NAS-National Research Council Committee on Vision Meeting, April 23-24, 1964 in Washington, D.C.

20 P.

N65-29381

(ACCESSION NUMBER)

20

(PAGES)

TMX-51978

(NASA CR OR TMX OR AD NUMBER)

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Visual Masking Using Different

Test Stimulus Patterns[1]

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Temporal delay in human visual processes assumes a greater importance as the velocities at which we travel increase. In fact, at very high velocities an observed event can occur and be past before the observer is even aware that he saw the event. This visual latency increases under conditions of low illumination. The data from the present study can give some idea of how visual latency increases as object luminance decreases.

One approach to the study of visual perceptual latencies is by means of a visual phenomenon which in this study shall be called visual masking. This same phenomenon has been studied under various names. It was called masking by Piéron (1925), rapid light-adaptation by Boynton and Kandel (1957), perceptual blanking by Lindsley (1961), and perceptual interference by Kietzman (1962) and Boyle (1963). For this study the term visual masking refers to the gradual reduction of correct responses as to the orientation of a patterned test stimulus as the temporal interval between the test stimulus and a succeeding brighter masking stimulus is decreased. In the present study a latency model of visual masking was used to explain the obtained results. It has been stated by Cheatham (1952) and Kietzman (1962) that a latency model of visual masking cannot explain the divergent results which are obtained when using different test stimulus patterns under otherwise similar conditions. It is the thesis of this experiment that even though the constants of an equation based on a latency model of visual masking may vary some with different test stimulus patterns, the variation, despite its significance, will be relatively minor and the equation will retain its general latency form.

Method

Apparatus.- Figure 1 shows a block diagram of the experimental system.

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Insert Figure 1 here

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Fourteen numbered program steps and the four test slide positions are pre-punched on paper tape and operate through the relay logic block to present the various conditions. The neutral density filter selector servo system is controlled by external panel controls. The test stimulus positioning servo system is directly controlled by the prepunched paper tape. Activation of the presentation switch by the subject starts a timing counter, begins the pulse generator, and prepares the tape reader to advance the paper tape to the next position. To indicate the test stimulus direction, the subject activates a four-position response switch which stops the timing counter and initiates test stimulus repositioning. The preselected stimulus position, the subject's selection of the stimulus position, and his

[redacted]

response latency (mainly to insure that the subject is not drowsy) are printed out on the digital printer. The buzzer informs the subject when the presentation switch is rearmed. The optical and monitor system is shown in Figure 2. The optical system consisted mainly of a monocular

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Insert Figure 2 about here

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Maxwellian-view optical system, with Sylvania R1131C glow modulators as light sources, and a red fixation-light source. The pulse generator initiates the pulses which "fire" the glow modulators, GM_{TF} and GM_{BF}. These in turn are activated by an ultraviolet source (UV) to eliminate erratic operation of the glow modulators in the dark. The filters F_1 and F_2 eliminate visible light from the ultraviolet light source.

Glass slides M_1 and M_2 reflect a portion of each light beam to a photomultiplier (PM) which permits equating the luminances of the two light sources by means of an oscilloscope (CRO). Beyond M_1 and M_2 the light beams are collimated by lenses L_1 and L_2 (508 millimeter focal lengths). F_4 is a filter holder for neutral density filters, and F_3 represents a pair of servo controlled filter wheels in the light path of the test flash. Similarly, S_2 is the fixed reticle holder for the blanking stimulus and S_1 is the servo controlled reticle holder for the test stimulus. The blanking flash beam is reflected at 90° from itself by means of a pentaprism (P), combined with the red fixation pattern (S_3) at glass slide M_4, and is superimposed upon the test flash beam at a beam splitter (BS). This combined beam is then focused upon the cornea of the subject's eye by lens L_3 (508 millimeter focal length) through a 3.65 millimeter artificial pupil (S_4).

To insure that the illumination is always set at the same level, a calibration circuit (CAL) is incorporated in the system. A beam of light is passed through a chopper and is reflected from mirror M_3 onto the photomultiplier (PM). Mounted on M_3 is a cadmium sulfide photocell which is one leg of a bridge circuit. The light source is varied until a zero reading is obtained from a meter in the bridge circuit. Then the amplitude of the calibration light source can be determined from the oscilloscope, and the test and blanking flash amplitudes are set at this same level.

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Insert Figure 3 about here

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Figure 3 shows the various reticles used in the experiment. A, B, and C are the three equal area test stimuli used, E the blanking flash stimulus, and D the fixation pattern. Each test slide has four positions, up (|), down (—), left (╲), and right (╱). As seen by the subject the blanking flash is superimposed upon the test flash in the open central area of the fixation pattern. The visual angle subtended by the test and blanking flashes was $1^{\circ}42'$. Both stimuli were effectively square waves of 10 milliseconds in duration with luminances of 4358 millilamberts for the blanking flash and 2566 millilamberts for the test flash (no filters) as measured at the plane of the subject's eye by means of a Pritchard Photometer. The red fixation pattern was easily visible and was present continuously throughout the session.

