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THE EFFECTS OF SIZE AND BRIGHTNESS ON THE SPEED OF IDENTIFYING NUMBER OF RANGE RINGS

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by

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SUMMARY

Introduction. In reading ranges from a polar coordinate display, the observer must first determine the range of the range ring nearest the target, and then make a visual interpolation for a precise estimation of range. One of the factors affecting how fast an observer can identify a particular range ring is the speed with which he can determine the total number of rings. These experiments were designed to investigate the effects of display size (visual angle) and brightness on the speed of reporting the total number of range rings.

Procedures. Various numbers of range rings were projected onto a screen, and the observer was required to call out the total number of rings as soon as he had decided what the number was. Accuracy was stressed, and the total time required for the correct identification was measured. Visual angles between one degree--10 minutes and 90 degrees, and brightness levels between 0.05 and 55 apparent foot candles were used.

Conclusions. The following conclusions were made on the basis of the results of the experiments.

1. The optimum visual angle for displays of this sort is between 20 and 60 degrees of visual angle. This optimum is not very pronounced.

2. Changes in visual angle are most effective when the total number of rings is great and are least effective when the number of rings is small.

3. The results suggest that larger displays viewed from greater distances give faster identification times than smaller displays viewed from shorter distances, even though the visual angle is the same in both cases.

4. The optimum screen brightness is about 10 apparent foot candles.

5. The effect of increasing the total number of rings is more severe than the effect of changes in either visual angle or brightness.

6. Individual differences are large and consistent and may be one of the most important factors affecting the efficiency with which this type of perceptual task is performed.

INTRODUCTION

The polar coordinate display is one of the most widely used types of display in present naval operations. Because of its importance, a great deal of research has been done on factors which affect the speed and accuracy with which ranges and bearings can be read from the polar coordinate display. This laboratory has studied the problem of range estimations, while the Psychophysical Research Unit at Mt. Holyoke College has worked on the problem of bearing estimations.

Psychological factors in range estimation. There are several psychological processes involved in determining the range of a particular target on a polar coordinate display, but for most purposes only two of these processes are important. In the first place, the observer must determine the range of the nearest range ring, in order to get a gross or crude range estimation. Secondly, he must estimate the fractional distance of the target between two successive range rings if the target does not fall exactly on one of the rings. He must, in other words, make a visual interpolation for his precise range estimation.

These two processes can be handled independently from a research point of view in such a way that the factors which affect each of them can be determined. This paper is concerned only with the identification of the range rings, and not with the visual interpolation process.

Identification of range rings. A particular range ring can be identified if it has some characteristic which distinguishes it from all other range rings on the display. It may have a specific coloring, or it may have a range number marked on it at various places. Or, on the other hand, a particular range ring can be identified if its position with respect to all other range rings is known. For example, suppose that the observer knows that there are eight rings to represent a total of 80 miles. Then when he realizes that a particular ring is the fourth ring, he knows what range it represents--in this case, 40 miles. In general, we can expect that the faster an observer can determine the total number of rings on a display, the faster he can correctly identify any particular ring (1). With this relationship in mind, we can see that it is important to investigate the factors which affect the speed of recognizing the total number of range rings on a display.

In a previous paper (3), the authors showed that the time required for correct identification of the total number of range rings increases as the number of rings is increased. Thus it takes longer to recognize that there are four rings on a display than that there are three rings. Even though the relation between time for correct identification and number of rings held for all numbers of rings investigated, there was a change in slope of the function at approximately five rings. This change suggested that the slowing-down effect of adding more range rings is more serious above than below five rings.

Purpose of experiments. The purpose of the present experiments is to determine the effects of two additional factors on the time required for correct identification of number of range rings. One set of experiments is concerned with the overall size of the display; and another set is concerned with the brightness of the display.

