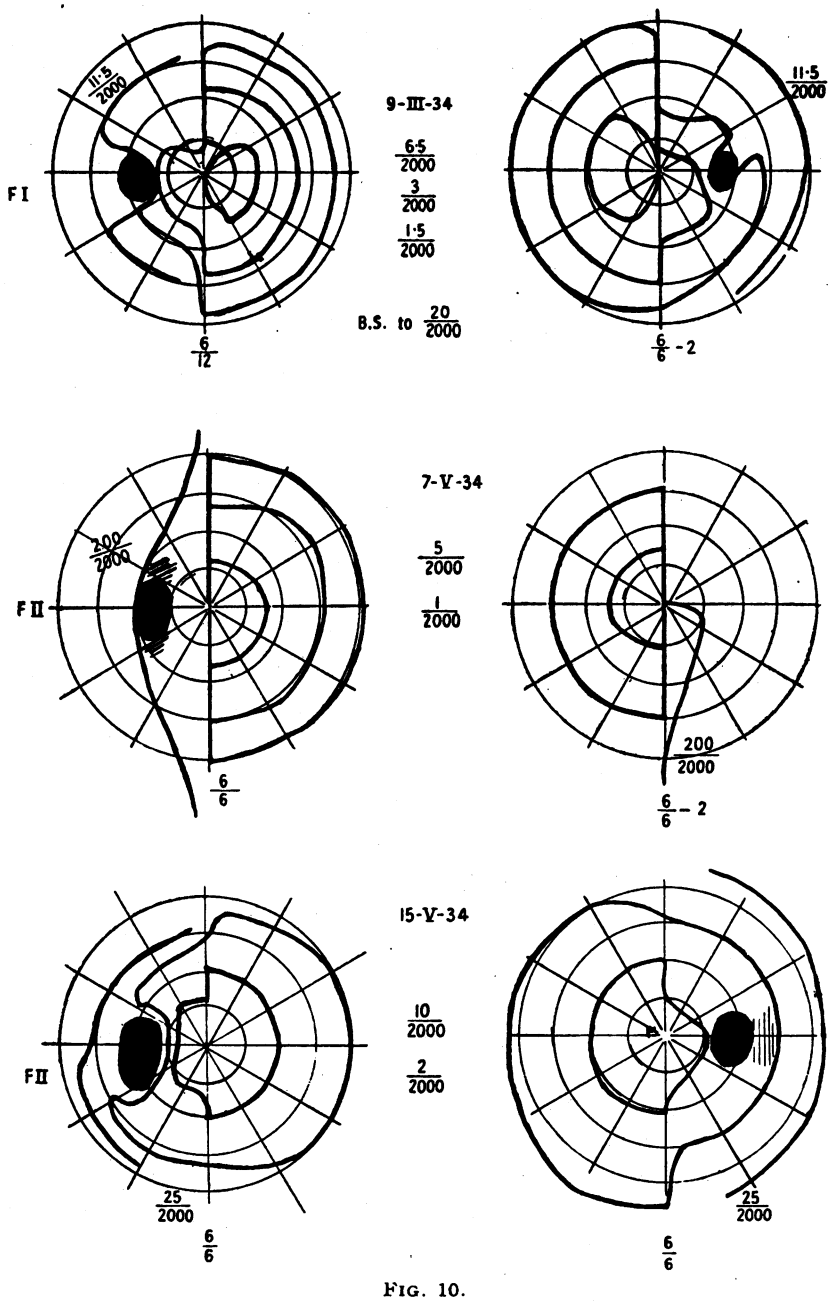

FIG. 10.

Fields of subject P.M. taken on the dates indicated at FI, II and III in Fig. 9. Sizes of white objects and distance in millimetres from black screen shown in figures.

