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THE FLICKER FUSION FREQUENCY OF THE BLUE-SENSITIVE MECHANISM OF COLOUR VISION

BY G. S. BRINDLEY, J. J. DU CROZ AND W. A. H. RUSHTON
From the Physiological Laboratory, University of Cambridge

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SUMMARY

1. The flicker fusion frequency for blue stimuli on zero background increases steadily with increasing luminance up to 50 c/s, but if a strong yellow background is added it increases steadily only to about 18 c/s, and then remains nearly independent of luminance over a range of a factor of 20.

2. It is argued that the maximum flicker fusion frequency is about three times lower for the blue-sensitive mechanism of colour vision than for the red- or green-sensitive.

INTRODUCTION

The red-, green- and blue-sensitive mechanisms of human colour vision can be stimulated separately if a test stimulus of a colour that favours one of them is superimposed on a steady uniform background of a colour that chiefly stimulates the other two (Stiles, 1939, 1949), or if such a test stimulus is given soon after a very bright adapting stimulus of a colour that chiefly stimulates the other two (Brindley, 1953). When the mechanisms were first investigated by these means, the blue-sensitive was found to differ from the red- and green-sensitive in two properties: it had a higher Weber fraction and a much lower visual acuity. Brindley (1954) found a third distinction: for the blue-sensitive mechanism, complete spatial summation (Riccó's law) occurs for stimuli of diameter up to 12 minutes of arc, but for the red- and green-sensitive it does not occur above 3 minutes of arc. In the present paper we show that flicker fusion frequency is a fourth property in which the blue-sensitive mechanism differs from the others.

METHODS

The apparatus gave a flickering field of diameter 2° superimposed on a steady field of diameter 5°. Both were presented in Maxwellian view and both could be varied in luminance and colour by filters and a photometric wedge. The rotating disk had equal open and opaque sectors and was driven by a velodyne motor. In the flicker measurements the luminance of each field was set by the operator and the subject adjusted the motor speed to obtain liminal fusion when he fixated the centre of the flickering field.

The colour filters used were Ilford 205 (red; indistinguishable in hue and saturation from monochromatic light of wave-length 640 nm), Ilford 626 (yellow; indistinguishable in hue and saturation from light of wave-length 578 nm), Ilford 625 (green; indistinguishable in hue from light of wave-length 550 nm but a trace less saturated), and a liquid filter of cuprammonia (blue; indistinguishable in hue and saturation from light of wave-length 443 nm).

The authors were subjects. The pupil of the eye used was dilated with phenylephrine hydrochloride.

