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63-3-4

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US Army Armor Human Research Unit
Fort Knox, Kentucky

The Effects of Two Types of Coordinate Systems on Localization of Peripheral Light Flashes

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Research Memorandum
April 1963

A report of work done in connection with Subtask XI, ARMORNITE, Task 11-27, "Human Factors in Armor Operations under Conditions of Limited Visibility"

NORMAN WILLARD, JR.
Director of Research

Research under the technical supervision of
HUMAN RESOURCES RESEARCH OFFICE
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INTRODUCTION

There are a number of perceptual tasks in which the observer is required to localize brief visual stimuli in a relatively unstructured field. The accuracy of his responses on such a task may be improved by introducing reference lines into the field.[1] The purpose of the present study was to determine how such localization responses vary as a function of two of the basic variables in the design of the reference lines: a) the type of coordinate system used, and b) the density of the coordinate lines. More specifically, the study was designed to compare the relative merits of Cartesian and polar coordinates and to determine the optimum line density for each.[2]

METHOD

Apparatus

The experiment was conducted in a completely blacked-out room. A flash presentation board was constructed in the following manner: On a plywood panel, 6 ft. square and 3/4 in. thick, 48 positions were chosen by stratified random sampling of a circular area 60 in. in diameter, located in the center of the panel. This area subtended a visual angle of approximately 64° at a viewing distance of 47 in. At the chosen points, type NE2 neon bulbs were set in 1/4-in. holes drilled through the panel. These bulbs produce an orange glow. A red fixation light was placed in the center of the circular area. The front of the panel was then covered by a thin white muslin sheet drawn tight to form a screen. A black circular frame placed over the borders of the panel outlined the field of view. To insure reliable performance of the neon bulbs, indirect ultraviolet light was provided behind the panel. A Stroblite lamp (with a 100-w. mercury bulb and a double ultraviolet filter) was used for this purpose.[3] No stray light from this source could be seen from the front of the panel.

The coordinate lines, reproduced on transparencies 6 in. square, were projected on the screen by two overhead projectors, one behind each side of the subject, and each projecting half of the design to prevent distortion. Figure 1 shows one quadrant of each of the four Cartesian