Fig. 9 shows the variations in the values for selected points in the fields of a case of pituitary tumour. The period covered is ten weeks, during which there was first X-ray therapy and then operation. The normal areas of the fields (centre and upper and lower nasal quadrants) show slight variations such as have already been referred to; but the affected areas show unmistakable big alterations. First a mixed response to X-ray therapy, followed by a decided drop; then a rapid improvement following operation. This case is instructive as showing what may be obtained from an intelligent and co-operative patient; but it is by no means

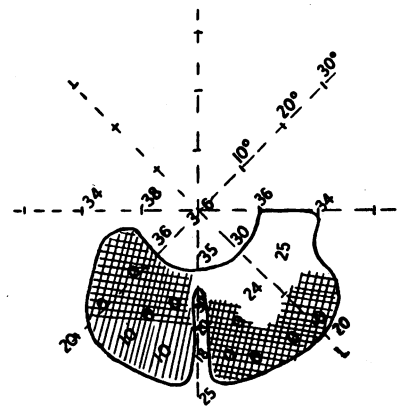

FIG. 11.

W.L., left eye. Scotoma, unknown origin, to 5/1000 white. Flicker conditions B I, aperture 30°. Shading represents depth of scotoma as suggested by flicker.

always possible. Again, it must be realised that although the depth of the temporal scotoma is well shown no contours were obtained; and it was impossible to show, as did the perimeter, that except just before operation the peripheral parts of the temporal fields were relatively intact (Fig. 10).

This application of the method is obviously not likely to be of use in cases of intracranial lesion; but it is probable that it may find much more use in cases of purely retinal lesion. Fig. 11 shows the type of defect that is meant. In this particular case, the cause of the scotoma was never discovered, but it illustrates the point fairly well; for the depth of the scotoma was not successfully shown with graded objects.

Flicker similarly may give an indication of whether the fixation point is involved in cases of field defects with moderate lowering of the visual acuity. As shown above, the central flicker

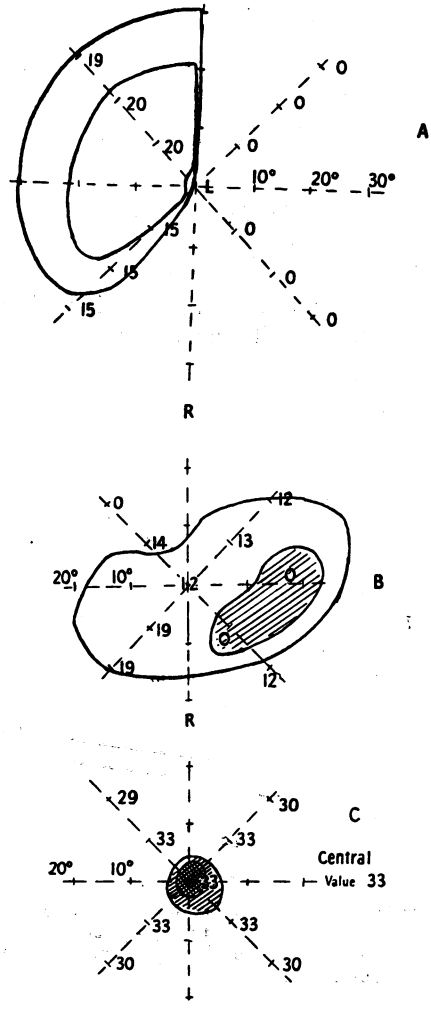

FIG. 12.

A. W.N., pituitary adenoma, right eye. Isopters to 6.5/2000 and 9.5/2000. Flicker conditions B.V., aperture 2°. L = light just visible at about 2-5 flashes per sec. V.A. 1/60.
B. L.W., left frontal meningioma, right eye. Isopter for 11.5/1000. C III, 2°. V.A. 6/36.
C. D.J., left eye. Apparent varying relative central scotomata for 9.5/2000 and 3/2000. Flicker values, nevertheless normal. V.A. 6/18. B.V., 1° 20′.

values are usually normally a little lower than those at 10 degrees; but when the fixation point is involved, there may be a marked lowering of the central value even though a 2 degrees object can be seen (Fig. 12). It is in such cases that the mirror method is useful in allowing blackness to be presented on the test patch in contrast to the white screen so as to ensure true fixation before the flicker appears.

