

ON THE USE OF THE FLICKER PHOTOMETER FOR DIFFERENTLY COLOURED LIGHTS.

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In recent years photometers of the flicker type have obtained a certain degree of prominence, and it is claimed for them that they enable the illuminating powers of sources of light of distinctly different colour to be compared with one another with an accuracy unattainable by means of photometers of the steady illumination type.

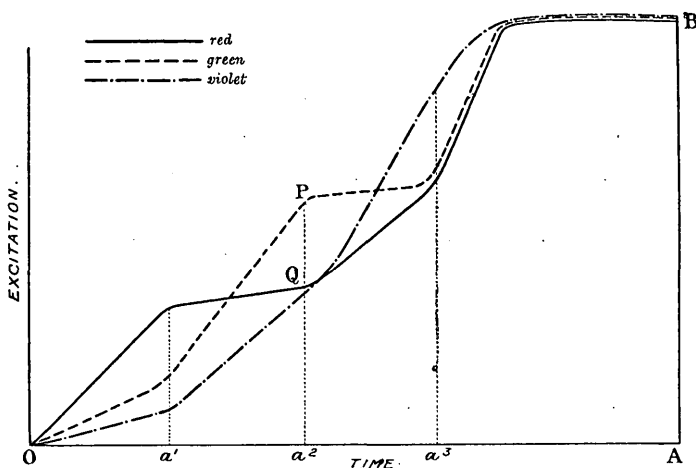
From time to time, however, suspicions have been raised as to whether the principle on which the flicker photometers are based does not involve physiological phenomena which disturb the conditions of illumination so that the numbers obtained are not a true representation of the illuminating powers of the sources to be compared. The exact rôle which the speed of rotation of the flicker head plays in the experiment is especially doubtful, while physiological evidence indicates that the effect is a very complicated one, and the simple theory of the flicker effect is not tenable.

The problem as to what actually happens in the retina when it is stimulated by steady or intermittent light is, of course, a physiological one, and in seeking for some generally accepted facts with regard to colour vision, we are met with the difficulty that the most eminent physiologists are hopelessly at variance. The physicist is accustomed to accept in a general way the Young-Helmholtz theory of three-colour vision, and the simplest physiological experiments seem to demand that the percipient structure of the retina involves two kinds of sensitive elements—the rods and cones. The rods are found in greatest numbers in the peripheral region together with a few cones, while in the small central region of clearest vision, the *fovea centralis*, the cones alone are present, the intermediate zone containing rods and cones intermingled.

The function of the rods is to perceive light of intensity insufficient to stimulate the cones, but they appear to be of a primitive type of sense organ, being capable only of one kind of sensation whatever the colour of the light falling on them. The cones on the other hand enable us to see in light which is bright enough to keep the rods in state of exhaustion. They have also the property of differentiating the various colours, the Young-Helmholtz theory assuming that they are of three

kinds specially sensitive to red, green, and violet respectively, any other colour being capable of being represented as a combination of these in suitable proportions. These assumptions enable one to explain many of the striking phenomena of colour vision such as the Purkinje Effect,* though recently doubts have been raised † as to their validity, and it is certainly significant that many of these effects (including the Purkinje Effect) have close analogies in the behaviour of a photographic plate towards coloured light. In this case a structure similar to that assumed for the retina seems excluded.

With every new theory of colour vision the physicist would have to change his starting-point in the explanation of phenomena like the flicker effect, and I suggest ‡ that a more stable foundation for a



physical theory is to be found in the experimental examination of the growth and decay of the retinal stimulus due to differently coloured lights, without any attempt to connect the form of the curves obtained with physiological theories which are admittedly of uncertain stability. The work of G. N. Stewart§ appears to afford us the necessary data. In reference to Talbot's law of the fusion of intermittent light stimuli, Stewart found that on observing the flashes of light reflected from a rotating mirror placed in a darkened room, a series of colour changes in the appearance of the image of the source took place as the speed of the mirror was altered. These changes take place at or under the speed necessary for the complete steady fusion of the flashes. The results are shown in the figure above.

* J. S. Dow, *Philosophical Magazine*, vol. 12, p. 120, 1906.

† E. Green, *Optical Society*, October, 1909.

‡ *Electrician*, vol. 63, p. 758, 1909.

§ G. N. Stewart, *Proceedings of the Royal Society of Edinburgh*, 1888.

The three curves represent the growth of the stimulus for red, green, and violet light. The time during which the light acts is measured horizontally, whilst the intensity of the excitation is given by the ordinates of the respective curves.

For a white light stimulus of long duration OA , the excitation of all three colours is equal, giving the sensation of white light. For stimuli of shorter duration, Ob , Oa , Oa_1 , the violet, green, and red excitations are predominant. The succession of colours in "after-images" as described by Helmholtz, Fechner, and others, is consistent with the assumption that the decay of the excitation follows a similar set of curves.

When the light stimulus consists of a series of short illuminations, we may therefore have different predominant tints according to the length of the stimulus and its frequency.

As these colours are observed with intermittent light when the frequency is about or under that required for complete fusion (*i.e.*, disappearance of the flicker), it seems difficult to avoid the conclusion that they will play an important part in the appearance of a flicker photometer head when used for comparing different colours.

Suppose we have adjusted the sources and speed of rotation so that the flicker has just disappeared and we have a balance. The flashes from either source considered independently evidently occur at a rate such that the excitation is not fully developed. If, for example, we were comparing a red and a green source and the duration of each illumination corresponded to Oa_2 , the effects *actually* being compared would be a red light of intensity $\frac{Q a_2}{A B}$ times the real intensity and a

green light whose intensity had been reduced by the ratio $\frac{P a_2}{A B}$, and though the appearance seen by the eye might be a steady illumination whose colour was that produced by mixing red and green light together, this can hardly be interpreted to mean that the actual brightness of illuminations at the flicker head has been adjusted to be the same. If the speed of the flicker head is altered, we shift the position of the ordinate we are considering, and shall then have to readjust the positions of the sources to regain the balance.

The same thing will apply when the sources are not pure red and pure green, but differently tinted lights, such as a carbon filament and a metal filament lamp, and this in practice leads to the results observed by Lauriol,* Wild,† and others.

Whatever may be the ultimate physiological explanation of the working of the flicker, I think the above discussion shows that the conditions under which the retina is excited during a measurement with the flicker type of photometer are not the practical conditions of illumination to which it is our object to apply the data we obtain from the experiment.

* *Bulletin de la Société Internationale des Electriciens*, vol. 4, p. 647, 1904.

† *Electrician*, vol. 63, p. 540, 1909.