APPARATUS

Presentation of stimuli. The primary apparatus consisted of two projectors and a ground glass projection screen. The slide projector was used to present the stimulus material on the screen, while the other projector provided a pre- and post-exposure field of equal brightness. The ground glass screen was mounted vertically, and had outside dimensions of five by five feet. The projectors were located on one side of the screen, while the observer was seated on the other side.

The stimuli projected onto the screen were various numbers of concentric rings, appearing on the screen as black rings on a white background. The rings varied in number from two to 10, and were arranged so that the distance between successive rings was always equal to the radius of the innermost ring. In other words, the rings were spaced equally from the center of the screen to the outside diameter. Regardless of the number of rings presented, the diameter of the outside ring was always the same for a given set of conditions. Thus as the number of rings changed, the spacing between the rings also changed.

A camera shutter with a solenoid was mounted on the slide projector. Whenever the experimenter pressed a telegraph key, the shutter of the slide projector was opened, and the other projector (providing the pre-exposure field) was cut off.

Measurement of identification time. Whenever the telegraph key which opened the shutter of the slide projector was pressed, a Standard Electric Clock (Model S-1) was started. The clock was stopped by the action of a throat microphone as soon as the observer reported the number of rings seen. Thus the clock reading (in hundredths of a second) was a measure of the total time required by the observer to report the number of range rings. The circuits used to provide this timing and shutter control have been described in detail previously (2, 4).

Control of display size. The diameter of the display (measured at the outermost ring) was varied by changing the distance of the projector from the screen. The visual angle subtended by the display was varied both by changing the diameter of the display and by changing the distance of the observer from the screen.

Control of brightness. The brightness of the display was varied in coarse steps by placing neutral filters in the projector. Fine gradations of brightness were obtained by adjusting the aperture on the shutter. Brightness levels of the screen were measured with a Universal Photometer

(Model A), with the sensitive element placed directly against the front of the display screen (i.e., the side viewed by the observer). The only illumination in the room was that provided by the two projectors.

PROCEDURE

A total of five observers, male college students, participated in these experiments, although data were collected from only one man at a time. After the proper visual angle and brightness level were arranged, the observer was seated on a stool with the throat microphone adjusted and checked. His task was to call out the number of rings that was presented to him each time. Approximately one second before each new exposure, the experimenter gave a verbal warning signal to the observer. The observers were asked to respond as rapidly as they could, but were repeatedly cautioned to be certain that their reports were correct. After each report was made, the experimenter recorded the time score and reset the equipment.

Number of observations. In one experimental session, each of the different numbers of rings was presented five times, making a total of 45 time scores per subject for each condition of visual angle and brightness. The various numbers of rings were presented in random order. The experimenter presented the exposures as rapidly as he could in a given session, with an average time of about 12 seconds between exposures. After the 45 scores were obtained for one experimental condition, the observer was given a brief rest while a new set of conditions was arranged. No observer participated for more than one hour at a time.

RESULTS AND DISCUSSION

Effect of Visual Angle on Speed of Identification

Conditions. Table I shows the various visual angles, display diameters, and viewing distances used to determine the effect of size on the time required to identify the total number of rings presented. The visual angles are presented in round numbers, but are well within the error of determining the actual distance of the observer's eyes from the screen. The viewing distances shown (distance of observer from screen) also are not precise, since no attempt was made to keep the observer's eyes in a rigidly fixed position. Notice that several of the visual angles were obtained with two different arrangements of display diameter and viewing distance. The order of presentation of the various conditions was random.

For each of the conditions shown in Table I measurements were made at two different brightness levels--0.1 and 2.0 apparent foot candles. It will be seen later, however, that the effect of brightness over this range is very small. Consequently we have averaged the data for the two brightness levels. Thus under each arrangement of visual angle, 10 identification times were obtained for each observer for each total number of rings.

