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DETECTION THRESHOLDS FOR POINT SOURCES IN THE NEAR PERIPHERY

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SUMMARY

Two observers have obtained visual detection thresholds for the foveal center and for thirty-two locations in the peripheral retina within a radius of 12 degrees from the fovea. The locations have fallen along eight equally spaced meridians of the visual field, at distances of 1, 2, 4, 8 and 12 degrees from the fixational center. These measurements have been made at each of nine levels of background luminance, ranging from zero to 75 foot-lamberts. A total of 368,250 observations have been made, utilizing the temporal forced-choice variant of the method of constant stimuli. The target was a circle, whose diameter subtended 1 minute of arc; the exposure duration was .01 second.

The data were analyzed separately initially for each of the meridians studied. There were significant differences in sensitivity among the different meridians, the pattern of sensitivity differences differing at different levels of background luminance. Although these differences are of considerable theoretical interest, they were rarely of sufficient size to be of practical significance. Accordingly, the data for different retinal locations equidistant from the fixational center have been averaged.

The primary data concern the effect of the extent to which a target falls eccentric to the fixational center upon the threshold contrast. As expected, the threshold contrast was considerably higher for off-axis locations than for the fixational center at high levels of background luminance. On the other hand, at low levels of background luminance the threshold contrast was somewhat lower at off-axis locations than at the fixational center. At a background luminance level of about 10^{-3} foot-lamberts, the sensitivity of the visual field within a 12 degree radius of the fixational center was essentially uniform.

It is possible to plot the relation between threshold contrast and background luminance for the foveal location and for the various peripheral locations. The data for each peripheral location exhibited a discontinuity which was more marked the farther was the location from the fixational center. These discontinuities presumably represent the well-known rod - cone "break".

I. INTRODUCTION

Previous reports from these laboratories (for example Ref. 1, 2, 3, 4, 5) have been concerned with the detection capability of the eye for targets located on the line-of-sight. These studies have been concerned with the influence of such variables of the physical environment as the luminance of the background, the size and shape of the target, the time the target is visible, the spectral composition of the target, and the non-uniformity of luminance of the background in the vicinity of the target. Data on the line-of-sight capabilities of the eye are sufficient for use in only a limited number of practical visibility situations. At high luminance levels where target detectability is greatest on the line-of-sight, these data enable us to compute maximum visibility ranges in various practical situations. At low luminance levels, it is generally accepted that targets are more detectable off the line-of-sight. In these cases, data for the line-of-sight obviously do not enable us to compute maximum visibility ranges.

In addition, many practical visibility problems are concerned with the visibility ranges of targets under conditions in which the range is less than maximum because the observers are not aware of the position of the target and hence must search and scan the visual field. Under these conditions, many targets never fall on the line-of-sight. Others may fall on the line-of-sight only very briefly in comparison with the time they fall at locations off the line-of-sight.

In order to assess visibility distances under these conditions, we require comprehensive data on the visual detection sensitivity of the eye for all regions of the visual field. The influences of such variables as background luminance, target size and shape, and target duration need to be studied for various regions of the visual field. The present study represents the first step in a program intended to provide these data. The sensitivity of the near periphery of the visual field has been studied out to 12 degrees from the line-of-sight, along each of eight meridians. Measurements have been made at nine levels of background luminance varying from zero to 75 foot-lamberts. A circular target subtending 1 minute of arc has been presented for 0.01 second.

In these experiments, the observers had complete knowledge of the off-axis position to be occupied by the target. Thus, these studies do not take account of the fact that in practical visibility situations, the observers not only are often looking away from the target, but also have no prior information as to where the target will appear. The influence of this informational variable has been studied to some extent is an earlier publication (Ref. 6) and will not be considered here.

II. APPARATUS AND PROCEDURES

The apparatus used to produce the background and target luminances is illustrated schematically in Figure 1. The observers viewed the far wall of a large cube which served as the background luminance, through a large opening in the near wall. The far wall was lighted by a series of luminaires, located on the near wall of the cube around the opening, which were shielded from the observers' eyes. The target appeared from time to time in the center of the far wall, as a luminance increment. The target was produced by a projection system located behind the far wall. The larger portion of the far wall was covered with a translucent plastic screen. The target was produced by transilluminating the screen over a restricted area. The screen was located at distances from 8.82 to 12.33 feet from the eyes of the observers in different experiments.

High background luminances were produced by four arrays of tungsten incandescent lamps, one array on each of the sides of the opening in the near wall. A level of 75 foot-lamberts was produced by 100-watt lamps, whereas a level of 1 foot-lambert was produced by 40-watt lamps. In each case, direct illumination of the plastic screen by the lamps was prevented by disc deflectors placed on the lamps. For all background luminances less than 1 ft.-L., the luminance of the plastic screen was provided by two small integrating light boxes containing 6-volt, 32-candle-power incandescent lamps. Each light-box had an opal glass screen. These screens were not used to illuminate the plastic screen directly, but were used to illuminate the near wall of the cube directly, the plastic screen being illuminated entirely by reflection from the near wall. These two boxes were mounted against the sides of the cube walls at a point which prevented the observers from seeing the opal glass surfaces. The luminance of the plastic screen was adjusted by use of Wratten neutral filters placed over the opal screens of the light-boxes.