QUADRANTS OF CARTESIAN COORDINATES
OF INCREASING DENSITY

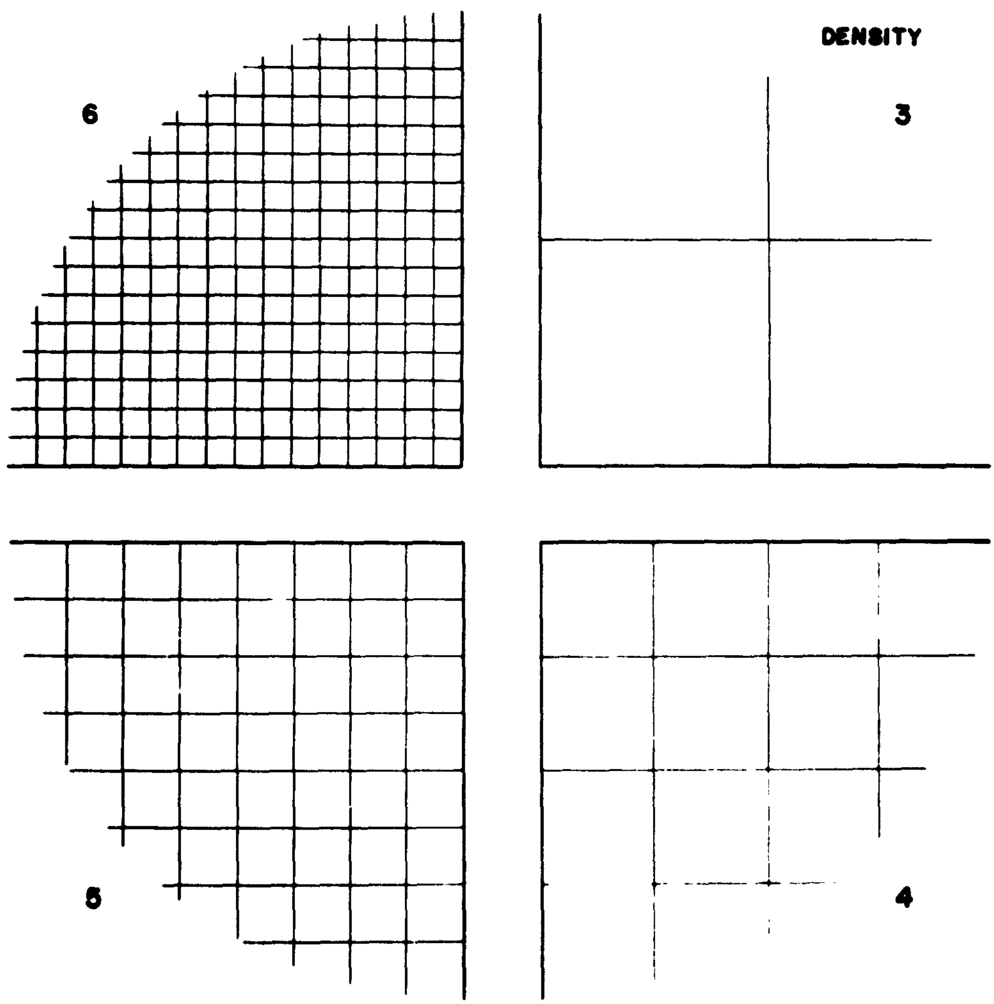


Figure 1

QUADRANTS OF POLAR COORDINATES OF INCREASING DENSITY

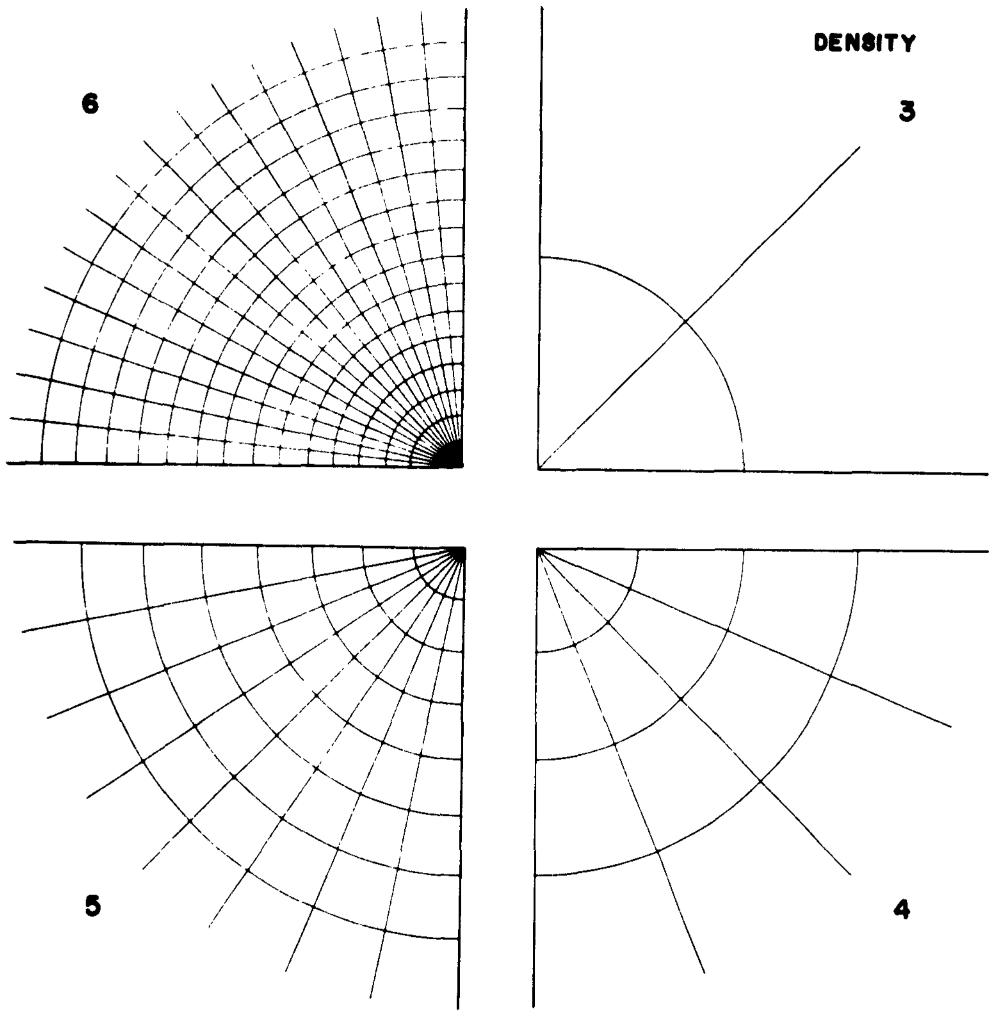


Figure 2

coordinate densities which were used. Figure 2 shows one quadrant of each of the four polar coordinate densities. The increasing densities for both types of coordinates were obtained by successive bisection beginning with the simple coordinate cross. Not shown in the two figures are two other types of visual field references: a) the simple coordinate cross (Density 2), which was also reproduced on a transparency; and b) the no-coordinate condition (Density 1) which employed only the red fixation light mounted in the center of the board. The lines were projected in red by covering the