ON INTERMITTENT STIMULATION OF THE RETINA. PART I.

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When the eye is subjected to an alternation of stimuli of a frequency below a certain limit, the sensation of flicker with the accompanying inference of a discontinuous source of light, is produced.

Schafhäutl[1] was the first to note that the limit depended upon the strength of stimulus and utilised the method as a means of measuring luminosity; but it is due to Rood showing that fusion of stimuli depended upon frequency and luminosity independent of colour, that flicker photometry has developed.

That the maximum speed at which the sensation of flicker is produced depended upon other factors besides luminosity was noted by Filehne[2], whose observations were made on white discs on some of which only four black sectors of 45° each were painted. Rotated at a speed to produce 25—30 alternations per second, fusion occurred, while if the number of painted sectors were great, flicker might exist at a frequency of 74 alternations per second.

Fick found that under certain conditions 170 alternations might be necessary to produce fusion; this was the case when parallel lines were drawn on a drum which was rotated around an axis parallel to the lines: if, however, the observations were made through a slit no flicker was seen above 40 per second.

Baader[3] experimenting independently made similar observations, and came to the conclusion that the size of the field of vision was a factor that must be taken into consideration when determining the speed of alternation necessary to produce fusion.

Fick suggested that movement of the eyes might be the explanation of the observations; when the speed of translation was small the eyes followed the sectors and thus flicker was not destroyed until high speeds were attained; the use of a window partially prevented this.

[1] *Akad. d. Wiss. München* VII. p. 465. 1855.
[2] *v. Graefe's Archiv* XXXI. p. 20. 1885.
[3] *Dissert. Freiberg*, 1891 (quoted from Schenk).

Schenk[1] has recently taken up the question, and found that in his own case fusion occurred when making observations through a definite aperture, on rotating discs with a variable number of black sectors, at approximately the same speed in all cases; a variation in the same direction as found by Filehne, Fick and Baader occurred in observations made by Schenk's co-observer Schmidt.

It is intended in this paper to show to what extent the ratio of the breadth of sector to that of aperture through which observations are made, exerts an influence upon the frequency of intermittence of stimulation at which the sensation of a discontinuous source of light passes into that of a continuous source.

The reason for avoiding the word flicker lies in the fact that under certain conditions a sensation of the stimulus not being constant is conveyed to the observer, while the sensation which commonly goes by the name of flicker is not experienced, but the screen when within focal range appears to possess Brownian movement.

When the screen is within focal range and of a nature that it can easily be focussed I do not find an abrupt transition from flicker to a steady smooth sensation, but there is always an intermediate condition of molecular movement even when the frequency of alternation is but 30 per second.

The method adopted consisted in determining at what frequency of alternation and at what luminosities fusion (disappearance of 'molecular' movement) occurred, when the ratio of the breadth of sector to the diameter of aperture varied from 1 to 20.

A series of discs were used from which a variable number of sectors had been cut 2—60, leaving an equal number of equiangular sectors: these were rotated by a motor, the speed of rotation being adjusted by altering the resistance in the motor circuit, and when necessary by varying the number of accumulators used to supply the current.

The discs were painted black on both surfaces, and were prevented from oscillating when revolving at high speeds by two pulleys. The speed of rotation was observed on a Napier's "show speed" indicator, which was found to be correct to 1 °/₀ when standardised by the counter. The source of illumination was usually a 16 candle power electric lamp, one side of which was frosted and used as the screen; the lamp was usually run at 135 volts instead of 100, and thereby a much whiter light was produced than under ordinary conditions.

Owing to one side of the lamp being plain an arc light could be

[1] *Pflüger's Archiv* LXIV. p. 165. 1896.

concentrated on the side which was frosted; this was found necessary when working with high luminosities.

Alteration of luminosity without altering the nature of the source of light was easily accomplished by utilising a slight modification of a method suggested by Arago[1], which depends upon the inclination of two Nicol's prisms. I compared this method of observation with that of the square of the distance of the source from the screen and found that the curves drawn as results of observations were similar.

The analyser of the apparatus had parallel faces normal to the incident light so that no correction had to be made for reflection, and the light which passed varied directly as the square of the cosine of the angle between the prisms.

An artificial pupil of ·75 mm. was placed on the ocular side of the analyser and an iris diaphragm on the further side of the polariser; by the aid of a tangential screw and vernier the angle could be read to 4 minutes.

The observations were all made with a light adapted eye. Although I recognise the theoretical advantage of utilising an eye adapted to darkness, it was found that practical difficulties were too great when working with moderate or high luminosity. The time taken to make a series of observations would then be days instead of minutes, and during that time it is probable that the eye would alter considerably and on returning to a part of the curve which had been drawn early the new observations would be found not to lie on it, which, however, is not the case if the series is made within an hour.