The target projector was based upon a special tungsten ribbon-filament lamp developed by the General Electric Company, the output of which was equivalent to a 1000-watt monoplane projection lamp. The ribbon-filament lamp was operated at 6-volts AC. Two sets of Wratten neutral filters were used to adjust target luminance. "Fixed" filters reduced the target luminance to the threshold range. These filters were fixed during any given session. Additional adjustment of the target luminance was obtained by the "psychophysical" filters. These filters adjusted the target luminance to the values desired within the psychophysical range. Five psychophysical filters were used, mounted on an electrically-driven filter-selector which could position one or another of them in the projection beam.

The presentation of the target was controlled by the operation of a flag-type shutter. Whenever a solenoid was activated, the shutter was removed from the projection beam.

The target projection system consisted primarily of condensing lenses which imaged the ribbon filament in the plane of a rotating sector disc used to time the target pulse. A collimator was used just beyond the sector disc. Then, a very short focal-length "magnifier" was used to form a small image of the filament on a metal aperture mounted flush against the rear wall of the translucent plastic screen. The aperture limited the size of the transilluminated target to approximately .035 inch.

The side of the plastic screen facing the observers was covered with an extremely thin layer of white sphere paint, designed to eliminate the specularity of the plastic screen without introducing spectral selectivity or blurring of the transilluminated target. The color temperatures of the target and of the background luminance were set for 2850° K.

The timing of the target presentation was arranged and controlled by a timer comprising two discs mounted on a single shaft, one rotating at seven times the speed of the other, and designed to juxtapose two adjustable slots in the perimeters of the discs and the projection beam. The timer wheels intercepted the projector beam in the plane of a filament image. Variation in the chord length of the slots could be utilized to produce continuous variation in the duration of the pulse of light from about 0.001 to 0.03 second. The time required for the target to come to full luminance was 0.0001 second. (The ribbon-filament was used in order to minimize the onset time.)

In the present experiment, an exposure duration of 0.01 second was used throughout. This duration was selected to be shorter than the critical duration (Ref. 7) at all values of B. The temporal forced-choice variant of the method of constant stimuli as described in detail by Blackwell (Ref. 8) was used in this study. Essentially, the temporal forced-choice method presents the observer with four successive, aurally delineated, 2-second time intervals. In one of these only, as determined randomly by the presentation sequence, there appears a target of randomly selected luminance. After a cycle of four temporal intervals is completed, the observer is allowed eight seconds to press one of four buttons located on his arm rest indicating in which of the four intervals he believes the target to have appeared. These responses are automatically tallied in a distant room on electrical counters and punched on record cards for permanent reference. Although ten targets of the same luminance succeed each other, each block of ten is randomly arranged with respect to all other blocks of ten in terms of luminance. Five such blocks, ranging in difficulty from a target visible nearly 100% of the time to a value virtually never visible are presented in one experimental session.

After the presentation of fifty targets, observers are permitted a five minute break while the equipment is re-set. A fifteen minute break for refreshment customarily follows the third block of stimuli.

Automatic presentation and recording equipment was used, designed for use with this method and described by Blackwell, Pritchard, and Ohmart (Ref. 9). The amassing of the great amounts of data necessary to this study would have been impossible without this equipment.

The basic experimental data were percentages of correct choice for each of five target luminance increments. Analysis of the data begins by eliminating the effect of chance successes by means of the relation:

$$p' = \frac{p-.25}{.75} \tag{1}$$

where p' = corrected proportion, and
p = raw proportion.

The corrected proportions were analyzed by a variant of the probit analysis developed by Kincaid and Blackwell (Ref. 10), based on the general probit method of Finney (Ref. 11). Basically, the probit method fits a theoretical curve to the data to satisfy the maximum likelihood criterion. In this case, the theoretical curve was the normal ogive. Analysis of the data in this manner yields the value of the threshold, the standard error of the threshold, the slope of the ogive, the standard error of the slope, and an estimate of the goodness of fit determined by the Chi-square test.

The basis of all photometry was the Macbeth Illuminometer, calibrated against standard lamps and standard reflectance surfaces certified by the Electrical Testing Laboratories, New York. The calibration of the illuminometer and filters was checked several times during the experiments.

High luminances of the screen were measured directly with the illuminometer, fitted with a lens which imaged the screen in the photometric cube of the device. Low luminances, produced by the light boxes described above, were photometered indirectly. The ratio between the luminances of the opal screens of these light boxes and the resulting screen luminance was measured at maximum output of the light-boxes. When the output of the light boxes was reduced by filters to produce low luminances of the screen, the luminances of the opal screens of the light boxes were measured and the ratio used to compute the screen luminance. This procedure is entirely adequate since the optics of the light sources were not altered by the use of the filters.

The luminance of the small target was difficult to photometer. The basic measurement involved what may be called a "candle-power box". A closed metal box was made with an opal disc at one end and a small aperture at the other. The aperture was fitted precisely in place so that the transilluminated target lay entirely within it. The target thus became a source for illumination of the opal disc at the other end of the box. Baffles were placed within the box to eliminate interreflections. The luminance of the opal disc was measured with the illuminometer. From the transmittance of the opal disc and the inverse square law, the intensity of the small target could be determined. The luminance of the small target was computed from the measured size of the target.