transparencies with a Corning molded glass filter, No. 2418. The projected thickness of the lines was .1 in., except for the center cross, which was .2 in. thick.

The S responded by moving an Ednalite projection pointer mounted on a tripod in front of him. The pointer was balanced in a double swivel joint so as to stay in any position to which S might move it. It projected a 1/4-in. spot of red light on the screen.

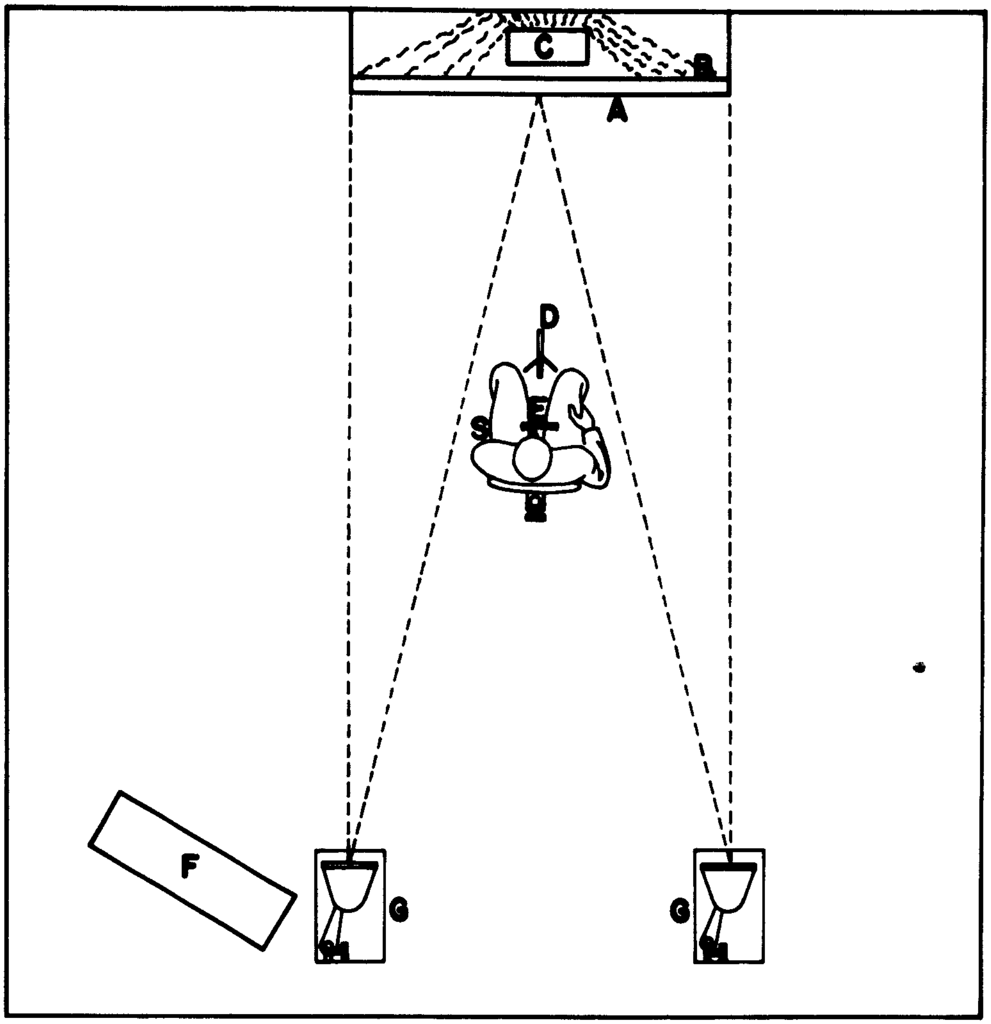
The S's head was maintained in the correct viewing position by a head rest mounted in front of his chair. Projection of the lines, time and duration of flash, and intertrial intervals were controlled by electronic timers. Flash locations were selected by E at a control panel located behind S. Figure 3 is a diagram of the experimental apparatus.

