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Evoked Potentials and Correlated Judgments of Brightness as Functions of Interflash Intervals

Abstract. *Computer-averaged evoked potentials were recorded from subjects presented with pairs of flashes having equal light energy but differing in duration of the brief interval separating the flashes. For the experimental conditions studied, the pair was always subjectively fused. Although the brightness did not change noticeably as the interval was varied, the use of the forced-choice psychophysical technique showed that apparent brightness declined with increase in the interval. Analysis of the evoked potentials revealed a correlated change in amplitude and wave form previously demonstrated for changes in flash flux alone.*

Bloch's law (the reciprocal relation of luminous flux and duration) applies for visual thresholds for detecting a flash, so long as the duration remains below a critical value. At least for durations less than 1.5 msec Brindley (*1*) has demonstrated its applicability also to the judgment of brightness of suprathreshold flashes. However, in a study in which flashes of various durations were matched for brightness with a standard 200-msec flash, Katz (*2*) noted an apparent departure from reciprocity as the duration of the test flash was increased from 8 to 25 msec. Wicke, Donchin, and Lindsley (*3*) published records of evoked potentials for foveal stimulation as luminance and duration of the stimulus flash were varied; in commenting on their records they emphasize that, although the latency appeared to be determined largely by the luminance, the wave form and amplitude of the average evoked potentials appeared to depend instead on the product of luminance and duration. Thus, by inference from Bloch's law, wave form and amplitude are closely related to perceived brightness when duration is varied below the critical value. In our study the effects on specific components of evoked cortical potentials were determined for stimuli comprised of pairs of brief flashes (10 μsec) of the same light energy but with different intervals between the flashes in each pair. We further determined whether such changes in the evoked response resemble those found with change in flash flux alone. Over the range of intervals studied there was no obvious difference in the apparent brightness of the fused flash pairs, but forced-choice judgments revealed the brightness order in which they fell.

The recording apparatus is described in detail elsewhere (*4*). Briefly, a Mnemotron computer of average transients was fed directly by an Offner type R dynograph equipped with a type 9806A input complex. Occipital cortical potentials were recorded with monopolar electrodes. The active electrode was 2.5 cm above the inion and 2.5 cm to the left of the midline. The reference electrode was attached to the left ear lobe. The computed average potentials from a set of stimulus presentations was recorded on graph paper with a Moseley X-Y plotter, model 2D2. The gain settings on all components of the recording system remained fixed during the study.

Flashes were presented to the right eye by a Grass photostimulator, model PS-2, mounted flush against a window (7.5 cm square) of an electrically shielded room. The subject sat inside the room with his eye approximately 90 cm from the window. One-half of a table-tennis ball was secured over his eye, its edges taped to the skin, thus rendering the flash stimulus a ganzfeld—that is, filling the entire field of vision. A low-level prevailing ganzfeld was provided by light from a projector, with filters, coming through a second window immediately below the first. The constant background was such as to raise the flash threshold about one-tenth logarithmic unit above the level found with full dark-adaptation. The photostimulator was operated at scale 1 (the lowest level) with no filters in some trials and with a 90-percent neutral-density filter for others. With no filters, stimuli were approximately four logarithmic units above threshold. All tests were run with a background of white noise well above the level required to mask clicks from the photostimulator.

Each subject was dark-adapted before being tested. Three subjects served in both phases of the experiment, and another was used only in the psychophysical judgments.

Tests were conducted in two phases. In the first, a train of three pairs of flashes, each pair having a different interflash interval, was presented after a "ready" signal. The subject indicated which pair was brightest, even though he may have felt that he was merely guessing. Intervals between pairs of flashes were approximately 2 seconds. Interflash intervals within pairs were 9, 16, and 25 msec; the order of the pairs in a trio was varied from trial to trial, according to a balanced design for a block of 27 trios. Two blocks, or 54 judgments, were recorded for each of the two flash luminances in a day.

In the second phase, evoked potentials were recorded for pairs of flashes having interflash intervals of 9 or 16 msec; no filter was used over the photostimulator. All four channels of the computer were used, two for the 9-msec condition and two for the 16-msec condition; thus we could check the reliability of the findings. Responses were recorded for 25 flash pairs, all of a set having one interflash interval (separation); 25 were then recorded for the other interval, in *A-B-B-A* order, until 100 responses

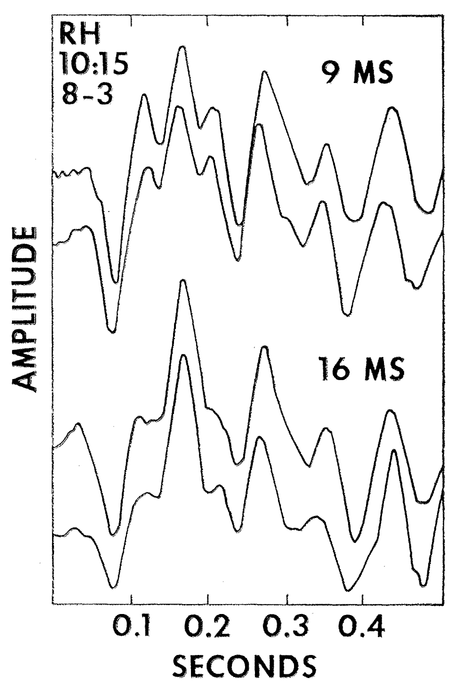

Fig. 1. Evoked potentials obtained in response to fused flash pairs with interflash intervals of 9 and 16 msec. Onset at start of trace, each trace representing the summation of 100 flash pairs in one channel of the computer. All four records obtained during a single session, in counterbalanced order, as described in text. Negativity downward. Equal gain-setting in all four channels.