The measurement with the candlepower box is somewhat tedious. Accordingly, occasional measurements were made in this way and more frequent measurements were made with a photoelectric telephotometer, calibrated in terms of the candlepower box measurements. The telephotometer consisted of a telescope which imaged the small target on the cathode of a 931 photomultiplier tube. The relative luminance of the target was determined by the emf required to compensate the photoelectric current produced by the target. The target increment provided by the projector is designated ΔB. When there is a finite value of the background luminance, B, it is customary to specify detection sensitivity in terms of target contrast, C, defined as follows:

$$C = \frac{\Delta B}{B} \qquad (2)$$

The target projection apparatus was fixed in position with respect to the screen and could present targets only in the precise center of the screen. Thus, to obtain off-axis target presentation, it was necessary to have the observers fixate various points which were not at the center of the screen. For the off-axis studies which make up the principal bulk of the data, a small bright fixation point was provided the observers. The fixation point was projected onto the side of the screen viewed by the observers by a projector mounted inside the light cube out of the view of the observers. This projector utilized the image of the filament of a 6-volt 32. candlepower tungsten lamp. The intensity of the fixation point was always maintained at a value approximately ten times the threshold intensity, since extended experience has indicated that this intensity is the dimmest which can be comfortably used for the control of fixation and accommodation during extended periods. For the background luminance of 75 foot-lamberts, it was difficult to obtain sufficient intensity from the projector to meet this criterion. Accordingly, four such projectors were used, and the images aligned on top of one another in order to increase the fixation point intensity to the required level.

For those comparison experiments involving foveal presentation, multiple fixation points were used to form a pattern around the point to be occupied by the target. Four points were normally used, each of one minute of arc diameter, surrounding the target and equidistant from its edges at a constant distance of eighteen minutes of arc. These four points were arranged in the form of the terminal points of the arms of a cross, with the point of target appearance located at the intersection of an imaginary line through each of the vertical and horizontal pairs. For a few foveal experiments, only the horizontal pair of fixation points was utilized. Earlier experimentation had revealed that equivalent results are obtained with two or four fixation points arranged in this manner.

For experiments involving zero background luminance, an appreciable error can be introduced by the reillumination of the screen from light produced by the fixation points which is reflected onto the floor and walls of the white cube and back onto the screen. To insure that the screen was perfectly dark, a special stiff black velvet cover was constructed which was mounted in front of the plastic screen, which covered the screen entirely. A small hole was cut out for the target, and a number of small holes were cut for the various positions to be occupied by the fixation points. Plugs were inserted in all the fixation point holes that were not actually in use in a given experiment.

Normal binocular viewing was used throughout, with natural pupils, so that the data would be directly useful for application to practical visibility problems.

The refractive condition of the eye of each observer was determined under the conditions of the experiment by a method outlined by Ogle (Ref. 12). An "oculometer" was used to measure dynamic refraction with the stigmatoscopic technique. Measurements were made with this apparatus under conditions identical with those of the experiment proper, with the exceptions that a stigma, or point of light appeared in the apparent location usually occupied by the target. The stigma was seen by reflection from a half-silvered mirror located in the oculometer.

The basic oculometric procedure may be described as follows: the observer fixates the fixation points situated perhaps 10 feet from his eye, and observes changes in appearance of the bright stigma centered among them. The assembly which houses a tungsten lamp, stigma, and reduction filters in the oculometer is movable along the optic axis parallel to a scale. The distance from the eye to the field lens is made equal to the focal length of the latter, making possible a linear scale calibrated in diopters whose modulus is determined by the dioptric strength of the field lens. (The zero point of the scale corresponds to the point at which the stigma-to-lens distance is equal to the focal length of the field lens and the image is at infinity.) Using the psychophysical method of limits, the observer adjusts the position of the lamp housing until the stigma appears to have minimum size. A mean of many such settings, translated into diopters by the affixed scale, reveals the refractive state of the eye. Accommodation on the stigma would give a spurious result. This possibility is precluded by causing the lamp to flash intermittently, the "off" period being sustained considerably longer than the "on".

The discrepancy between the mean of these oculometric settings and the theoretical "normal" refractive state of the eye at the actual viewing distance represents the refractive "error" of each observer. From refractive errors, it is possible to compute refractive corrections.

Two observers were utilized for all experimental measurements, both females of age 30. One of the observers (ABM) was also the experimenter; the other observer (LP) was a laboratory technician. The measurements extended over a period of about 30 months; the motivation of the observers in the tedious task of observing was truly exceptional.

The observers were fitted with ophthalmic corrections for the purposes of the experiment, on the basis of oculometric measurements, as follows:

Observer ABM	O.D.	-1.12 S
	O.S.	-1.12 S

Observer LP O.D.
O.S. -.375 S; -.25 165°

A regime of prior dark adaptation was adopted, on the basis of well-known relations between pre-exposure luminance and sensitivity in the dark. At zero background luminance, Navy red adaptation goggles (Polaroid type) were used for 20 minutes before entering the experimental room, followed by a 10 minute period in the dark. Alternatively, a total period of 20 minutes in the dark could be used at the discretion of the observers. The control of pre-exposure luminance was less stringent for the studies involving higher levels of background luminance. At 10^{-3} foot-lamberts background luminance, the red goggles were used for 10 minutes before entering the experimental room, followed by 3 minutes in the experimental cube.