(2) *The Effect of the Condition of the Retina upon Fusion Frequency.*

(*a*) *In cases of intracranial lesions*:—The possibility of the use of flicker to record the progress of field defects due to retinal conditions has already been mentioned, and it will be referred to again below. The question of summation, however, probably merits more attention than it has received. In cases of relative

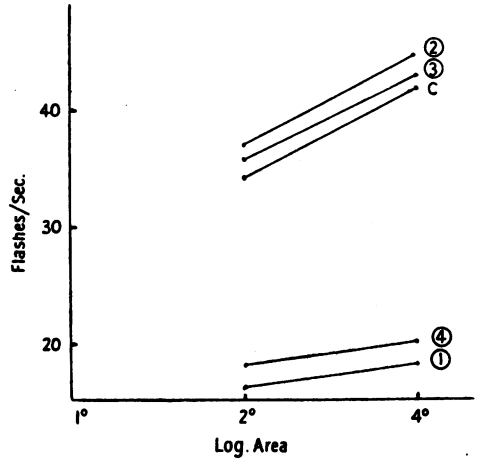

FIG. 13.

J.O.H. Case of pituitary adenoma (field shown in Fig. 8A). Left eye. (1) upper left quadrant (2) upper right quadrant, (3) lower right quadrant (4) lower left quadrant. All taken at 20° in periphery. Conditions C III.

scotoma, as has been said, the Granit-Harper law holds good, but the slope of the line is often less than in the normal parts of the field (Fig. 13). This would argue retinal damage, as distinct from nerve or tract damage; for Granit and Harper[9] have produced good evidence that summation is mediated by the intraretinal synapses.

An analysis has been made, therefore, of the forty-one cases in which summation was tested. They separated into two main groups, those with good summation and those with poor summation; and they were further subdivided according to the condition of the fundi, whether normal, or showing primary optic atrophy, papilloedema or secondary optic atrophy.

The material is obviously too small, when divided into so many categories, to draw very definite conclusions from. But the following points may be noticed. It seems that if the fundi are normal, summation is almost sure to be normal. Secondly, a lesion affecting the retina or the optic nerve is very liable to produce poor summation; but primary atrophy, which presumably would affect only the retinal ganglion cells (through their axons), is just as likely to produce it as is papilloedema, which may very likely affect also other retinal cells. From this it may be argued that either summation depends upon the presence of the full complement of ganglion cells, or else that degeneration of the ganglion cells can cause degeneration of other retinal cells as well.

Another point that suggests itself is that papilloedema with poor summation or very low values may mean a poor prognosis, even though the intracranial pressure is relieved; for of seven such cases, three died soon after operation, one had a very stormy convalescence, and one has not improved either in vision or in general health; of the other two, whose convalescence was good, one was a case of metastatic carcinoma and has since died, the other is very well indeed. On the other hand, five cases of papilloedema with good summation all had a fairly steady convalescence, and three showed definite improvement in vision; only one of them, whose tumour was not located, has failed to regain very good health.

(*b*) *In cases of ocular lesions*:—I have had no personal experience of this work; but much has been done and is still being done with the flicker method at the University Ophthalmic Clinic in Helsingfors, and mention is made of it here for the sake of completeness and to offset the rather adverse criticism of the method which this paper produces.

Teräskeli[22] found that in twenty-one out of fifty cases of monocular amblyopia with squint the central values of the diseased eye were high like the peripheral (10 degrees) values. She then further investigated fourteen of these twenty-one cases and showed that in twelve of them summation at the centre was also high, as in the periphery. She argues from this that in many cases of unilateral amblyopia with squint the fovea is lacking in the affected eye, and that the squint in these cases is due to the amblyopia, and not vice-versa.