Subjects.- The three subjects who were studied were Moffett Field Naval personnel. They were all trained on all three test stimuli over a two-week period. All three had emmetropic vision with 20/20 visual acuity or better for the right eye as measured by a Bausch and Lomb Ortho-Rater. Throughout the experiment each subject used only his right eye.

Procedure.- A given subject aligned himself in the apparatus and dark adapted for 10 minutes. At the end of this time a ready signal was given and, when he was prepared, the subject could initiate the signal presentation by pressing a hand-held switch. The subject's task was to identify the position (up, down, left, or right) of the test stimulus. He had to indicate his response each time by means of the four-position response switch or the programmed tape would not advance to the next step. Two conditions were run during each session. Generally the conditions were randomized except that one test stimulus pattern was completed before a new test stimulus pattern was begun. Each condition consisted of a preliminary warm-up run of 12 presentations, followed by six more runs of 23 presentations each with a minimum of 7-1/2 seconds between presentations. The first 3 presentations of each run were eliminated from the data as they were for light adaptation purposes only.

The dependent variable was per cent of correct responses (0 to 100 per cent) corrected for a 25 per cent chance level. The independent variables were test flash luminance (1.61 to 5.61 log microlamberts in six 0.1 log neutral density filter steps for each condition), test stimuli forms (three), and the interval between test and blanking flash onsets (10, 13.5, 18, 26, 39, and 70 milliseconds). The blanking flash luminance was 6.64 log microlamberts. Each condition was repeated three times and these were averaged to obtain a better estimate.

Results

Preliminary data are shown in Figures 4, 5, and 6. From Figure 4 it

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Insert Figures 4 and 5 about here

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can be seen that visual masking decreases as test flash luminance is increased or as the interval between the test and blanking flashes is increased. Figure 5 gives the same data as in Figure 4 but for all three test stimuli. It can generally be seen that the coarse grating is most easily seen while the rectangular form is generally the hardest to see.

Test flash luminance values were taken from all of the curves of Figure 5 at the 50 per cent correct level. These are the points plotted in Figure 6. A preliminary equation was fitted to each set of these data

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Insert Figure 6 about here

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and these equations are included in Figure 6. The smooth curves were plotted from values that were calculated from the equations. When the data are plotted in the form of Figure 6, it can easily be seen that as the test flash luminance is increased the interval between stimulus onsets must be decreased in order to operate at the same level of performance (50 per cent correct). It should also be noticed that all three curves are quite similar to each other.

Discussion

The equations derived from the data were based upon a latency model. In other words, it was hypothesized that the time interval between stimulus onsets could be determined from the difference between some inverse function of the test flash luminance and the blanking flash luminance (see equation (2)). A schematic of this model is shown in Figure 7. If one

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Insert Figure 7 about here

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imagines an electrode implanted in the brain to measure evoked potential latencies at the point where visual masking occurs, TF refers to the time the test flash was initiated, and T_{TF} to the latent period after which an evoked potential (TF_e) to the test flash appears. D refers to the time after the test flash (TF) was initiated that the blanking flash (BF) was initiated, and T_{BF} is the latent period after which an evoked potential (BF_e) to the blanking flash appears. $(\Delta T)_i$ refers to the time differential between test flash and blanking flash evoked potentials under visual masking conditions. $(\Delta T)_i$ is assumed to vary directly with per cent of correct responses. The entire relation can easily be stated in mathematical form.

$$D = T_{TF} - T_{BF} + (\Delta T)_i \tag{1}$$

$$= f\left(\frac{1}{I_{TF}}\right) - f\left(\frac{1}{I_{BF}}\right) + f'(Z) \tag{2}$$

D is the interval between test and blanking flash onsets, I_{TF} is the test flash luminance, I_{BF} is the blanking flash luminance, and Z is per cent correct (corrected for chance) converted to standard score form. The equations shown on Figure 6 follow the latency form of equation (2). The constant on the right would be some inverse function of blanking flash luminance (Boyle, 1963) if that parameter had been varied.

In Figure 6 there is probably a significant difference between at least the coarse grating curve and the other two curves. This would indicate that the neural interaction between test and blanking flash evoked potentials is dependent upon the form of the test stimulus. This could be expected because slightly different retinal elements are activated by the different test patterns even though the over-all test pattern areas are equated. Nevertheless, as hypothesized, it should be noticed that all three curves are very similar to each other. This is also verified by the equations on Figure 6 in which the differences between the various constants of the equations are relatively minor and all of the equations have the same general form.