The two observers differed in their relative sensitivity under different experimental conditions. In order to equate them sufficiently so that they could observe at the same time, advantage was taken of the fact that the distances from the observer's eyes to the screen differed among the four chairs available for the observers (see Figure 1). The observers were shifted freely from chair to chair to equate their thresholds for each experimental condition, the range of viewing distance varying from 8.82 to 12.33 feet. All data obtained at different distances from the screen were corrected to the standard distances at which the target subtended 1 minute of arc, on the basis of the inverse square law. Experimental checks substantiated the validity of this manipulation of the data.

Nine different levels of background luminance were studied in all. The order in which the different levels were studied was haphazard, with all the data for a given background generally collected during one consecutive period of time. The observer were extensively practiced before the collection of the data reported here, having been used for more than 100 hours of observing during preliminary experiments.

The standard routine of study at each background luminance included several sessions with foveal presentations for comparison purposes, interspersed during the peripheral studies. An off-axis location, or eccentricity, of about 1 degree was studied along N, S, E, and W meridians. Similarly, a 2 degree eccentricity was studied along these four major meridians. Measurements were made along eight meridians for eccentricities of about 4, 8, and 12 degrees. Thus, there were 32 basic peripheral locations to be studied. In general, two separate sessions were conducted for each peripheral location. If the data from the two sessions did not show good agreement, an additional session or two were conducted under these same conditions.

III. RESULTS

The raw data of all the studies except those conducted at zero background luminance represented values of threshold contrast, $\mathring{C}$, for each of the two observers under each of the numerous experimental conditions. These values were expressed in logarithmic terms from the outset, and the averages which were obtained represent logarithmic averages. As has been pointed out in an earlier report (Ref. 5) it is possible to render threshold values of ΔB, obtained at zero background luminance comparable with threshold contrast values obtained at finite values of background luminance by assigning an arbitrary low background luminance, B, and computing "contrast" from equation (2). When this was done in the earlier report, B was set equal to 10^{-3} foot-lamberts. This procedure was admissible in the earlier study because only foveal presentation was involved and the cone photoreceptors operate in an equivalent manner at 10^{-3} or zero luminance, as shown in an earlier study (Ref. 2). In the present case, rod photoreceptors are presumably involved in at least most of the peripheral locations. In this event, as was reported in 1946 (Ref. 13) a background luminance of 10^{-6} is required to be equivalent to zero. In this report, "contrast" values for the zero luminance data were specified from equation (2) with $B = 10^{-6}$.

Data for the two observers were analyzed separately at first, to evaluate the extent of similarity observed. The initial data graphs involved plotting the values of log $\mathring{C}$ obtained at various peripheral locations in comparison with data for the foveal target. For these graphs, the data obtained along the different meridians were averaged. It was found that the relations between log $\mathring{C}$ and the extent to which the target was presented eccentric to fixation were very similar for the two observers, at all the luminance levels studied. Accordingly, the data for the two observers were averaged and all data to be presented here represents average results of this type.

Concern was felt for the fact that eight meridians were included in the averages for the 4, 8, and 12 degree eccentricities, whereas only the four major meridians were included in the averages for 1 and 2 degree eccentricities. Accordingly, an analysis was made of the similarity between averages of the 4, 8, and 12 degree data based upon four or eight meridians. Only haphazard differences were found, so that it was felt admissible to use all available data in the averages at each eccentricity.

Analyses were made of the extent to which the values of log $\mathring{C}$ were independent of the aximuth of the meridian along which the targets were presented. It was found that maximal azimuthal differences were found at the 12 degree eccentricity. Sample data are presented in Figure 2, illustrating the variations in log C as a function of azimuth, for four of the levels of background luminance studied. There appears to be a regular change in sensitivity as a function of azimuth for the 75 foot-lambert background luminance, but there are less pronounced differences at the other luminance levels. If it is indeed the case that azimuthal differences depend upon background luminance, this may imply that, as has been suggested elsewhere (Ref. 14), the visual neural system alters its network of connections at different luminance levels.

At least for practical purposes, we are primarily concerned with average data from all aximuths. The main results of the present experiments are presented in Table I. These data represent the staggering total of 368,250 observations.

In averaging the data from the two observers, account was taken of the fact that as they changed seats in the experimental room, the eccentricity angle changed. Thus, in Table I, each average value of log $\hat{C}$ has a value of E, which represents the eccentricity or extent to which the target was presented off-axis.

The initial data graphs are presented in Figures 3, 4, and 5. Each graph contains the results obtained at three of the background luminance levels. (These data have been separated into three graphs so that sufficiently large scales can be used in each graph to reveal the precise shape of the functional relationship between log threshold contrast and eccentricity.) It is apparent that there are large differences in sensitivity within a 12 degree radius of the foveal center. As expected on the basis of common experience, considerably more contrast is needed to detect a point target off-axis than on-axis at the higher luminances, whereas less contrast is needed off-axis at low background luminances. The fact that the visual field is relatively homogeneous in sensitivity at a background luminance of about 10^{-3} foot-lamberts is an interesting result. The existence of even less sensitivity 1 degree off-axis than at the foveal center for the lowest background luminance levels is a new finding of some theoretical interest.

