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TWO-FLASH THRESHOLDS AS A FUNCTION OF COMPARISON STIMULUS DURATION

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I. Problem.

The recent proposal to approve use of strobe lights for collision avoidance instead of the rotating beacon suggests that the luminance requirement for collision avoidance lights is inappropriate for light flashes shorter than the critical duration of Bloch's law. According to Bloch's law, flashes of constant luminance (L) but different duration (t) are of equal brightness only when the durations of the flashes exceed the critical duration (t_c), generally taken to be 100 msec. ($L=C$ when $t>t_c$). When the flash durations are shorter than the critical duration, equal flash brightness is achieved with equal flash energies, the product of luminance and duration ($L \times t=C'$ when $t \leq t_c$).[2] Thus, for strobe lights producing flashes shorter than the critical duration, the luminance requirement should be increased to produce flash energy equivalent to that obtained when the luminance is presented in a flash that exceeds the critical duration. Consequently, it is essential that the value of the critical duration for human vision be accurately known. However, recent studies of two-flash thresholds have indicated that the critical duration may be much shorter than the 100 msec. value generally cited.[7 10] The current study was undertaken to determine whether the suggested shorter critical durations are valid.

Based on Davy's[5] finding that in peripheral vision temporal discrimination ceases when flashes are wholly presented within the critical duration (t_c) of Bloch's law, it was proposed[9] that two-flash thresholds may be used as direct measures of the critical duration. If responses are equal to equal energy stimuli that are shorter than t_c, then two-flash thresholds should be invariate with changes in the duration of comparison stimuli as long as these comparison stimuli are shorter than t_c. Increases in the duration of comparison stimuli beyond t_c should produce increases in the two-flash thresholds.

Nilsson[11] examined the discrimination of two-flash stimuli as a function of the duration of the comparison stimulus. In a three-stimulus forced-choice situation, he measured, for each comparison stimulus duration, the probability of correct discrimination as a function of the difference in duration between comparison and test stimuli at three luminances. Nilsson's results indicate that two-flash thresholds are an increasing function of the comparison stimulus duration. Nothing about critical durations may be inferred from these data; since test stimuli were varied in 15 msec. steps, the possibility of detecting critical durations less than 15 msec. was excluded.

Past work on the effect of luminance on two-flash threshold has indicated that there is a small effect of varying stimulus luminance above about 1.0 log mL.[7 9] The current experiment also reexamines effect on two-flash threshold of varying luminance in the range between 1.0 and 3.0 log mL.

II. Method.

Subjects. The two male subjects (*S*s) had normal acuity; one (BR) with correction. Both *S*s had previous experience in a similar experiment, but neither was familiar with the purpose or design of the current experiment. Both were screened for color vision deficiency on a battery of tests that included the A.O.-H.R.R. and Dvorine plates, the Farnsworth-Munsell 100-hue test, the Farnsworth Dichotomous (Panel D–15) test, and an anomaloscope examination. No evidence of color deficiency was found.

Apparatus. The apparatus, previously described[9] included a Maxwellian view optical system with a Sylvania Glow Modulator tube used as a light source, and associated Iconix logic for control of stimulus duration. Luminance was calibrated with an SEI Exposure Photometer using a method described earlier.[8]

Procedure. The procedure adopted was a variation of the Block Up and Down Two Interval Forced-Choice (BUDTIF) method described by Campbell,[3] the method modified for a random double staircase.[4] After dark adapting for 10 min., the *S* adjusted the intensity of four fixation lines until they were just visible and, on an auditory ready signal, pressed a button to start a trial. A low intensity one-half sec. duration white noise defined three observation intervals which were separated by one-sec. intervals. A pair of one-msec. flashes was presented at the end of each observation interval: In two intervals a comparison pair was presented with an interflash interval that was constant on all trials of a session and of 1, 2, 5, 7, 10, 15, or 20 msec. in duration, thus producing comparison stimulus durations of 3, 4, 7, 9, 12, 17, and 22 msec., respectively; in the other interval a test pair with a variable and always longer interflash interval was presented. A comparison stimulus was presented in the first observation interval, while test and second comparison stimulus alternated randomly from trial to trial in the second and third observation intervals. On each trial, *S* was instructed to report in which interval, the second or third, the different stimulus most likely occurred. He was told to use any characteristic (apparent duration, brightness, color, etc.) of the flashes which he found useful to make the discrimination. The *S* used two push buttons to indicate his choice and was informed of the accuracy of his responses by a noise that came on momentarily following correct responses.