Table I

Experimental Conditions Used to Determine Effect of Visual Angle on Speed of Identifying Number of Rings

Visual Angle (in degrees)	Diameter of Outside Ring (in feet)	Distance of Observer from Screen (in feet)
1° 10'	0.5	24
3° 30'	1.0	16.
"	0.5	8
7°	1.0	8
"	0.5	4
14°	1.0	4
"	0.5	2
28°	4.0	8
"	1.0	2
53°	4.0	4
90°	4.0	2

Relation between visual angle and number of rings. Figure 1 shows how the time for correct identification increases as the number of rings is increased, when various visual angles are used. Each of the three largest visual angles was obtained with two different combinations of display size and viewing distance, and the curves shown in Fig. 1 are the averages of the two combinations.

The smallest changes in identification time, as the total number of rings is increased, occur with the largest visual angle, as shown in Fig. 1. As the visual angle becomes smaller, the identification time rises more rapidly with an increase in the total number of rings. At the smallest visual angle, the observers were unable to identify the greater number of rings regardless of how long they were allowed to look. With this small a visual angle, they could not discriminate between the lines when there were more than four.

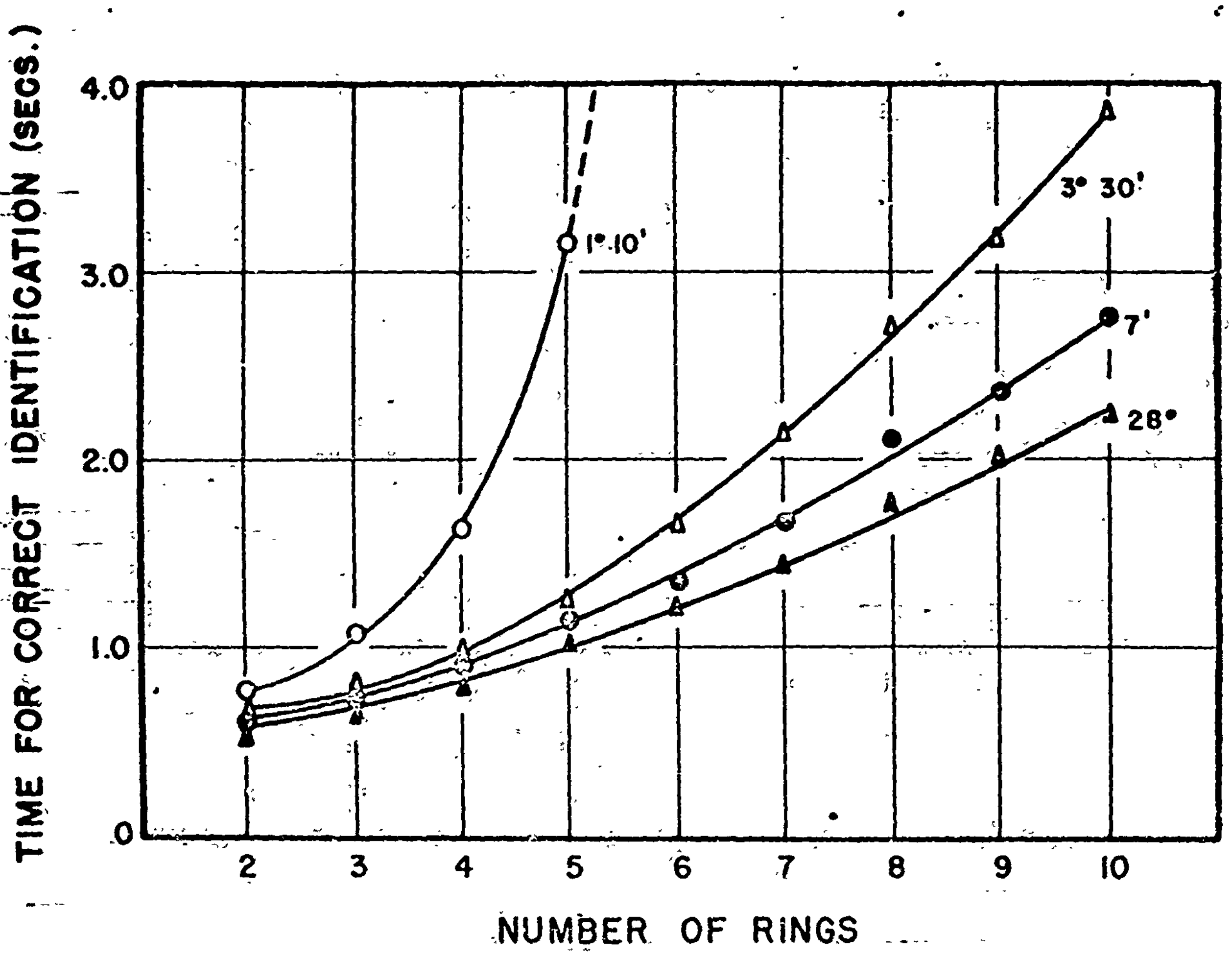

Fig. 1. Speed of Identifying Different Numbers of Rings with Various Visual Angles.

Each curve is for a different visual angle as indicated, and is the average for two brightness levels. In addition, each curve for the three largest visual angles is the average for two display sizes. Thus each plotted point for the three largest visual angles is the average of 100 observations. For the smallest visual angle, each plotted point is the average of 50 observations.

Figure 2 shows the same set of relations as Fig. 1, but in another way. Here the time for correct identification is plotted as a function of the visual angle with various numbers of rings. It can be seen that differences in visual angle have practically no effect at the low numbers, but have a very noticeable effect at the higher numbers.