It is perhaps apparent that the smooth curves drawn through the data points in Figures 3, 4, and 5 do not fit the points as well as they might. The curves used to fit these data were derived from a method of curve fitting which may be best described by reference to Figures 6 - 11. These figures present the relations between log threshold contrast and log background luminance for a foveal target location and for each of the following eccentric locations: 1, 2, 4, 8, and 12 degrees off-axis. Now, values for the foveal graph (Figure 6) are taken directly from Table I when E = 0. However, all the other graphs have to be produced by interpolation from the smooth curves in Figures 3 - 5 since the values of E in Table I are unequal and do not represent integer values of the eccentricity angle.

The process of data-smoothing proceeded in the following steps. Smooth empirical curves were fitted to the experimental data in Figures 3 - 5 and values were interpolated for Figures 7 - 11. The curves in Figures 7 - 11 were not smooth, there appearing to be considerable haphazard irregularity in the various graphs. It was assumed that the curves from Figures 7 - 11 should not be haphazard, but should be generally smooth, although a discontinuity corresponding to the well-known cone-rod "break" was expected. Curve fits were alternated back and forth until smooth curves were generated in Figures 7 - 11 with curves which fit the experimental data in Figure 3 - 5 as well as possible. It was not required that the curves in Figures 3 - 5 be smooth, since the different retinal locations have different receptor populations, different peripheral blood supply etc. Thus, there need not necessarily be a smooth relationship between eccentricity and threshold contrast.

The curve for foveal viewing presented in Figure 6 is very similar to other curves reported from these laboratories, both with respect to shape and absolute value. The curves for the peripheral locations always give some evidence of a discontinuity, even for the 1 degree eccentricity. The discontinuity is of course more marked the more eccentric is the location. In the case of a 12 degree eccentricity, presumably the segments at the higher luminance levels represent cone activity whereas the segment at the lower luminance levels represents pure rod activity. At less extreme eccentricities, mixed cone and rod activity probably occurs in the segment obtained at the lower levels of background luminance.

The curves presented in Figures 7 - 11 allow us to assess the effect of target eccentricity, by comparison with the curve presented in Figure 6. These data should be useful in computations of practical visibility situations in which the target fails to fall upon the observer's line of sight. It should be pointed out, however, that the target used in these studies subtended only 1 minute of arc. It is not safe to assume that the effect of target eccentricity will be the same as we have found in this study for targets of considerably larger size.

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TABLE I: Average Threshold Contrast Values

Log Background Luminance (foot-lamberts)

-6.00		-5.10		-4.10		-2.75		-2.00		-1.50		-1.00		.00		1.87	
E	Log $\mathring{C}$	E	Log $\mathring{C}$	E	Log $\mathring{C}$	E	Log $\mathring{C}$	E	Log $\mathring{C}$	E	Log $\mathring{C}$	E	Log $\mathring{C}$	E	Log $\mathring{C}$	E	Log $\mathring{C}$
0	6.54	0	5.63	0	4.63	0	3.29	0	2.54	0	2.17	0	1.78	0	1.18	0	.38
.9	6.64	.9	5.71	1.0	4.63	.9	3.48			1.1	2.33	.9	2.01	1.0	1.38	.9	.57
1.8	6.43	1.8	5.60	1.9	4.64	1.8	3.53	2.0	2.76			2.0	2.14	2.0	1.55	1.8	.91
3.5	6.05	3.7	5.22	3.6	4.34	3.6	3.55	4.0	3.03	4.0	2.71	4.0	2.39	4.0	1.87	3.9	1.41
7.2	5.82	7.4	4.98	7.0	4.27	7.2	3.54	7.8	3.20			8.0	2.66	8.0	2.19	7.2	1.74
12.0	5.78	11.8	5.08	12.0	4.32	10.8	3.56	11.4	3.29	12.0	3.04	12.0	2.81	11.8	2.42	11.2	2.07

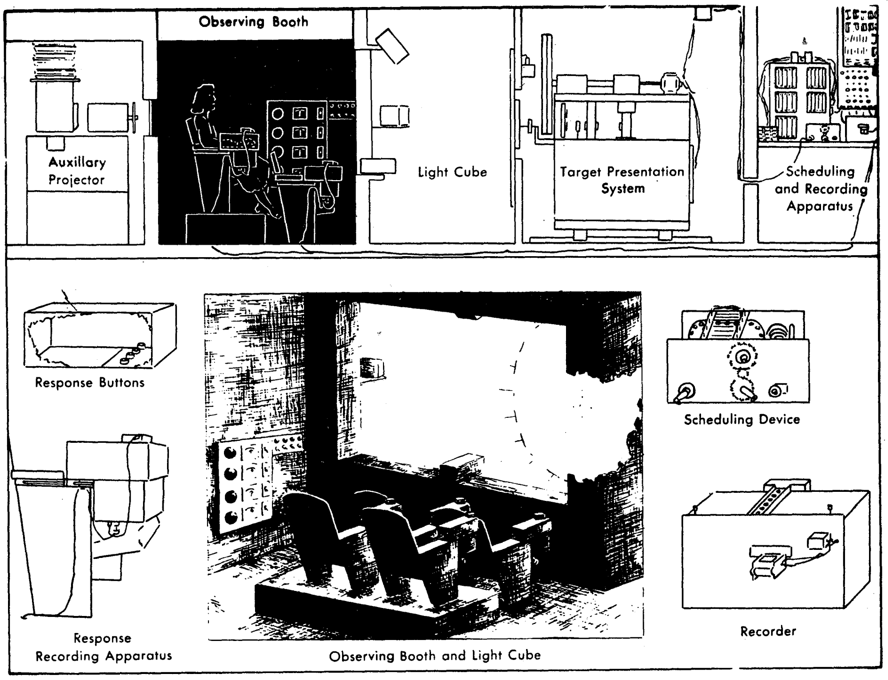

Fig. 1. Artist's conception of the basic psychophysics test facility.