Enroth and Werner[5] have compared the adaptation curve as obtained by the ordinary measurement of the threshold of dark-adaptation with a similar curve giving flicker readings. The results are interesting; and are being applied to the study of changes in glaucoma.

It seems undoubted that the flicker method is to have a place in ophthalmic work, whatever its deficiencies in the type of case studied in this paper. It is also probable that just as the method has been used to study such a fundamentally neurophysiological problem as inhibition[12], so it may be used in the study of changed neuronic responses in neuropathology, for instance in the Psychoneuroses.

Conclusions

(*a*) *In cases of intracranial tumour*:—(1) Campimeter fields and flicker fields in general agree.

(2) Neither is the more sensitive; flicker will show no defect that cannot also be found with careful campimetry; and moreover flicker results are much more difficult to interpret, owing to their greater dependence upon external conditions such as lighting, and upon age, etc.

(3) Flicker cannot show contours as in campimetry.

(4) Flicker may, however, be used to estimate the density of scotomata with fair accuracy. It may also serve to indicate if the fixation point is especially involved in cases that show a lowered visual acuity.

(5) The flicker method is at least as difficult as campimetry, and the technique is just as difficult to learn. One set of conditions should be decided upon and adhered to, as otherwise calibratory control cases, which are essential, become invalid.

(6) The apparatus recommended is a compact one (C III of the Appendix). If it is hoped to *detect* field defects, the flicker should be of the same intensity as the screen; but if *known* scotomata are to be measured, a brighter light may be easier to use.

(*b*) *In other conditions*:—The method will probably find greater application in purely ocular conditions, as suggested by the work of Granit, and as successfully used already by Teräskeli and by Enroth and Werner.

It may also prove of use in some purely neurological conditions.

I am indebted to so many people, that it is impossible to mention all. Chiefly, to Mr. Cairns for his interest and the permission to use his cases for the work; to the students and the assistants in the clinic who so willingly acted as controls; to Mr. Phillips, who showed me the method, to Dr. Granit for much further help and

advice; and lastly to members of the Hospital Surveyor's Department who were responsible for most of the apparatus.

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Appendix

DESCRIPTION OF THE APPARATUS AND ITS MODIFICATIONS.

A I. Phillips's arrangement ([17]) is shown in Fig. 2A. Dark background reflecting no light; brightness of flicker about 7·5 equiv. f.c. at 1 metre (position of patient); apertures of 1·5 degrees and 2·5 degrees.

A II. Black cloth screen instead of X-shaped frame for the fixation discs. White diffusing screen behind patient, so that black screen was lit fairly uniformly by diffused light. This gave the white fixation discs brightness of 3 equiv. f.c. as seen by patient. Apertures of 12 min. to 3 degrees used.

B I. White screen (of about 1·5 sq. metres at 1 metre distance) used so as to allow some degree of light adaptation and thus increase flicker perception ([4]). White shutter and diaphragm. Test patch in view all the time (as before), with brightness of 1 equiv. f.c. when not lit by flicker light. Average brightness of white screen 2·5 equiv. f.c.

B II. Test patch placed behind fan so that it was completely occluded in each dark phase. Flicker generally brighter than ground (7·5 equiv. f.c. compared with 2·5 equiv. f.c.). " Falling " method first tried.

B III. Fan placed just in front of light again so as to give rapid cut off; but test patch moved back till unlit by general lighting. Flicker thus reduced to 7 equiv. f.c., but with more definite dark phases.

B IV. Distance of white surrounding screen 1·5 metres, so as to allow more even illumination. Its brightness was now about 1 equiv. f.c. Apertures of 20 ft. to 2 degrees. Shutter removed.

B V. Flicker reduced in brightness till equal to screen (1 equiv. f.c.)

C I. Mirror method. Brightness of screen reduced to 0·5 equiv. f.c. to match flicker, which was reduced of course by the interposition of the mirror.

C II. Stronger lamp. Flicker and screen now 1 equiv. f.c. again.