Within each staircase, the stimuli were presented in blocks of four trials with a minimum intertrial interval of 20 sec. The interflash interval for the test stimulus was changed according to the following rules: If the subject was right more than three times in a block of four trials, the interflash interval was decreased by one msec. If *S* was right exactly three times, the test stimulus was unchanged. If the *S* was right less than three times in a block of four trials, the interflash interval was increased by one msec. Two independent staircases were run, one starting at a short interflash interval, the other at a relatively long interval. On any trial, the particular staircase which was presented was randomly determined. Thirty blocks of four trials in each of the two staircases comprised a single session. Each session lasted approximately 120 min. Under each condition (of constant luminance and comparison stimulus duration), the staircases were maintained across sufficient sessions for stable estimates of threshold to be achieved; the staircases were miantained across at least three sessions at each condition. The mean interflash interval for the last two sessions at each luminance and comparison stimulus duration was taken to be the threshold.

The luminances used were 1.0, 2.0, and 3.0 log mL. The random order in which each combination of luminance and comparison stimulus duration was selected for testing was different for each *S*.

III. Results and Discussion.

The results are given in Figure 1 with two-flash threshold plotted as a function of comparison stimulus duration. Luminance is the parameter. The data indicate that two-flash threshold, over the range of durations tested, is an increasing function of comparison stimulus duration at all luminance levels and the amount of increase in two-flash threshold is an increasing function of stimulus luminance. Stimulus luminance also has a significant effect on two-flash threshold with thresholds doubling between the 1.0 and 3.0 log mL. levels in contrast to the smaller effects observed previously.[7, 9]

In general, the data indicate that it may be inappropriate to apply the critical duration of Bloch's law to two-flash thresholds. That is, the discriminations made among equal energy stimuli need not reflect processes which determine threshold responses[5, 6] or responses to brightness criteria[1, 8] at different durations.

The current study indicates that the previous suggestions of critical durations shorter than 100 msec. are not valid. Consequently, in specifying brightness requirements for anticollision lights, an energy requirement is appropriate when flash duration is shorter than 100 msec. Although the current study indicates that well trained *S*s may discriminate among equal energy flashes, the departures from Bloch's law are not great enough to justify variation from a Bloch's law requirement for flash specification.

Previous research[8, 10] suggests that Bloch's law is applicable for the specification of anticollision light luminance. The results of the current study imply that deviations from Bloch's law are rela-