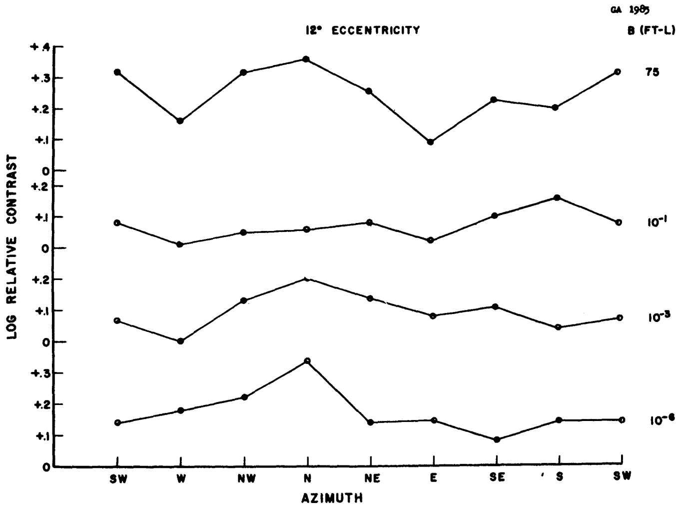

Fig. 2. The effect of target azimuth.

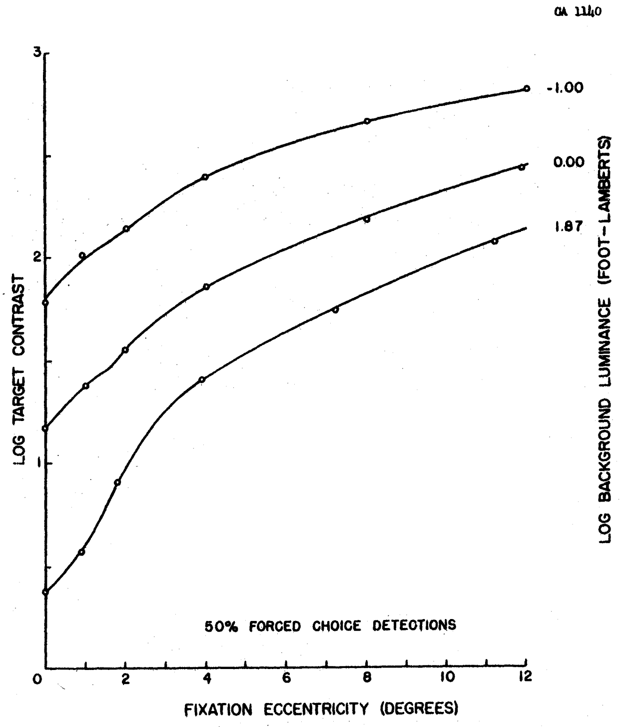

Fig. 3. Eccentricity data: three highest luminances.

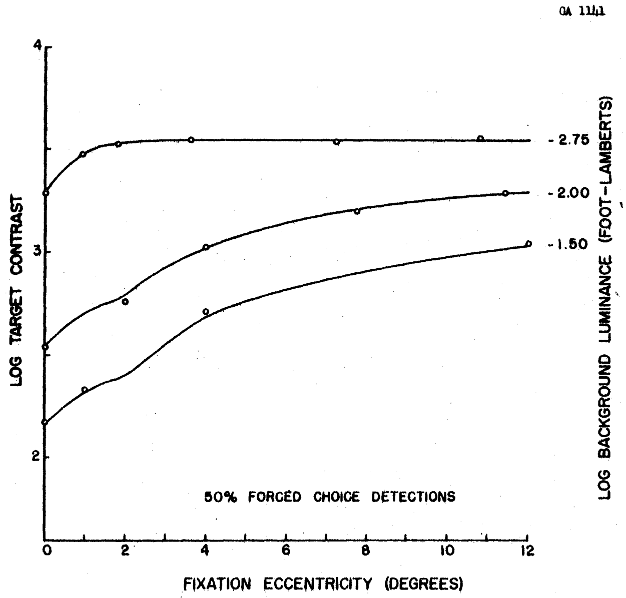

Fig. 4. Eccentricity data: three intermediate luminances.

