The perceived brightness of a flickering moving spot

CLAUDE BONNET[1]
SORBONNE, PARIS

Ss judged the brightness of a flickering spot which moved along a circular track around the fovea. Perceived brightness was a decreasing curvilinear function of the length traversed during the intermittency of flicker. This function tended to be more linear as the duration of intermittency increased. These results are related to the linear positive function between CFF and the velocity of the flickering moving spot.

Miller, Anderson, & Simonson (1965) found a linear relation between the critical fusion frequency (CFF) and the velocity of an intermittent visual stimulus only when the image moved across the retina. This occurred while the S maintained fixation on a stationary point. Their explanation of these results involved the interaction of spatio-temporal cues, and particularly spatial factors (visual acuity) at high levels of velocity. In addition, numerous investigators (see Brown, 1966) have demonstrated that temporal cues are essential for both perceived brightness and CFF. The present experiment was a study of the interaction between spatial and temporal cues in order to relate them to perceived brightness and CFF.

Preliminary tests

As a first step, we verified the linearity of the relation between CFF and the velocity of the moving flickering stimulus. These unpublished results support those of Miller et al (1965).

Second, we verified the relation between perceived brightness and temporal cues. This control is necessary because of the large number of parameters involved in such a situation (see Brown, 1966). Above a critical time (about 0.1 msec) the product of perceived brightness (i) and the duration of stimulation does not remain constant according to Bloch's law.[2] Piéron (1961) has shown that beyond a critical time this product is a parabolic function of the duration of stimulation. In our experimental situation each stimulus flash had a constant duration (t_1). Consequently, in order to apply Piéron's law, the time parameter had to be changed. As a time index, we used the "duty cycle" which is defined as the ratio of the duration of one flash to the duration of the entire cycle. One S participated in the experiment which involved the general apparatus and method described below. However, there was no stimulus movement, though the spot was still presented in extrafoveal vision. Six frequencies were used ranging from 5 cps to 30 cps. This gave a range of intermittency duration (t_d) from 237 msec to 24.1 msec. The transformed Piéron's law involving the duty cycle appeared to fit the data. Next, these results were transformed in order to express perceived brightness (i) as a function of time of intermittency (t_d). This relation is presented in Fig. 1. With a constant flash duration, the perceived brightness is a decreasing (hyperbolic) function of the intermittency duration. This relation is given by Eq. 1 which is only another expression of Piéron's law.

$$i = a(t_d)^{-n}.$$

Having accomplished these preliminary controls we undertook the main experiment to explore the relation between spatial and temporal factors in perceived brightness.

Apparatus and method

The apparatus consisted of a variable frequency generator which produced square pulses in a neon lamp via an amplifier system. This lamp turned in a counterclockwise direction behind a plastic white screen (70 x 70 cm), and its speed of rotation was adjustable through an electronic variator. Stimulus movement never stopped but the sequences of intermittent light were timed at 2 sec. The S was seated in a dimly illuminated room with his eyes 60 cm from the screen. During the observation phases a headrest-chinrest combination served to stabilize his position, and a central black cross was provided as a fixation point. The moving spot (33 min of arc diameter) appeared around the fixation point along a circular track which was located at a radius of 6° from the center of the fovea. A nitometer (illuminometer) allowed the S to adjust the perceived

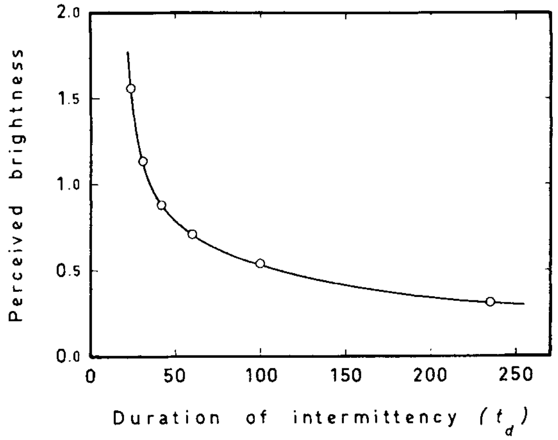

Fig. 1. Perceived brightness (ft-L) as a function of duration of intermittency (t_d).

