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**FURTHER RESEARCH ON THE EFFECT OF VIEWING
ANGLE AND SYMBOL SIZE ON READING EASE**

TECHNICAL DOCUMENTARY REPORT NO. ESD-TDR-64-633

JANUARY 1965

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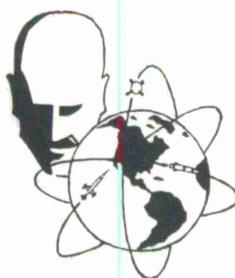
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Project 703.0

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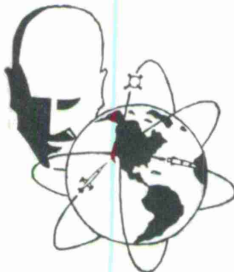
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1. The first part of the paper is devoted to a general discussion of the problem.

2. The second part is devoted to a detailed study of the case of a single

3. The third part is devoted to a study of the case of a double

ABSTRACT

The effects of viewing angle and visual symbol size upon the time required to read familiar words were studied for angles of 90, 60, 45 and 30 degrees and for symbols whose height subtended 16 and 10 minutes of arc at the viewer's eyes. Recommendations for large-board, wall-display layout and viewer-seating arrangements are offered.

REVIEW AND APPROVAL

This Technical Report has been reviewed and is approved.

FOR THE COMMANDER


DONALD W. CONNOLLY
Chief, Display Division
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Laboratory

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SECTION I

INTRODUCTION

The effect of viewing angle on a person's ability to read text is important in planning the size and layout of large-board wall displays (see Fig. 1). The words on this page become distorted when seen from an oblique viewing angle. This visual distortion makes reading slower and more difficult, and the degree of distortion determines seating arrangements, screen sizes, and other layout details. Previous studies^[1] have shown that errors made in recognizing briefly exposed, common, five-letter words increase gradually as the viewing angle is reduced from 90 degrees (straight-on) to 45 degrees. At the shallower angle of 30 degrees, the error rate is intolerably high. This report, like Ref. 1, describes the effect of viewing angle on word recognition time (or verbal reaction time) for two different sizes of symbols.

The symbol size is of interest whenever different viewers are seated at different viewing distances from the display screen since symbols of a given height will subtend a smaller visual angle for the more distant viewers. Furthermore, the smaller the symbol the more symbols a given screen can accomodate, there is a good reason to use the smallest symbol consistent with easy reading. Unfortunately, the effect of the viewing angle may not be the same for small symbols as it is for larger, more easily read symbols. If there were such an interaction between the effects of symbol size and viewing angle, it would be necessary to sacrifice display capacity in order to retain good reading for all viewers.

[1] Karp, S. , The Effect of Viewing Angle on Word Recognition, The MITRE Corporation, Working Paper W-6202, W-6202C # 1, W-6202C # 2, July 1963.

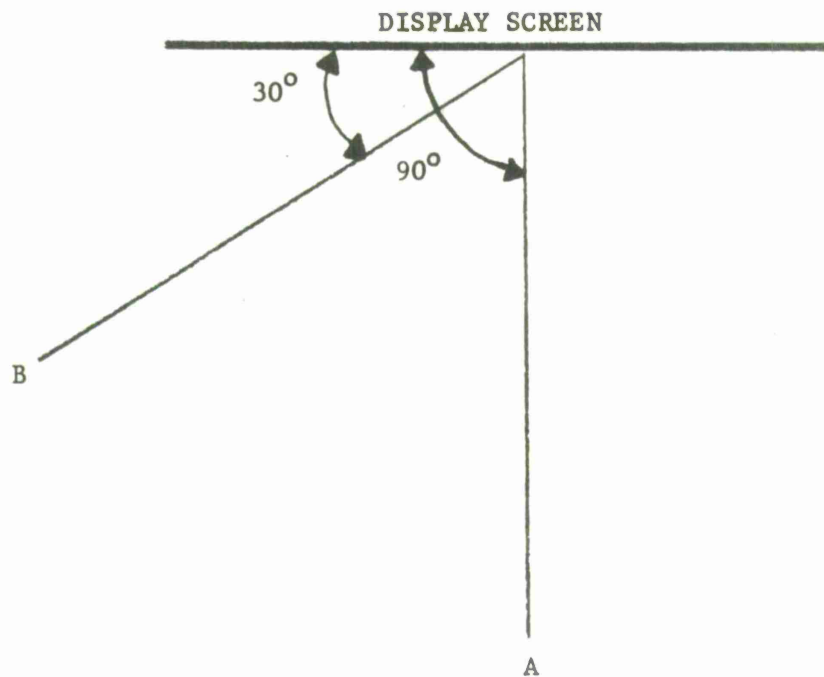


Fig. 1. Showing the Viewing Angle for Subjects Seated at A and B

One way of measuring the relative reading ease, for various angles and symbol sizes is to expose, say, a common, five-letter word to a subject and to record the time which elapses between the onset of exposure and the subject's pronunciation of the word. The measurement may be made at either long or short viewing distances, as long as the visual angle subtended by the symbols remains constant at about 16 minutes of arc, and the symbols are white on black, with good contrast and adequate brightness.* Therefore, it is feasible to study the effects of viewing angle and representative symbol sizes in a laboratory simulation of a large-board, wall display.