There is an optimum visual angle at about 30 degrees, although this optimum is not very pronounced. An analysis of variance shows that the increase in identification time for the two largest visual angles is significant beyond the 0.5 per cent level of confidence. Even with this high degree of statistical significance, however, there is little practical significance in the slight rise in identification time with the larger visual angles. Thus we can at least say that visual angles between about 20 and 60 degrees are about equally satisfactory for displays on which range rings must be identified.

Effect of display diameter. Four of the various visual angles studied were obtained with two different combinations of display diameter and viewing distance. All visual angle data presented so far have been average values for the two different combinations used.

Table II

Average Time (in Seconds) for Identifying Number of Rings with Different Visual Angles and Display Diameters

These data are the average identification times for all numbers of rings (two to ten). The actual sizes of the display diameters can be determined from Table I.

	Visual Angle				
	3° 30'	7°	14°	28°	Average
Larger Diameter	1.761	1.667	1.426	1.261	1.529
Smaller Diameter	2.087	1.372	1.494	1.373	1.582
Average	1.924	1.520	1.460	1.317	

Table II shows the overall average identification times (the average for all numbers of rings) for these four visual angles, at the larger and the smaller diameters separately. On the average, the larger diameter (with the concomitant larger viewing distance) produces shorter identification times than the smaller diameter. In three out of four cases, this is true. An analysis of variance indicates that the overall effect could have occurred by chance once in five times, but that the specific differences (including the reversal) could have occurred by chance less than once in a hundred times.