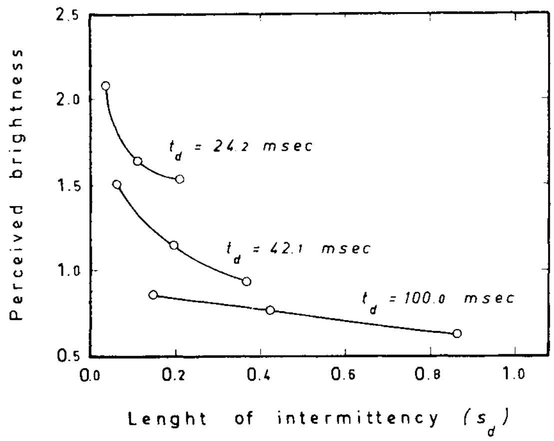

Fig. 2. Perceived brightness (ft-L) as a function of length traversed by the spot during intermittency (s_d). One curve for each level of duration of intermittency (t_d).

brightness of a non-moving spot to that of the moving one. He was free to move back and forth between viewing the screen and adjusting the nitometer. Careful fixation was restricted to the observation phase. Each measurement started with the brightness of the adjustable spot equal to the brightness of the background, when both were viewed through the nitometer. This gave a measure of the adaptation state of the eye. The mean threshold was 0.146 ft-L. This value was rather constant throughout the experiment and among Ss.

The parameters of the stimulus were its frequency and its velocity. They could be analyzed into spatial and temporal components. The time of one flash was constant ($t_l = 10$ msec). Then, with constant velocity a change in frequency was manifested as a change in the duration of intermittency (t_d) and as a change in the length (space) traversed during intermittency (s_d). Conversely, if the frequency was constant, changing the velocity altered the length traversed during one flash (s_l) and the length traversed during intermittency (s_d). A combination of three frequencies and three velocities was employed.

Four sophisticated Ss were used on several occasions. Each of them made four brightness adjustments in each of the nine situations.

Results and Discussion

The results are given in Fig. 2 where the mean adjustments in ft-L are plotted against the length traversed during intermittency.

No statistical test was applied because each curve is based on only three points. However, the trends are similar for every S. Namely, the perceived brightness of a flickering moving spot was a decreasing curvilinear function of the length traversed during intermittency. The degree of curvilinearity diminishes as the time of intermittency increases. This means that if perceived brightness is plotted against the time of intermittency, the relation is a curvilinear decreasing function which agrees with Pieron's law.

Because of the limited range of physical values, these results should be interpreted with caution. However, they seem quite coherent. Increasing the velocity of the spot increases the length traversed across the retina. With a constant time of intermittency, the physical energy during one observation time remained constant, but as the distribution of energy on the retina became larger, each retinal point received less and less energy. Furthermore, it can be postulated that the amount of physical energy per retinal point is inversely proportional to the spatial distribution of this energy. If perceived brightness is only a function of physical energy per retinal point, then perceived brightness has to be a hyperbolic function of spatial distribution. This argument must also consider the hyperbolic function between perceived brightness and duration of intermittency (see Eq. 1). The interaction of these two factors could explain the results in Fig. 2 but exact quantitative predictions cannot be made.

Another approach would be to relate this result to the relation between CFF and velocity. Analyzing the parameters of this situation, one could say that increasing the length traversed by the spot will decrease (1) the critical time of intermittency needed for fusion, and (2) the perceived brightness. Then the former could be partly a consequence of the latter, or more probably (see Brown, 1966) they both depend upon the same factors. Thus, further analysis of the spatio-temporal parameters are necessary to determine their exact interaction.

References

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Notes

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2. In photochemistry this is called the Bunsen-Roscoe law.