C III. Small white screen of 30 square degrees at 0·5 metre. Apertures of 2 degrees and 4 degrees actually cut in interchangeable screens, so as to avoid the break in the reflecting surface caused at the junction of screen and diaphragm. Screen and flicker equal at about 1 equiv. f.c.

REFERENCES

1. Adrian, E. D., and Matthews, R.—*Jl. of Physiol.*, Vol LXIII, p. 378. 1927.
2. Braunstein, E. P.—*Zeitschr. f. Physiol. der Sinnesorgane*, Vol XXXIII, p. 241, 1903.
3. Cooper, Creed and Granit.—*Jl. of Physiol.*, Vol. LXXIX, p. 185, 1933.
4. Creed and Ruch,—*Jl. of Physiol.*, Vol. LXXIV, p. 407, 1932.
5. Enroth, E., and Werner, S.—*Finska Läkaresällsk. Handb.*, Vol. LXXVIII, p. 161, 1935.
6. Granit, R.—*Amer. Jl. of Physiol.*, Vol. XCIII, p. 651, 1930.
7. ——— and v. Ammon.—*Amer. Jl. of Physiol.*, Vol. XCV, p. 229, 1930.
8. ——— and Hammond, E. L.—*Amer. Jl. of Physiol.*, Vol. XCVIII, p. 654, 1931.
9. ——— and Harper, P.—*Amer. Jl. of Physiol.*, Vol. XCV, p. 211, 1930.
10. ——— and Riddell, L. A.—*Jl. of Physiol.*, Vol. LXXXI, p. 1, 1934.
11. ——— and Riddell, L. A.—Unpublished observations.
12. ——— and Therman, P. O.—*Jl. of Physiol.*, Vol. LXXXIII, p. 359, 1935.
13. Grindley.—Medical Research Council, Special Reports, No. 163, 1931.
14. Hartline, H. K.—*Amer. Jl. of Physiol.*, Vol. LXXIII, p. 600, 1925.
15. Kohlrausch.—*Kurzes H. d. Ophthal.*, p. 149, 1932.
16. Lythgoe, R. J., and Tansley, K.—Medical Research Council, Special Reports, No. 134, 1929.
17. Phillips, G.—*Brain*, Vol. LVI, p. 464, 1933.
18. Riddell, L. A.—*Jl. of Physiol.*, Vol. LXXXIV, p. 111, 1935.
19. Riddoch, G.—*Brain*, Vol. XL, p. 15, 1917.
20. Rubinstein, B.. and Therman, P. O.—*Skand. Arch. f. Physiol.*, Vol. LXXII, p. 26, 1935.
21. Sachs, E.—*Klin. Wochenschr.*, Vol. VIII, p. 136, 1929.
22. Teräskeli, H.—*Acta Societatis Med. Fenn.* "*Duodecim*," Ser. B., Tom. XIX, p. 3.
23. Traquair.—Clinical Perimetry, pp. 34, 38, 1931.
24. Weymouth, F, W., and others.—*Amer. Jl. of Ophthal.*, Vol. XI, 1928.

A RETRO-TRANSILLUMINATOR

BY

J. GRAY CLEGG

MANCHESTER

CASES occur not infrequently in the practice of a busy ophthalmologist where a dark mass is discerned in the fundus. The question then arises, is it, or is it not, malignant? Such a mass may be opaque to the passage of light. If the suspected growth is in the anterior third of the globe, transillumination through the conjunctiva and sclera in the ordinary way is a most satisfactory proceeding. If, however, the mass is more posterior, grave doubt may arise. Some time ago Lancaster, of Boston, U.S.A., suggested transillumination by means of a lamp passed, after a cut in the conjunctiva and Tenon's capsule, towards the back of the globe. This method was mentioned by Rönne, of Copenhagen, in a lecture given to the North of England Ophthalmological Society. I decided to have a special lamp constructed, which was carried in a narrow