Another point of interest is that when the data are plotted in the form of Figure 6 an approximate idea can be obtained as to how long it takes the human eye to perceive a given object over a wide range of object luminances. Transposing the terms of equation (1) to obtain

$$T_{TF} = D + T_{BF} - (\Delta T)_i \qquad (3)$$

and assuming some low value of per cent correct, one or below, $(\Delta T)_i$ can be assumed to be zero or close to zero. Therefore, if a value was known for the evoked potential latency of the blanking flash (T_{BF}), then the evoked potential latency of the test flash (T_{TF}) could in effect be determined. From work with humans, Ciganek (1961) has determined that a value of 28.6 milliseconds would be the minimum latency of a visual evoked potential for a very bright stimulus which filled the entire eye. For the small foveal blanking flash used in this experiment, although very bright, this is too small a figure and therefore quite conservative. Accordingly, it would take longer to perceive a visual stimulus than the following figures would indicate. There is also an unproven assumption about the relationship between evoked potentials and the phenomenon of visual masking when any recorded value of evoked potential latency is used. Referring to the one per cent correct level in Figure 4 and keeping the above limitations in mind, adding 28.6 to 70 would give 98.6 milliseconds as the time required to see a foveal stimulus just one per cent of the time very near to the absolute threshold of the test stimulus. Even with the same test stimulus 2.6 log units above this threshold, it would still take 38.6 milliseconds to perceive the stimulus. These latencies could have important ramifications for the operation of very high velocity spacecraft. As an example, at a velocity of 30 feet per millisecond, which is in the order of the velocity required to escape the earth's gravitational field, a dim object which would require 98.6 milliseconds to be perceived would appear to be 3,000 feet away when in actuality it would be in the same position as the observer. Even with the much brighter object which would require 38.6 milliseconds in order to be perceived, the object would appear to be 1,200 feet away. Such visual latencies suggest that, in cases of the extreme velocities associated with space flight, our traditional concepts of pilot observation of the external environment will have to be modified.

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Footnotes

[1]Paper presented before the Armed Forces-National Research Council (Committee on Vision), Washington, D. C., April 23 and 24, 1964.

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Figure Captions

Fig. 1. Block diagram of the experimental system.

Fig. 2. Schematic diagram of the optical system.

Fig. 3. Reticle patterns used in the experiment. A, B, and C are equal area test flash patterns, D is the fixation pattern, and E is the blanking flash pattern. The white areas represent the lighted portion of the pattern as seen by the subject.

Fig. 4. Per cent correct (adjusted for a 25 per cent chance level) as a function of test flash luminance and the interval between test and blanking stimulus onsets for the coarse grating test stimulus. Each curve on this graph represents the average of three repetitions of each condition for all three subjects.

Fig. 5. Per cent correct (adjusted for a 25 per cent chance level) as a function of test flash luminance, the interval between test and blanking stimulus onsets, and test stimulus patterns. Each curve on this graph represents the average of three repetitions of each condition for all three subjects.

Fig. 6. Time between test and blanking flash onsets as a function of test flash luminance and test stimulus patterns at a constant 50 per cent correct level. The plotted points were obtained from the curves of Figure 4, and the smooth curves were calculated from the indicated equations. A break from the calculated curve, for which data were not obtained in this experiment, occurs beyond 10 milliseconds as is indicated by the dashed line at that interval.

Fig. 7. Hypothesized relationship between test flash evoked potential latency (T_{TF}), blanking flash evoked potential latency (T_{BF}), interval between test flash and blanking flash onsets (D), and the difference in latency [$(\Delta T)_i$] between T_{TF} and T_{BF} under visual masking conditions. TF and BF refer to the physical light stimuli, while TF_e and BF_e refer to the physiological potentials evoked by the TF and BF stimuli.