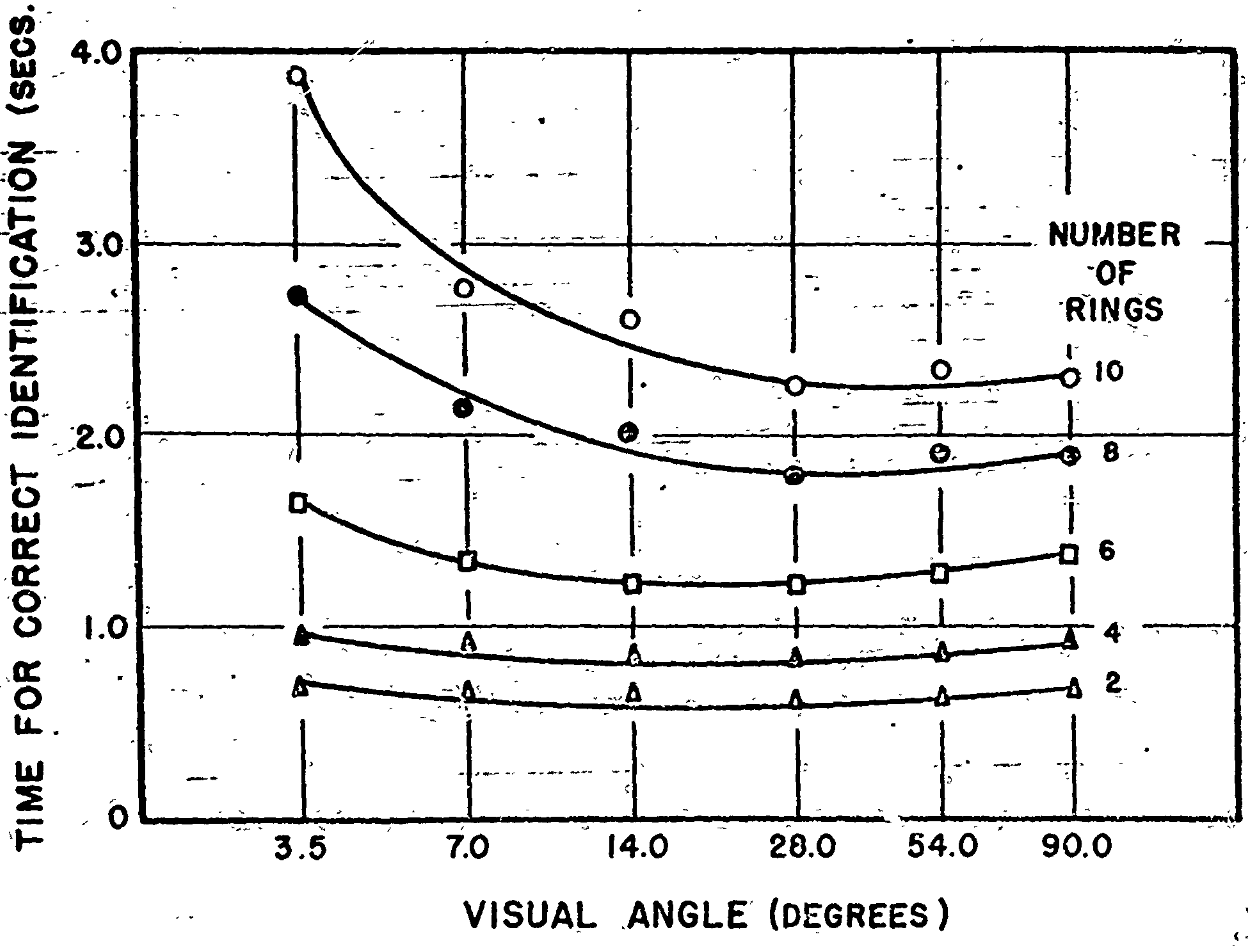

Fig. 2. Speed of Identifying Number of Rings as a Function of Visual Angle

All plotted points are averages for two brightness levels. Measures at visual angles of 3.5, 7, 14, and 28 degrees were made with two different display sizes, and each point is thus the average of 100 observations. All other plotted points are averages of 50 observations.

Thus we can say that the overall advantage of the larger diameters is not significant, although the advantage is significant in the specific cases in which it occurs. There seems to be no good reason why the smaller diameter is better with a visual angle of 7 degrees, when the larger diameter is better for all other visual angles.

Effect of Brightness on Speed of Identification

Conditions. Table III shows the various brightness levels which were used to determine the effect of brightness on the speed of identifying total number of rings. In these measurements, two different visual angles were used, with the conditions indicated in Table III. Different brightness levels were used for the two different visual angles. The various conditions shown were run in a random order.

Table III

Brightness Levels Used to Determine Effect of Brightness on Speed of Identifying Number of Rings.