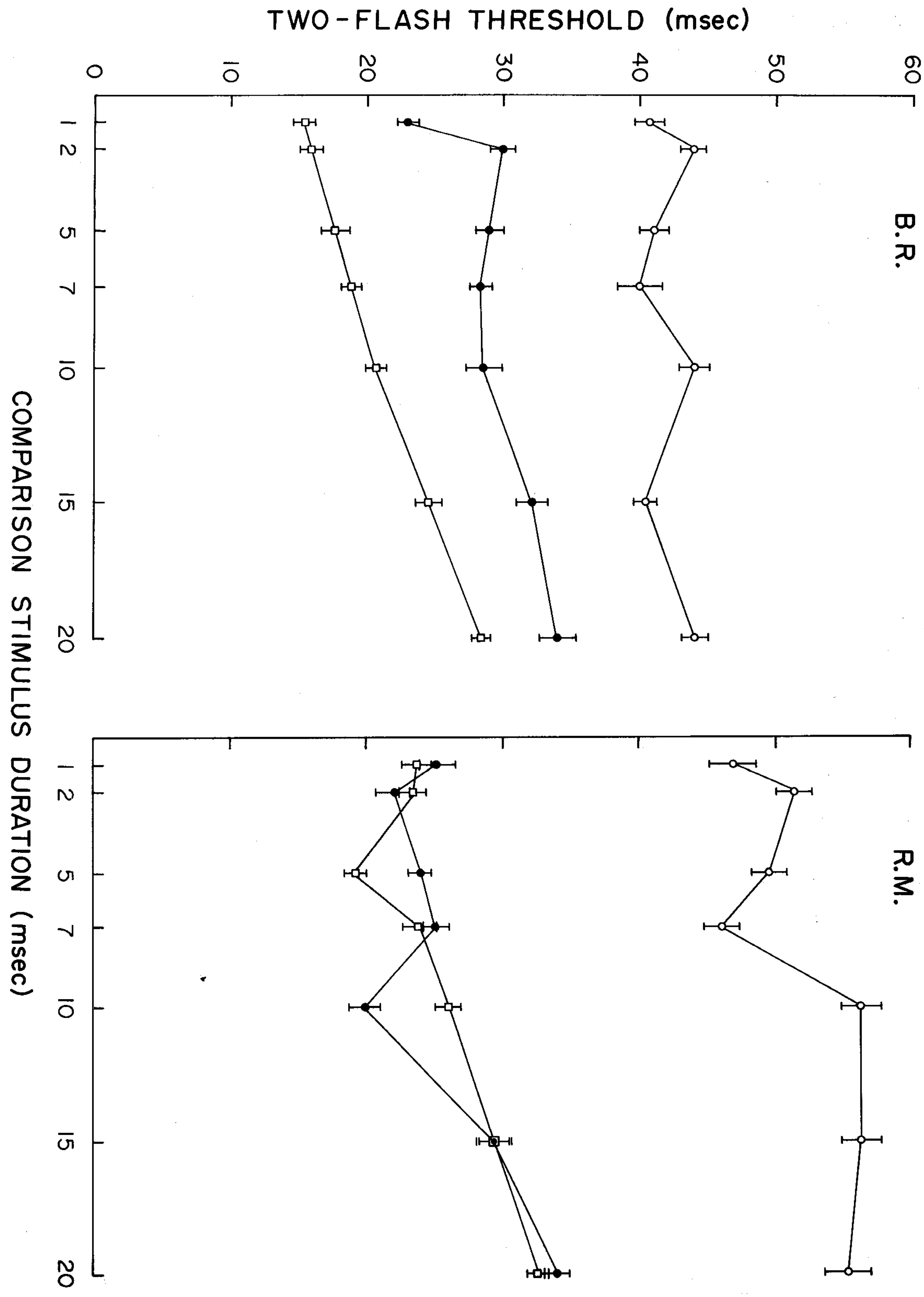

FIGURE 1. Two-flash thresholds as a function of comparison stimulus duration at three luminance levels. Luminance levels of 1.0, 2.0, and 3.0 log mL. are designated by open circles, closed circles, and squares, respectively.

tively insignificant. We conclude that use of a Bloch's law specification reflects a more general retinal process than does the current use of the Blondel and Rey[12] empirical equation.

Conclusions:

1. Two-flash thresholds are an increasing function of comparison stimulus duration over the range investigated.

2. The extent to which two-flash thresholds are affected by comparison stimulus duration is reduced by decreases in luminance.

3. The previous finding that two-flash thresholds are a decreasing function of luminance has been replicated at all values of comparison stimulus duration. This effect was larger than previously observed.

4. When strobe lights are used as collision avoidance lights, the luminance requirement should be increased to produce flash energy equal to that produced by equal luminance flashes of 100 msec. duration. When the flash duration exceeds 100 msec., the luminance requirements is appropriate.

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