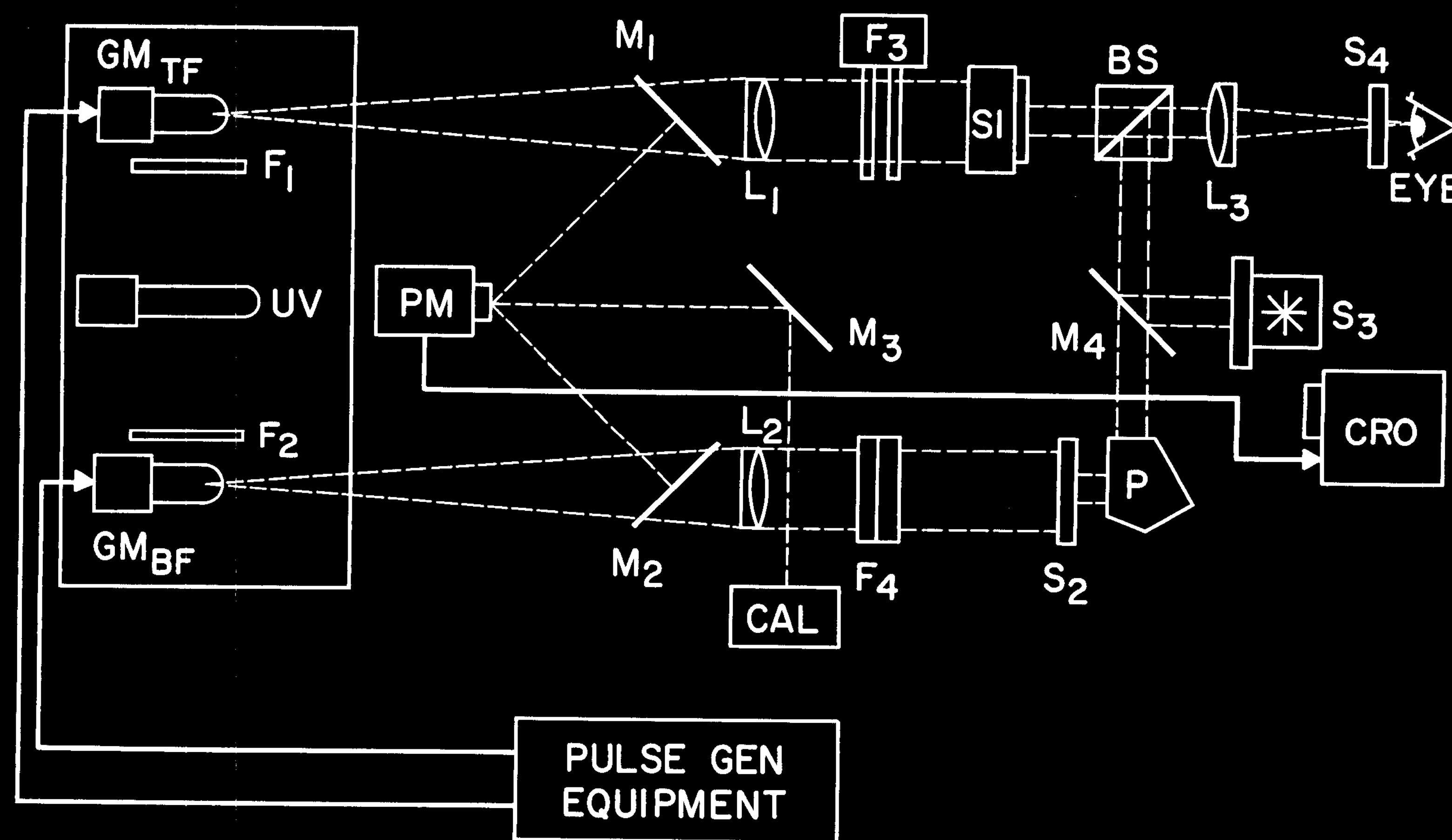

Figure 2.

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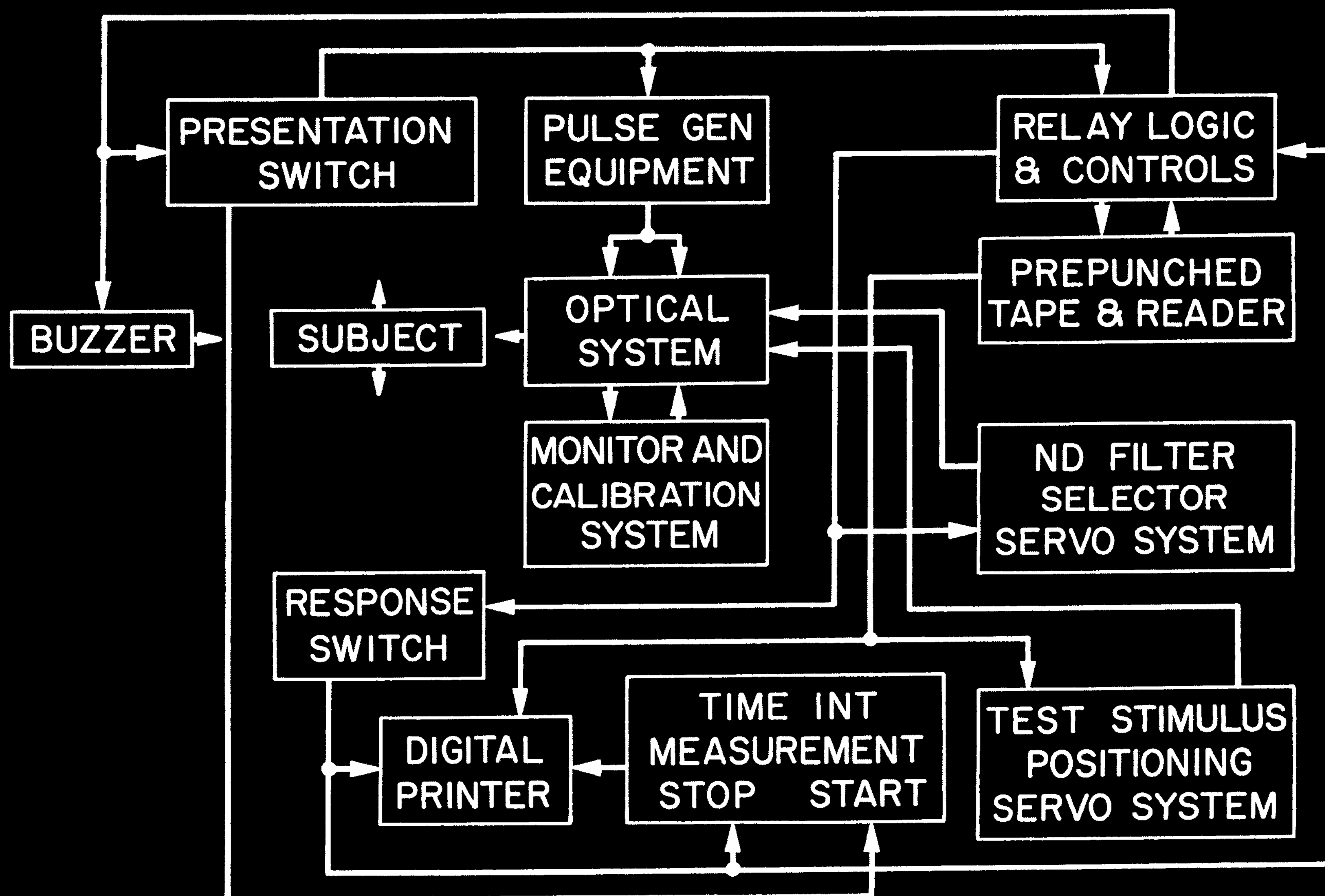
PRESENTATION SWITCH
PULSE GEN EQUIPMENT
RELAY LOGIC & CONTROLS
PREPUNCHED TAPE & READER
BUZZER
SUBJECT
OPTICAL SYSTEM
MONITOR AND CALIBRATION SYSTEM
ND FILTER SELECTOR SERVO SYSTEM
RESPONSE SWITCH
DIGITAL PRINTER
TIME INT MEASUREMENT
STOP START
TEST STIMULUS POSITIONING SERVO SYSTEM