The diaphragm on the ocular side of the analyser removes effects which might occur owing to alteration in the size of the pupil.

Exp. 1. Size of aperture ·5 cm. Breadth of sector, 12 cm.
Distance of eye from aperture, 8 cm.
Distance of light from aperture, 7·6 cm.
Source of light, 16 candle power lamp run at 135 volts instead of 100.
Zero reading of apparatus 0° 0′.

No. of alternations per sec.	Angle at which flicker just disappears	Sine of angle	$\frac{\text{Sine}^2}{4}$
34	2° 36′	·04536	·000513
36	2° 48′	·0488	·000595
43	5°	·0871	·00189
48	8° 40′	·1506	·00562
58	30°	·500	·0625
60	40°	·642	·1030

No flicker visible above this speed.

[1] *Œuvres de Fr. Arago* x. pp. 184—224. 1858.

Contrast these results with following observations where the only alteration was that the disc used had 60 sectors removed and the breadth of the sector was 1 cm.

Owing to the distance of the diaphragm from the disc the field was wholly light and wholly black only for a very short period.

EXP. 2.

Alternation per sec.	Angle	Sine	$\frac{\text{Sine}^2}{4}$
62	2° 28′	·0430	·0004622
73	2° 40′	·0465	·0005405
83	2° 52′	·0500	·000625
93	3° 8′	·0546	·000745
97	3° 28′	·0604	·000912
118	3° 36′	·0628	·000975
123	4° 4′	·0709	·001256
131	4° 20′	·0756	·001428
162	5° 32′	·0964	·002323
193	5° 48′	·1010	·002550
249	6° 0′	·1045	·002720
292	6° 36′	·1149	·003306
341	7° 12′	·1253	·00392
495	10° 36′	·1839	·008372

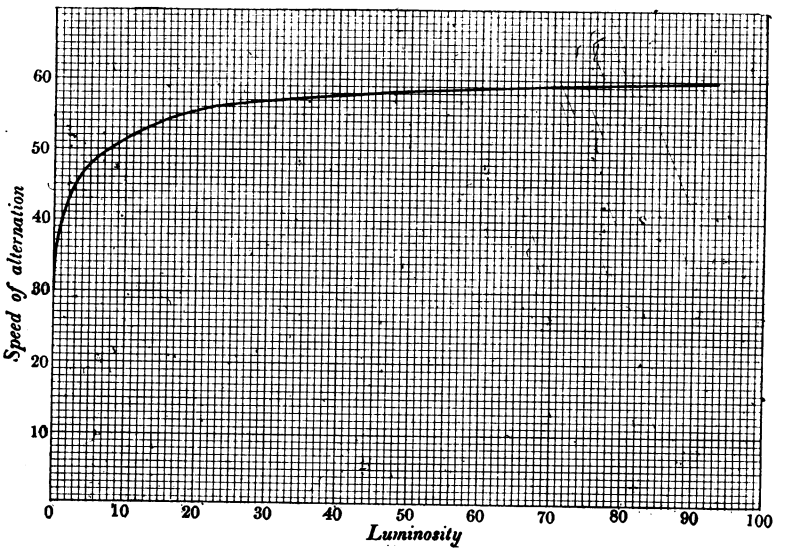

FIG. 1.

Scale of fig. 1 ten times that of fig. 2.

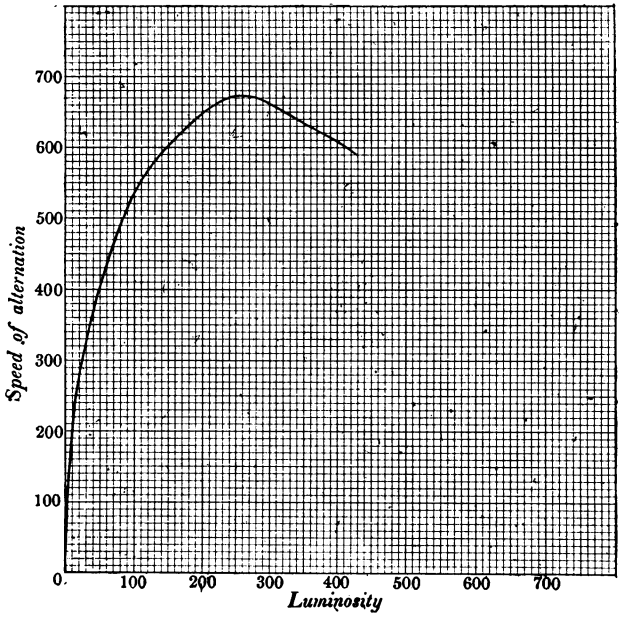

FIG. 2.

Intermediate curves exist for intermediate ratios and will be given in Part II.

The effect of the ratio of breadth of sector to that of the aperture is shown best by keeping the light constant and varying the breadth of the former.