The various brightnesses (in apparent foot candles) are indicated under each of the two different visual angles used. For the smaller visual angle, the diameter of the outside ring was 1.0 ft.; for the larger visual angle, it was 4.0 ft. In both cases, the observer was 4 ft. from the screen.

Visual Angle	
14°	53°
0.05	0.05
4.30	0.30
10.00	1.00
30.00	3.60
55.00	4.30

Brightness effects. The effect of brightness on the identification time for number of rings is shown in Fig. 3. The plotted points there represent the average identification times for all numbers of rings. The identification time decreases with an increase in brightness level when the larger visual angle is used, and there is an optimum brightness at 10 apparent foot candles when the smaller visual angle is used. It seems safe to conclude, then, that there is an optimum brightness for this type of perception at about 10 apparent foot candles.

Analysis of variance shows that the effect of brightness is significant for both visual angles at less than the 1.0 per cent level of confidence. Once again, however, the practical significance of the brightness effect is small. The total difference in identification time between the best and the poorest brightness levels is just over 0.1 second.

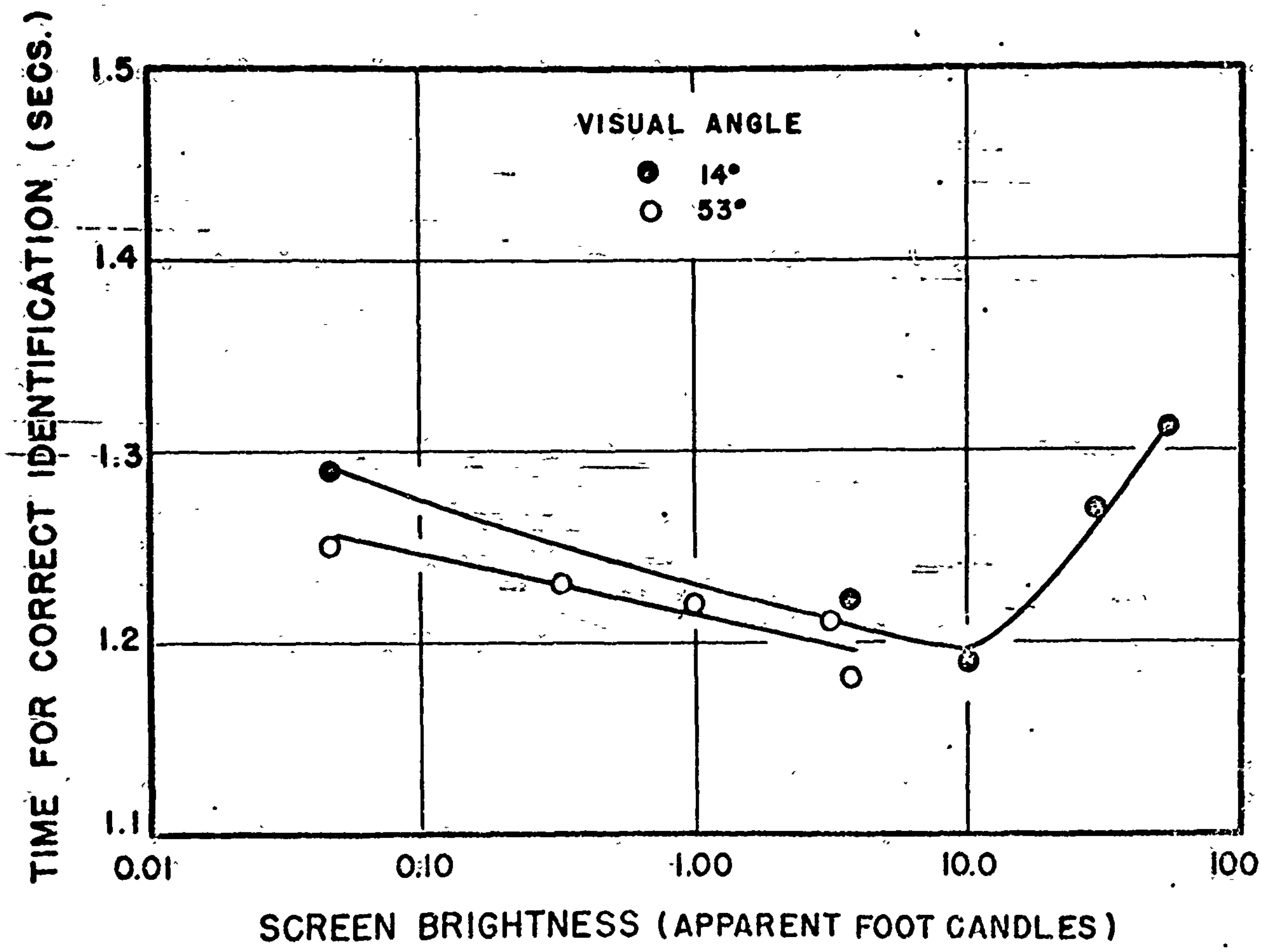

Fig. 3. Speed of Identifying Number of Rings as a Function of Brightness Level

Each plotted point is the average identification time for all numbers of rings (two to ten). The experimental conditions are shown in Table III.

Total number effect. The effects of both visual angle and brightness are small compared to the effect of total number of rings. For example, under best conditions, changing the number of rings from six to seven increases the identification time by approximately 0.2 second. This slight increase in total number has almost twice as much effect as a change in brightness of a factor of 100. Likewise, the effect of changes in visual angle, except at the very small angles, is much less than the effect of changing total number of rings. The most important factor, then, in this type of perception, is the total number of rings which must be identified. While both visual angle and brightness have some effect on the speed of identifying total number, their effects are small compared to the factor of number itself.

Individual Differences

Five subjects were used in these experiments, and the differences between their average identification times are quite large. Taking all conditions used in these experiments together, the five overall average identification times for the five observers were: 1.03, 1.27, 1.39, 1.46, and 1.60 seconds. Thus there is a difference of over 50 per cent between the longest and the shortest average times. Once again, these differences are large compared to differences produced by changing visual angle and brightness. While no further work was done in these experiments on differences between individuals, such work might be profitable. Selection of observers for this type of display situation might be the best way of increasing efficiency.