Design

One hundred twenty enlisted men were assigned at random to 10 groups of 12 men each. They had a minimum General Test score of 100, and a minimum right eye far acuity of 20/40 (as measured by the Armed Forces Vision Tester). One group saw only the fixation point (Density 1). For another group only the cross was projected (Density 2). Four groups were shown the Cartesian coordinates, and the other four groups were shown the polar coordinates.

Each S made one localization for each of the 48 flash positions. The sequence of flash locations was randomized and was the same for each S,

DIAGRAM OF EXPERIMENTAL APPARATUS



A = SCREEN
B = BULB PANEL
C = ULTRAVIOLET LIGHT BOX
D = PROJECTION POINTER
E = HEADREST
F = CONTROL PANEL
G = PROJECTORS
S = SUBJECT

Figure 3

but the starting point in the sequence was systematically shifted for each successive S, to distribute practice effects over all flash positions.

<u>Procedure</u>

Each S was dark-adapted for 10 min. before the experimental trials were begun. Flashes were presented at the rate of 1 per min. Flash duration was .05 sec.[4] The coordinate lines were projected 7 sec. before each flash and remained on until the response was completed.

After four practice trials with flashes which differed in position from those used during the experimental trials, each S localized the 48 test flashes, receiving a 10-min. rest after the first 24. The S viewed with the right eye, the left eye being covered. He was instructed: a) to fixate on the center cross (except for the group which saw only the fixation light) until the occurrence of the flash; b) as soon as he saw it, to look at the place where he thought it had appeared; and c) to move the pointer light to that place. The importance of both accuracy and speed of response was emphasized. The S's head position was maintained during fixation and until the completion of the pointing response. His responses were recorded by plotting the position of the projection pointer light after each trial. No knowledge of results was given; and once the plot was completed, S was told to direct the pointer light to a position below the edge of the board.

RESULTS

The coordinate values of the plotted responses were transformed into measures of visual angle. Figure 4 shows the mean localization errors as a function of increasing line density, for each coordinate system. The point on the left represents the mean error made by the group which saw only the fixation point in the center of the field. As shown, mean errors were practically the same for both types of coordinates. Introduction of