Alternations to produce fusion	Breadth of sector	Diameter of aperture
43	11	1
44	6·1	1
49	4·6	1
53	3·8	1
112	1·8	1
225	1	1

What conditions are altered? Speed of translation, which entails an alteration in the ratio of the time during which the eye is exposed to light or darkness completely, and the time of transition is reduced. For instance, if a disc of 15 cm. radius be utilised and an aperture of 1 cm. the observations being made near the circumference, when a semicircle is rotated, the time occupied is $\frac{2}{2\pi \times 15}$ of a revolution, and therefore

the ratio is $\left(1-\frac{2}{2\pi\times 15}\right):\frac{2}{2\pi\times 15}$. Now by increasing the number

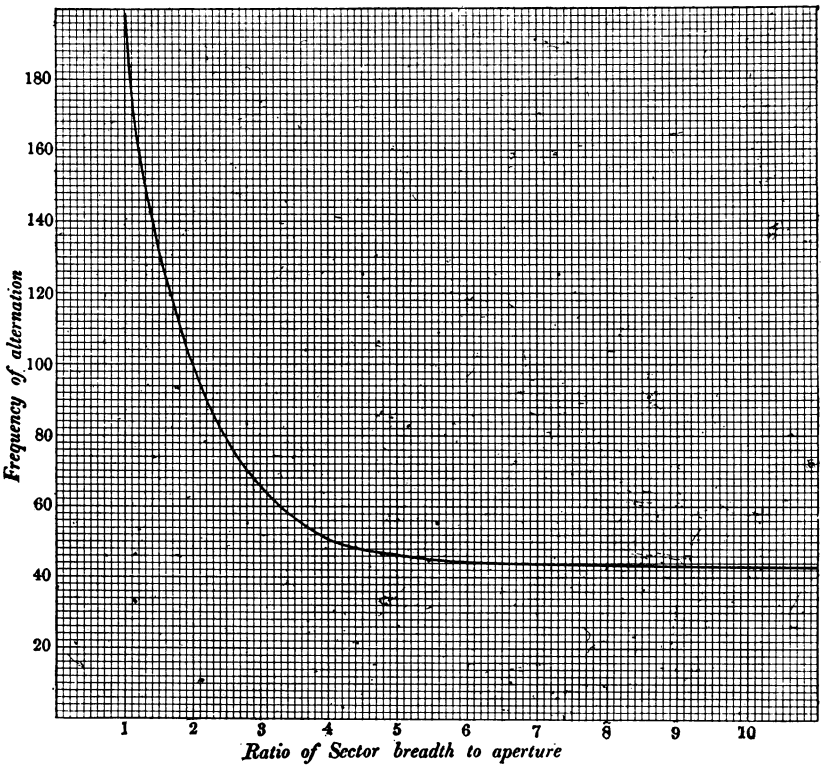

FIG. 3.

of sectors to a we get a ratio of $\left(1-\frac{2a}{2\pi\times 15}\right):\frac{2a}{2\pi\times 15}$, and therefore when $a=\frac{2\pi\times 15}{2}$ the ratio becomes unity and the time that the field is completely light or dark is infinitely small.

It seems to me improbable that any movement of the eye can occur when an aperture of 5 mm. is used and the eye focussed for a cross drawn upon the screen.

The effect seems to be due to simultaneous contrast which occurs when the field is partly light and partly dark; by increasing the time during which this can take place as in experiment 2, the sensation of a discontinuous source of stimulation persists until the frequency becomes

five or six hundred alternations per second. Recently Sherrington[1] has shown that flicker does not depend on frequency of alternation and physical luminosity alone, but also on apparent or physiological luminosity, and that simultaneous contrast as well as successive contrast plays an important part. It is due to this phenomenon I believe that the difference between the two curves fig. 1 and fig. 2 exists. Evidence in this direction exists in the following observation.

If a large disc be rotated and observations be made through two apertures of diameters proportionate to their distances from the centre, flicker appears and disappears at the same speed with the same luminosity at both apertures. This is only the case when the apertures are small so that their images fall entirely within the macula since the sensibility to intermittent stimuli of that part differs from the rest as shown by Exner[2] and Bellarminow[3].

From fig. 2 it is seen that the curve possesses an apex denoting that a sensation of continuous stimulation results if the luminosity be too small or too great: the nature of the descent of the curve I reserve until Part II., not yet having a sufficient number of observations. I may however state here that whatever be the ratio of sector-breadth to aperture the curve descends before the luminosity becomes such as to produce a blinding after-image of a pathological character.

[1] This *Journal*, XXI. p. 38. 1897.
[2] *Pflüger's Archiv* III. p. 237. 1870.
[3] *Archiv f. Ophthalmologie* XXXV. p. 25. 1889.

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