Figure 1.

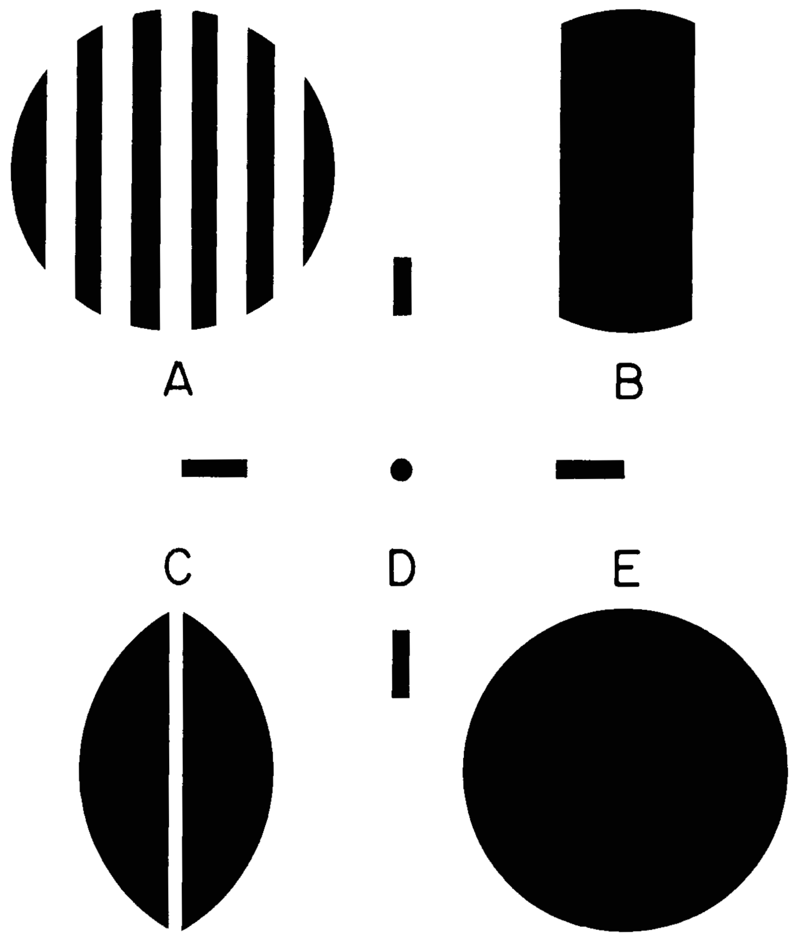

Figure 3.