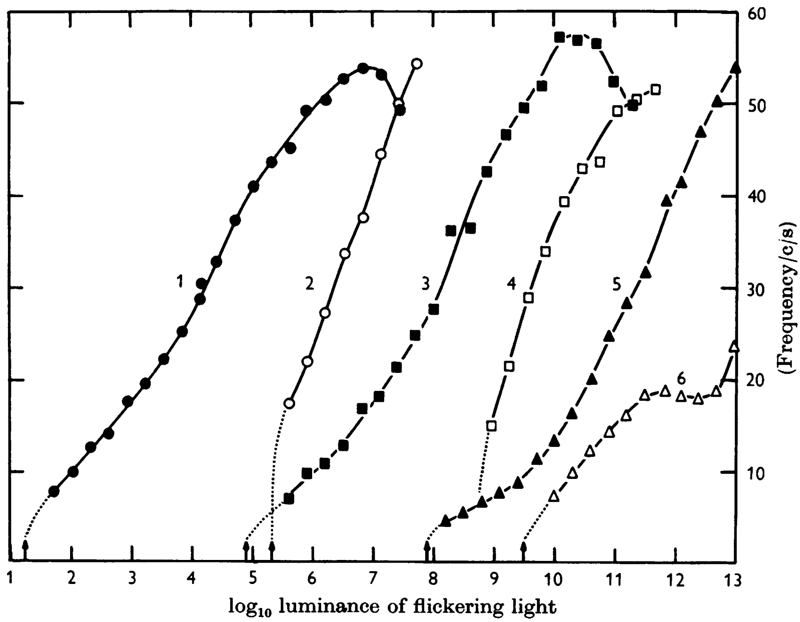

Fig. 1. The relation between the flicker fusion frequency and the luminance of the flickering light for one subject (G.S.B.). Filled circle: red flickering stimulus, no background. Open circle: red flickering stimulus, green background. Filled square: green flickering stimulus, no background. Open square: green flickering stimulus, red background. Filled triangle: blue flickering stimulus, no background. Open triangle: blue flickering stimulus, yellow background. The units of luminance are the same within pairs of curves (1 and 2, 3 and 4, 5 and 6), but differ arbitrarily for different pairs. Each arrow shows the threshold (absolute or incremental) corresponding to the curve that is joined to it by an interrupted line.

The effectiveness of the three backgrounds in raising the thresholds of the red-sensitive (π_5), green-sensitive (π_4) and blue-sensitive (π_1) mechanisms were determined by Stiles's increment threshold technique. They are (in decadic logarithmic units): red raises π_5 threshold by 4·45 and π_4 by 3·5; green raises π_5 by 4·45 and π_4 by 4·55; yellow raises π_5 by 4·5, π_4 by 4·55 and π_1 by 1·1. Each background gave a retinal illumination of roughly 10,000 trolands.

RESULTS

Figure 1 shows six curves of flicker fusion frequency plotted against the logarithm of the luminance of the flickering stimulus. Those for red, green and blue stimuli on zero background (curves 1, 3 and 5) are very similar except for the arbitrary horizontal displacement. When a constant steady background is added to a flickering stimulus, the usual effect is that the flicker fusion curve is unaffected at high luminances (where the background, even if absolutely strong, is relatively weak), greatly lowered at low luminances, and made uniformly steeper between. This description holds for most combinations of colours, for example, flicker of any colour on background of the same colour (as was shown by de Lange, 1958), red flicker on green (curve 2 of Fig. 1) or green flicker on red (curve 4 of Fig. 1). But when blue flickering stimuli are superimposed on a strong red, yellow or green background (e.g. curve 6) a new property appears: instead of rising smoothly to frequencies above 50 c/s, the curve levels off at about 18 c/s, and rises again only after having been horizontal for about 1·2 decadic units. Similar results were obtained with the other two authors as subjects.

DISCUSSION

Our observations are what would be expected if the relation between the flicker fusion frequency of the blue-sensitive mechanism and the luminance of the stimulus were nearly that shown in curve 6 of Fig. 1 (omitting its highest point) and if the three colour-receptive mechanisms acted independently of one another (or nearly so) in the detection of flicker. On these assumptions, the flickering of the blue stimulus throughout curve 5 is detected by the green-sensitive mechanism, perhaps with the help of the red-sensitive. When the steady yellow background is added (curve 6), the red- and green-sensitive mechanisms are so much desensitized by it that only the blue-sensitive remains capable of detecting the flicker, except at the highest luminance of blue flicker available, which gives a fusion frequency well above the 'plateau' of 18 c/s, and so is presumably stimulating the green-sensitive mechanism.

The above is the obvious explanation of our results, but there is one rival hypothesis that deserves brief mention. It might be supposed that in the unadapted eye the blue-sensitive mechanism is as good at resolving flicker as the red- and green-sensitive, but that its best performance falls to 18 c/s when flicker signals in it have to compete with strong non-flicker signals in the other pathways. This rival hypothesis can never be absolutely excluded by any experiment, since the blue-sensitive pathway cannot be isolated without the help of some kind of adaptation of the other two, but the following facts show how artificial it is. (1) It would need a very strong interaction between pathways, and Stiles's increment threshold experiments reveal no such interaction. (2) We find that the fusion frequency on the horizontal portion of curve 6 is not increased (it is probably a little decreased) by decreasing the luminance of the yellow background by a factor of eight, so if there is an interaction it must have a very odd relation to the strength of the stimulus. (3) No comparable interaction occurs between the red- and green-sensitive mechanisms, as curves 2 and 4 of Fig. 1 show.

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