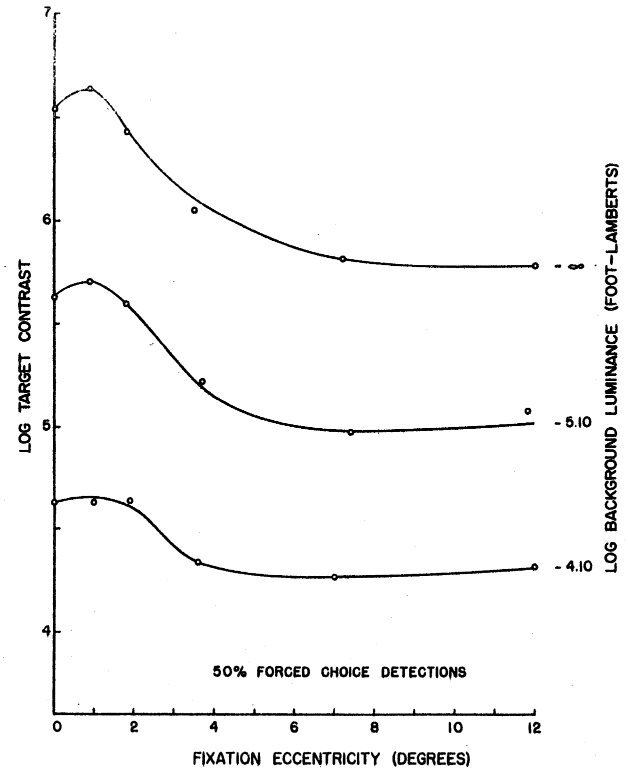

Fig. 5. Eccentricity data: three lowest luminances.

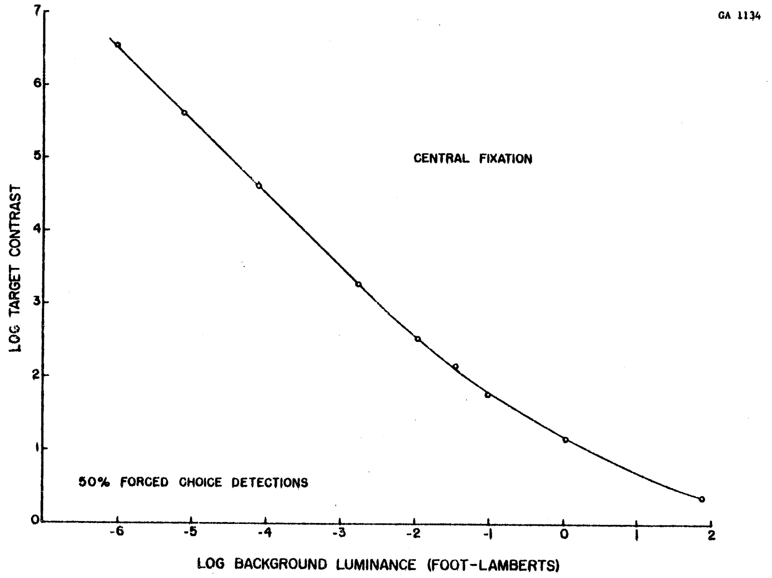

Fig. 6. Background luminance effect.

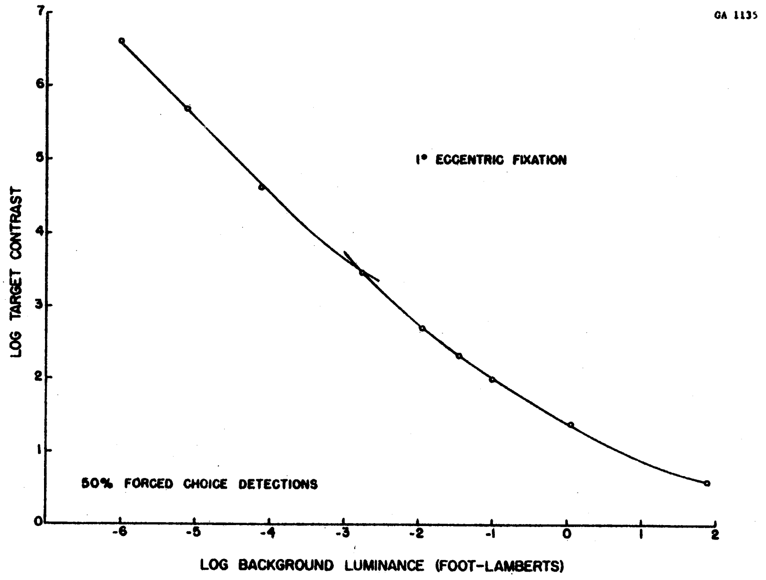

Fig. 7. Background luminance effect.

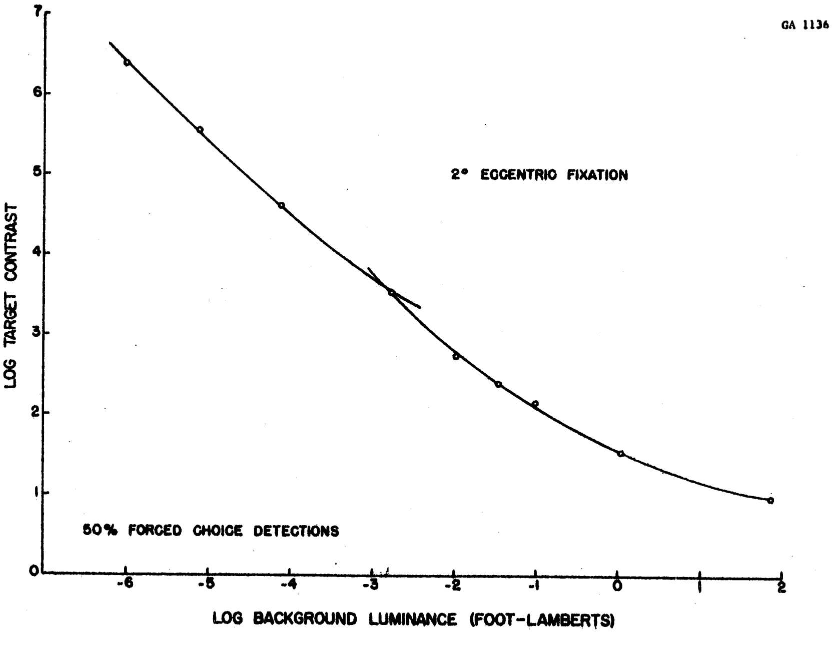

Fig. 8. Background luminance effect.