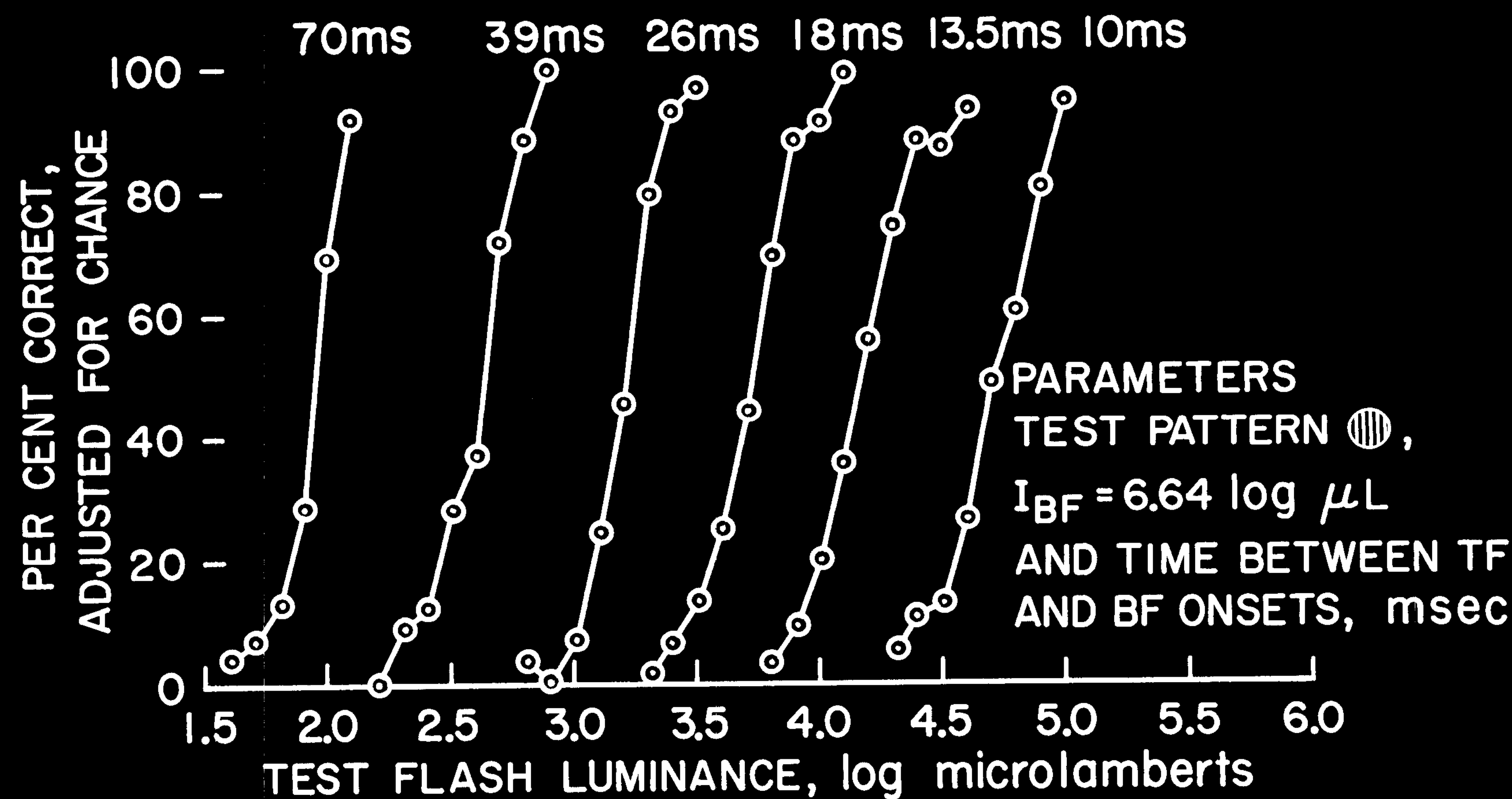
70ms
39ms
26ms
18ms
13.5ms
10ms
PER CENT CORRECT,
ADJUSTED FOR CHANCE
100
80
60
40
20
0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
TEST FLASH LUMINANCE, log microlamberts
PARAMETERS
TEST PATTERN,
I_{BF} = 6.64 log μL
AND TIME BETWEEN TF
AND BF ONSETS, msec

Figure 4.