MEAN FLASH LOCALIZATION ERROR AS A FUNCTION OF INCREASING LINE DENSITY FOR TWO COORDINATE SYSTEMS

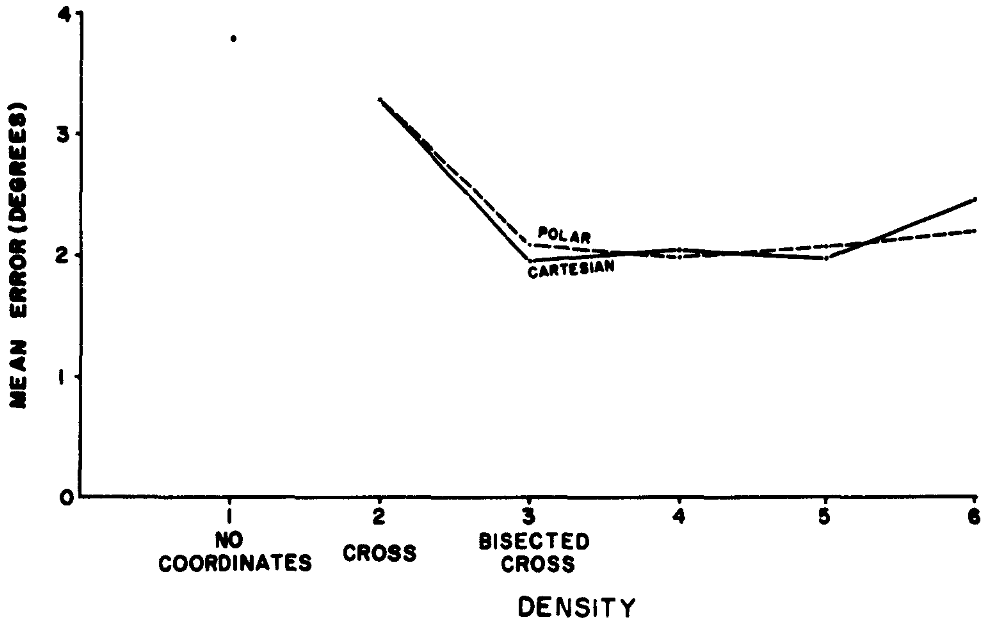


Figure 4

the coordinate cross (Density 2), and the bisection of the cross (Density 3), led to successively smaller errors, but further increases in the density of the coordinate lines did not result in further reduction of error. In fact, it seems that with Density 6, a point of diminishing returns was reached. Figure 5 shows the mean errors for each of three regions of eccentricity. For the outer two-thirds of the field there was no further reduction of error beyond Density 3 (the bisection of the cross), and for the inner third only small additional gains in accuracy were obtained when coordinate density was increased.

All groups displayed a constant error of localizing the flashes closer to the visual axis than they actually were. To compare this constant

MEAN FLASH LOCALIZATION ERROR AS A FUNCTION OF FLASH ECCENTRICITY, TYPE OF COORDINATE, AND LINE DENSITY

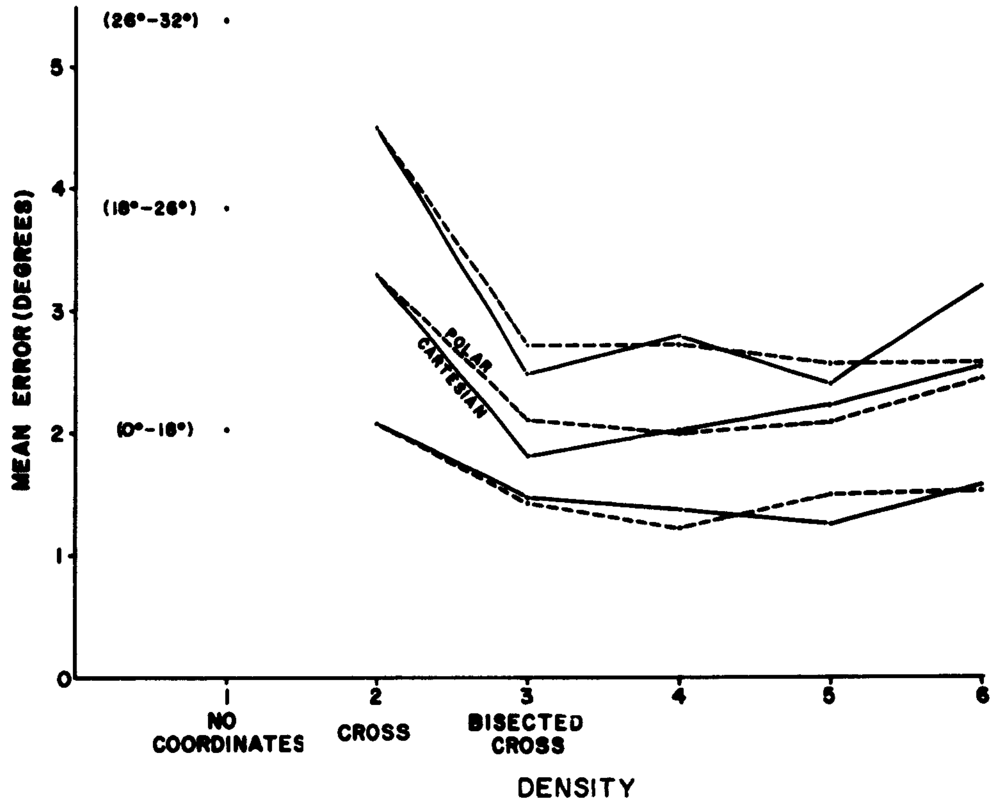


Figure 5

error to the total error, both kinds of error were expressed as percentages of the angle of eccentricity of the stimulus. Table 1 shows these percentage values. The constant error accounts for about 60% to 80% of the total error. The mean constant error was practically the same for

Table 1
Means of Relative Total Errors and Displacements of Localizations Toward the Visual Axis (all 48 flash positions pooled)

Coordinate System	Line Density 1	2	3	4	5	6
Cartesian						
Relative Total Error (%)	17.9	16.3	10.3	10.7	9.9	12.2
Relative Constant Error (%)	15.0	13.0	7.0	5.0	7.0	10.0
Polar						
Relative Total Error (%)	17.9	16.3	10.8	9.9	10.6	11.1
Relative Constant Error (%)	15.0	13.0	7.0	6.0	7.0	8.0

both types of coordinate lines, and the relation between line density and constant error was about the same as that between density and total error.