Table 1. Judgments of the brightest pair of flashes in a trio.

Subject	Interflash interval (msec)			N
	9	16	25	
	With filter			
E	76	23	9	108
H	72	32	4	108
L	175	35	6	216
S	67	29	12	108
	Without filter			
E	84	14	8	106
H	63	30	15	108
L	147	42	27	216
S	65	25	18	108

Table 2. Number of times (of 16 comparisons) the pairs of flashes with 9-msec interflash intervals produced amplitudes greater than those with 16-msec intervals.

Subject	Ordinate		Measured (sum of 10)
	120	210	
E	12	15	15
H	14	14	16
L	15	15	15

were obtained for each channel. (For example, if channels 1 and 3 were used for 9-msec separations and channels 2 and 4 for 16-msec separations, the recording sequence would be 1-2-4-3, repeated four times.) The computer stored and averaged the output of the Offner over the 0.5-second interval initiated by the first flash of each pair. Flash pairs followed one another at intervals of 1.1 seconds. Six to eight flash pairs were presented before each set was recorded. Four complete sessions as described were run with each subject.

The data for the first phase (Table 1) show that pairs of flashes with 9-msec interflash intervals were most frequently judged to be brightest, pairs with 25-msec interflash intervals were judged as brightest least frequently. Simple statistical tests (chi square) show the finding to be significant for each of the four subjects at each of the two luminances. Thus, although the subjects were "guessing," forced judgments indicate that the sensory response varied as a function of flash separation. For this method of stimulus presentation, wherein light is not continuously present for a given interval of time, Bloch's law seems to be valid only as a first approximation.

Figure 1 illustrates the nature of the differences in the evoked potentials obtained with the 9-msec and the 16-msec interflash intervals during a typical recording session. The two top tracings represent the 9-msec condition, while the two bottom tracings represent the 16-msec condition. Differences in the overall wave forms, representing differences in the relative amplitudes of the various components of the complex response pattern, are evident for the two conditions.

The records were analyzed by measuring amplitudes at certain points in time following the onset of stimulation. Three such indices of response amplitude were agreed upon before the experiment was performed, this choice being based on the results of previous studies in our laboratory in which flash luminance was varied systematically. One index was the trough-to-peak amplitude between the large negative peak at a latency of about 80 msec and the positive peak at about 120 msec; a second was the trough-to-peak amplitude for the positive peak at about 210 msec; and the third was the sum of the ordinates, again from the 80-msec trough as a baseline, as measured at 20-msec intervals from 60 to 240 msec. Thus the last was the sum of 10 ordinates specified by latency. Then each index was compared with the corresponding index for each of the two recordings of the evoked potential for the alternative interflash interval in the same block. Thus four comparisons were made in each of the four blocks for each subject. For most of the comparisons (Table 2), the pairs with the shorter interflash interval show the larger index. Application of the sign test shows that the differences found are statistically significant at a high level of confidence.

These findings, obtained with the average-response computer, attest to the power of this technique for studying the relation between neural and sensory events; it was necessary to employ what is probably the most sensitive psychophysical technique available in order to establish the relative brightness of the various fused flash pairs.

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Some Kinetic Properties of a Deterministic Epidemic Confirmed by Computer Simulation

Abstract. *Representative epidemic transients were generated by computer by a known, plausible mechanism. Accurate retrieval of the individual rate constants and confirmation of their predictive value resulted from a manual test of the mechanism by which the computer outputs were generated. The method is applicable in principle to any regenerative process opposed by exponential decay.*

Muench (*1*) has discussed the applicability of certain deterministic models to epidemiology. His treatment deals, however, with the properties of an already established endemic steady-state, and not with the transient behavior that typifies the true epidemic. Muench's work, if read without proper attention to this distinction (*2*), can lead to the unrealistic conclusion that the rate of growth of an epidemic should be greatest at the moment of its birth.

Bailey (*3*) has described a model that acknowledges the need for an autocatalytic component in the propagation of an epidemic outbreak, but incorporation of the opposing process of extinction required to account for its transience leads to a set of differential equations that appears not to have a general analytic solution. The approximation that Bailey presents is of little or no use as a mechanistic criterion, and probabilistic treatment of the same (*4*) or an even simpler (*5*) model leads to similar (*6*) and equally cumbersome results.

A test for consistency between the Bailey model and a given set of experimental data requires a method for calculating separate numerical values for the two specific rate constants for the processes of infection and recovery during a significant part of the duration of the epidemic. The same mechanism should, by definition, also be applicable to the dynamic behavior of other real systems whose parts likewise appear by self-replication (*7*) and disappear by 1st-order attrition (*8*); it seems desirable, for this reason, to describe here a simple, graphic method by which the required mechanistic test can be performed on suitable experimental data, and to assess the predictive usefulness of the resulting rate constants by analysis of a computer-simulated Bailey epidemic. The epidemiologic context