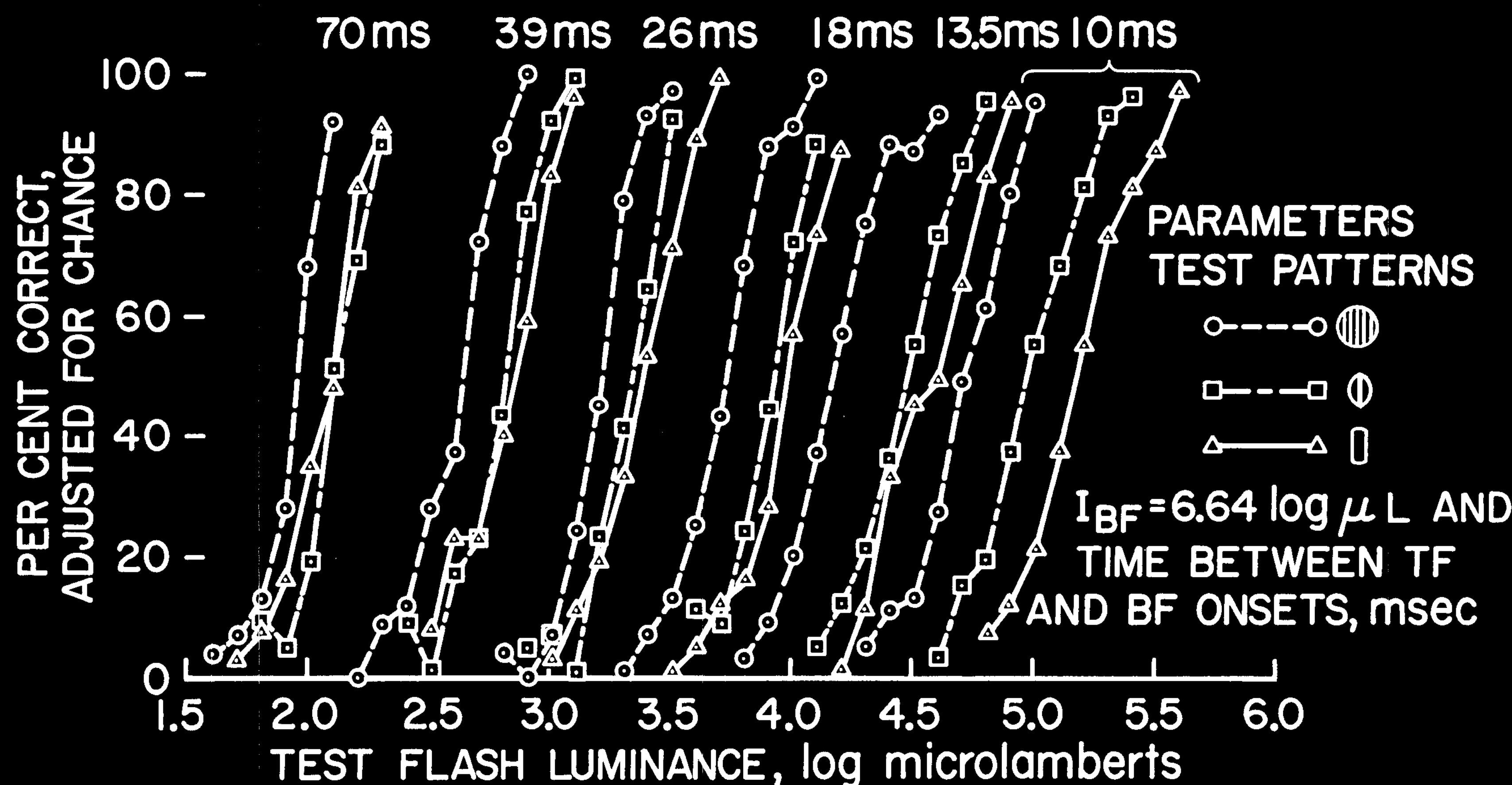

Figure 5.

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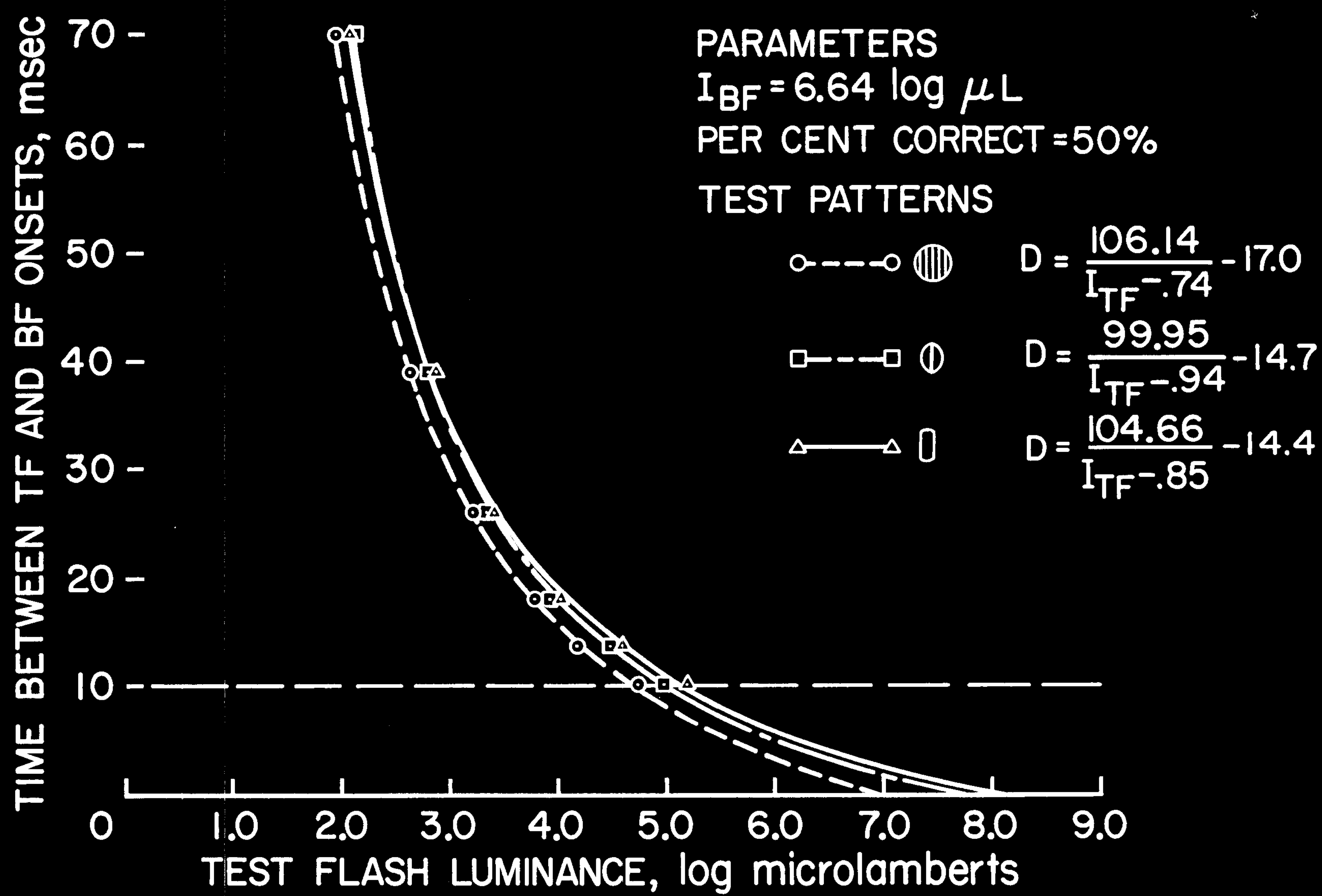