DISCUSSION

The results showed that accuracy of localization of a light flash does not depend on the type of coordinate system employed. Although reference lines increase the accuracy with which localizations are made, little gain in accuracy, if any, is obtained by systematically increasing the line density of the grid, after the cross is bisected. The farther the flash source from the visual axis, the greater the gain in accuracy which results from bisecting the cross.

Although it was anticipated that accuracy would increase and then level off as line density was progressively increased, it was not suspected that the leveling off would occur so soon. It would seem that accuracy of localization is at a maximum once there is a simple framework of lines throughout the visual field. Instead of providing more structure in the field, the increase in number of lines apparently made the field more homogeneous. Support for this hypothesis can be derived from the fact that further increases in density tended to result in reduced accuracy.

Of interest was the finding that all groups displayed a constant error of localizing the flashes closer to the visual axis than they actually were. Some conditions of the experimental situation were examined to determine what factors might be responsible for this constant error of localization. Because the response involved the movement of a pointer, the constant error could have resulted, at least in part, from a tendency of the subjects to underestimate the amount of pointer movement. The pointer, however, was always directed to a place below the lower edge of the field between responses. If underestimation of pointer movement had been a factor, the direction of the constant error would have had to be toward a point below the center of the visual field rather than toward the center. This, however, was not the case.

To check this possibility further, four additional subjects localized flashes without using the pointer. For these subjects, a grid (the intersections of which were numbered) was projected on the screen within 1/2 sec. after the flash, and the subjects responded by reading the coordinates of the perceived flash position. All subjects displayed the same kind of constant error toward the center. For these reasons, underestimation of pointer movement was ruled out as a contributing factor.

One factor which is likely to have contributed to the constant error in localization would seem to be eye movement. The localization response required the subjects to look at the place where they thought a flash had appeared, then to move the pointer to that place. This response had to be made without head movement. Since there was a short delay between eye movement and pointer movement or projection of the grid, it is likely that during the delay the natural tendency of the eye to revert to its normal position caused the line of regard to be shifted toward the center by the time the pointer movement or reading was completed.

SUMMARY

Ten groups of subjects localized single flashes, viewing monocularly, and responding with a projection pointer. Flash sources were located within a 64-degree circular field in a blacked-out room. One group saw only a fixation point. For another group only a cross was projected. Four groups were shown Cartesian coordinates, and four groups were shown polar coordinates. The density of the coordinate lines for the respective groups was increased by successive rectangular or polar bisection of the coordinate units, beginning with the cross. There were no appreciable differences in localization error between the groups which used one type of coordinate system and those which used the other. Introduction of the coordinate cross, and the bisection of the cross, led to successively smaller errors in localization, but further increases in line density did not. All groups made constant errors of localizing flashes closer to the visual axis than they actually were.

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NOTES

1. There have been a number of studies which have dealt with the problem of visual localization, such as those by Rogers et al. (1947); Saltzman et al. (1950); Attneave (1955); Leibowitz et al. (1955a, 1955b); Bartley (1959); and Harcum (1960). None, however, have been concerned with the effects of a systematic introduction of reference lines in an otherwise unstructured field.

2. Papers based, in part, on this research were presented at the 1961 meeting of the Midwestern Psychological Association in Chicago, and at the 1961 meeting of the American Psychological Association in New York.

3. A .05-sec. DC pulse was used to "flash" the lamps. This, in some cases, did not allow sufficient ionization time to ignite the lamps. To insure immediate ionization and flash, it was necessary, by some external means, to begin ionization of the gas in each lamp prior to the pulse. For this purpose, an ultraviolet lamp was used. Ultraviolet rays help to ionize or "heat" the gas particles in the neon lamp, without lighting it.

4. Leibowitz, Myers, and Grant (1955) found that localization accuracy for brief visual stimuli is independent of duration within the limits of .01 to .64 sec.