CONCLUSIONS

The conclusions drawn from these experiments can be summarized as follows:

1. There is an optimal display size for identifying the total number of range rings. The effect of size is not pronounced, however, except at small visual angles. In general, it seems best to use visual angles between 20 and 60 degrees.

2. The effect of visual angle is much more severe with large total numbers than with small total numbers. For example, changing the visual angle from 28 degrees to approximately 3.5 degrees increases identification time almost by a factor of two when 10 rings are used. A similar change in visual angle for two rings increases identification time less than 10 per cent.

3. There is a suggestion that, at a constant visual angle, identification time is faster with a larger diameter display with the observer farther away than with a smaller diameter display with the observer closer.

4. The optimum screen brightness is approximately 10 apparent foot candles, although the effect of brightness is small over a wide range of brightnesses.

5. The effect of increasing the total number of rings is much more severe than any of the effects due to differences in size or brightness, except when very small visual angles are used with large numbers of rings.

6. Individual differences in speed of identification are large, and selection of observers for this type of perceptual task may be the best means of increasing efficiency.

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ABSTRACT:

The effects of size and brightness on the speed of identifying number of range rings was investigated. In reading ranges from a polar coordinate display, the observer must first determine the range of the range ring nearest to the target, and then make a visual interpolation for a precise estimation of the range. Various numbers of range rings were projected onto a screen, and the observer was required to call out the total number of rings as soon as he had decided what the number was. Accuracy was stressed, and total time required for correct identification was measured. Visual angles between 1° 10 min and 90°, and brightness levels between 0.05 and 55 apparent foot candles were used. Speed of identifying different numbers of rings with various visual angles; speed of identifying numbers of rings as a function of visual angle; and time for correct identification are plotted.

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