Figure 6.

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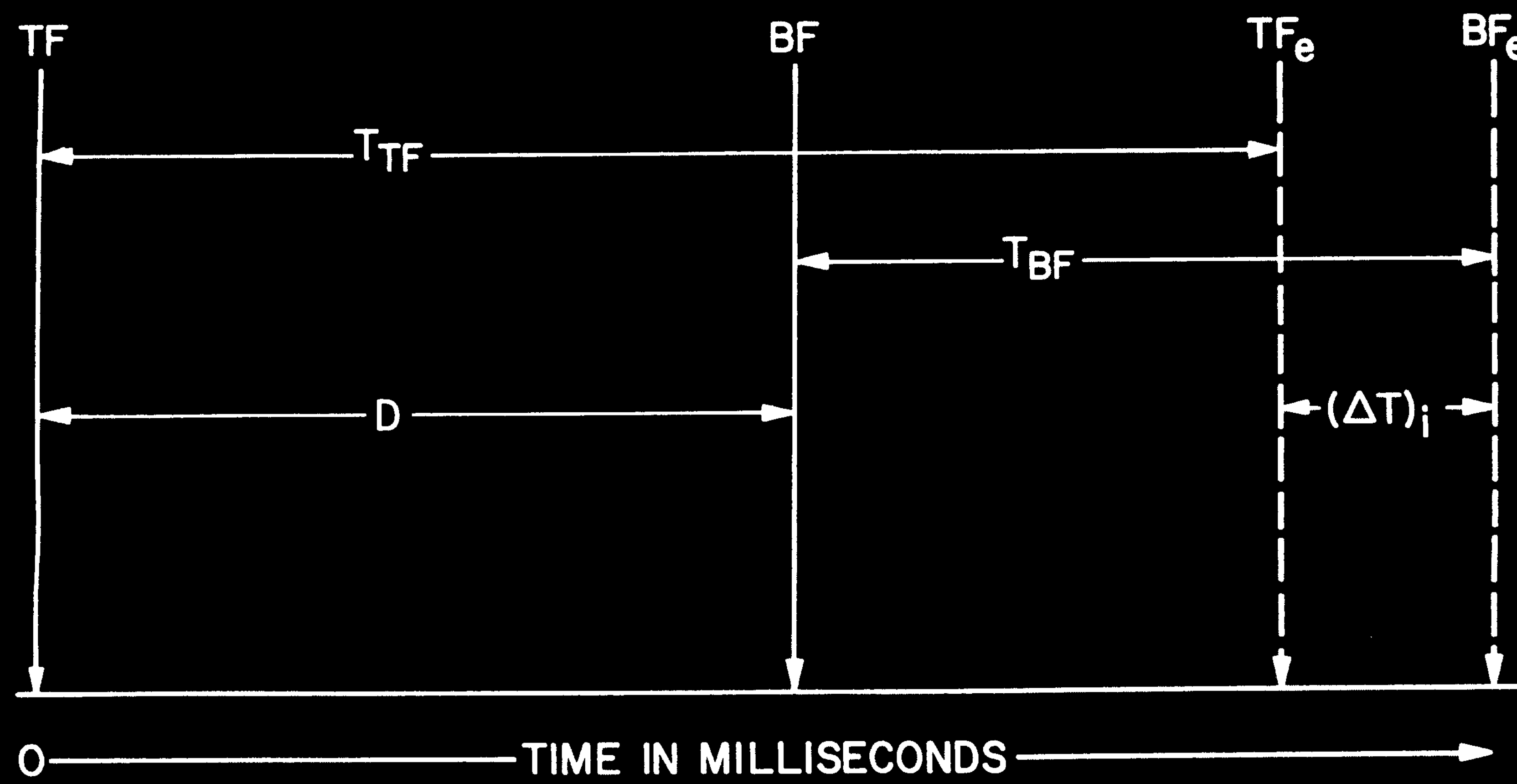

Figure 7.

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