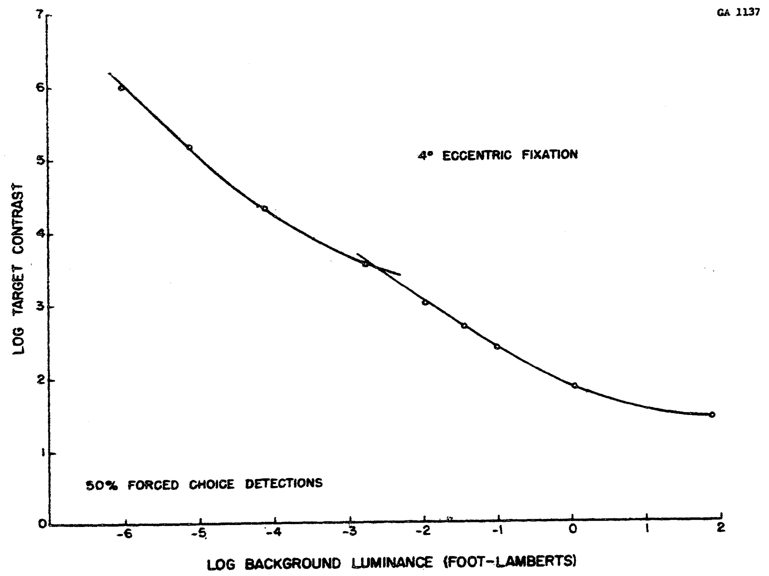

Fig. 9. Background luminance effect.

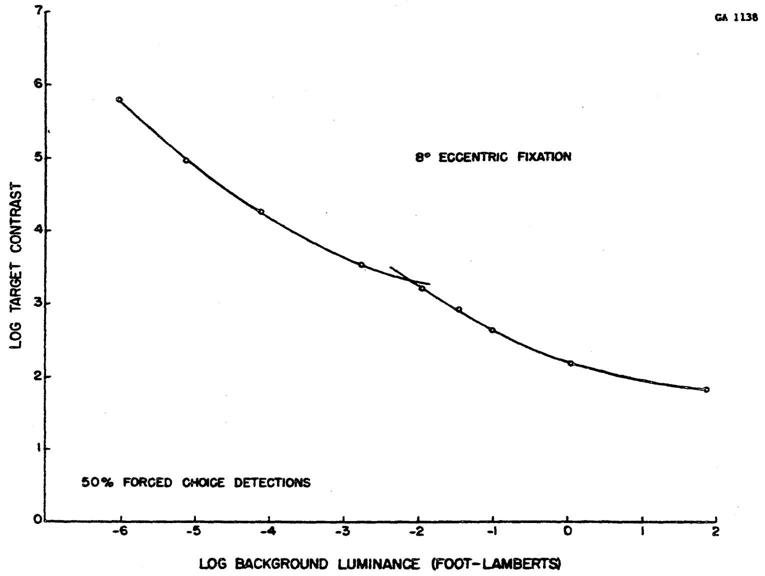

Fig. 10. Background luminance effect.

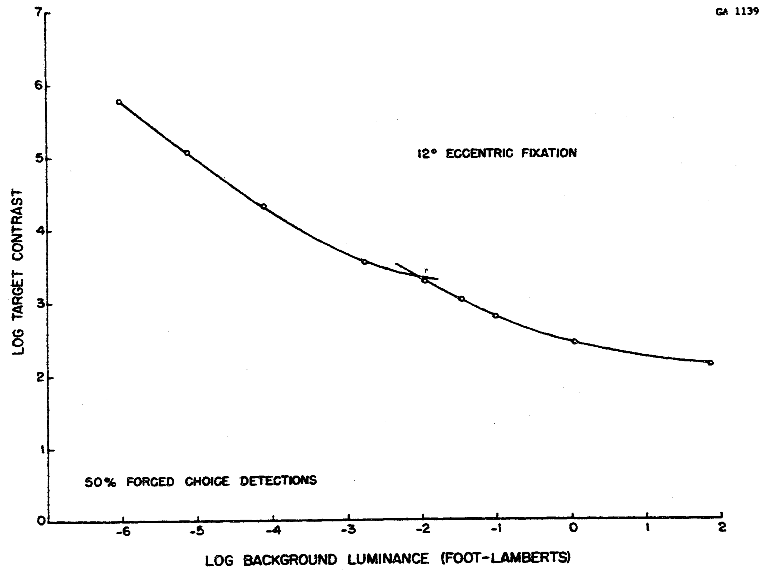

Fig. 11. Background luminance effect.