*Recalling that chromatic aberration of the eye is not important except for some colors, notably blue, at long viewing distances, especially for stimuli well above visual threshold in visual size.

There are three questions of interest in this paper:

- (1) Does the reaction time depend upon the viewing angle?
- (2) Does the reaction time depend upon the visual angle subtended by the symbol height at the viewer's eyes ?
- (3) Does the effect of viewing angle on reaction time depend upon the symbol's visual size (or vice versa)?

SECTION II

APPARATUS

A selection of 110 five-letter words with Thorndike-Lorge word-count frequencies between 20 and 30 per million (1944) were printed on white paper with a headliner machine. Two words, printed in the Tempo typeface, are shown as examples in Fig. 2. The words were photographed on 35 mm. film and made up in glass-mounted slides. A Viewlex projector was mounted behind a black screen. A 6-inch square hole in the screen's center was covered with a piece of opalized glass. The projector was adjusted to throw symbols 1/4 inch in height with a brightness of 20 foot Lamberts, as measured with a Spectra Brightness Spot Meter. The diffusivity of the opalized glass provided constant brightness at all angles out to less than 30 degrees. The screen and projector were placed on a table. The screen was fixed so that it could be pivoted about its vertical centerline to the desired angle.

W E A V E V A P O R

Fig. 2. Examples of Headliner, Tempo Type Face

The subject sat at a second table and rested his forehead against a horizontal bar. The table was placed so that the subject's eyes were either 54 inches from the screen center, at which distance the symbol height subtends approximately 16 minutes of arc, or 86 inches, where the symbol height

subtends approximately 10 minutes of arc. The experiment room was diffusely lighted by standard cool white fluorescent lamps dimmed to provide 0.4 foot candles horizontally on the screen and vertically at table height.

A microphone was placed on the table close to the subject's lips. The projector lamp was turned on manually, which started a standard electric timer. The timer was stopped by a voice-operated relay, which also turned off the projector lamp. A large screen was placed before the subject to conceal the activities of the experimenters.

SECTION III

PROCEDURE

Thirty-seven male and 11 female MITRE employees were screened for normal color vision and visual acuity with a Bausch and Lomb, Modified Ortho-Rater. All subjects had 20/20 vision, near and far, with both eyes, and at least 20/22, near and far, with each eye alone, corrected or uncorrected. Any subject whose color performance on the Ortho-Rater was questionable, later passed the test for normal color vision with the American Optical Pseudoisochromatic plates (a better test, but requiring more time to administer).

The subjects were given the experimental procedure one at a time. Each subject was assigned an angle (90, 60, 45 or 30 degrees) and a distance (54 or 86 inches from the screen) by randomly selecting (without replacement) a prepared slip of paper on which one of the angles and one of the distance were printed, the selection being made when the subject reported for the experimental session. Half the subjects began with the 54-inch distance, and half with the 86-inch distance. The subject was seated, and a prepared statement of instructions was read aloud to him.

The word slides were shown to the subject, one at a time, in an unpredictable order. The subject was instructed to read the word aloud as quickly as possible upon its appearance. Each subject was first seated at 54 inches and 90 degrees, and was given 10 word slides for practice and additional instruction or coaching. For each slide, the experimenter said, "Ready," the subject fixed his eyes on the screen's center, and, after a delay of one or two seconds, the word appeared, and the subject read it aloud.

The subject was then seated at the distance and angle he had selected (all angles less than 90 degrees were to the left of the normal), and was shown

50 more words. Each subject's median reaction time for the 50 words was taken as representative of his performance. If a subject read a word incorrectly, or missed it for some other reason, the data were recorded, but not included in the analysis. The subject was then moved to the other viewing distance (at the same angle), and the procedure was repeated with a second list of 50 words.

No subject was informed of his reaction times, or his errors, until the session was ended. There were very few errors, and each session lasted approximately 40 minutes.

SECTION IV

RESULTS AND CONCLUSIONS

The results are shown in Table I and Fig. 3. An analysis of variance of median reaction times for the symbol size of 16 minutes of arc revealed that the differences among the means for the four angles were not statistically significant (F equalled 1.06). * In a similar analysis for the 10-minute size, the differences among the means for the four angles were statistically significant at the .01 level (F equalled 9.60). For the 10-minute size, Duncan's Range Test showed that the mean for 30 degrees was significantly distinguishable from the mean for 90 degrees and from the mean for 60 degrees at the .01 level, and from the mean for 45 degrees at the .05 level. In summary, for the 10-minute size, the mean reaction times for 90, 60 and 45 degrees were not distinguishable from each other, but each was significantly smaller than the mean reaction time for 30 degrees.

Table I

Group Average of Median Reaction Time

Viewing Angle (Degrees)	Symbol Size		Mean Difference
	16 Minutes	10 Minutes	
90	0.610	0.652	0.042
60	0.597	0.664	0.067
45	0.620	0.701	0.080
30	0.659	0.799	0.140

*For 3 and 44 degrees, F is 2.82 at .05, and 4.26 at the .01 level.

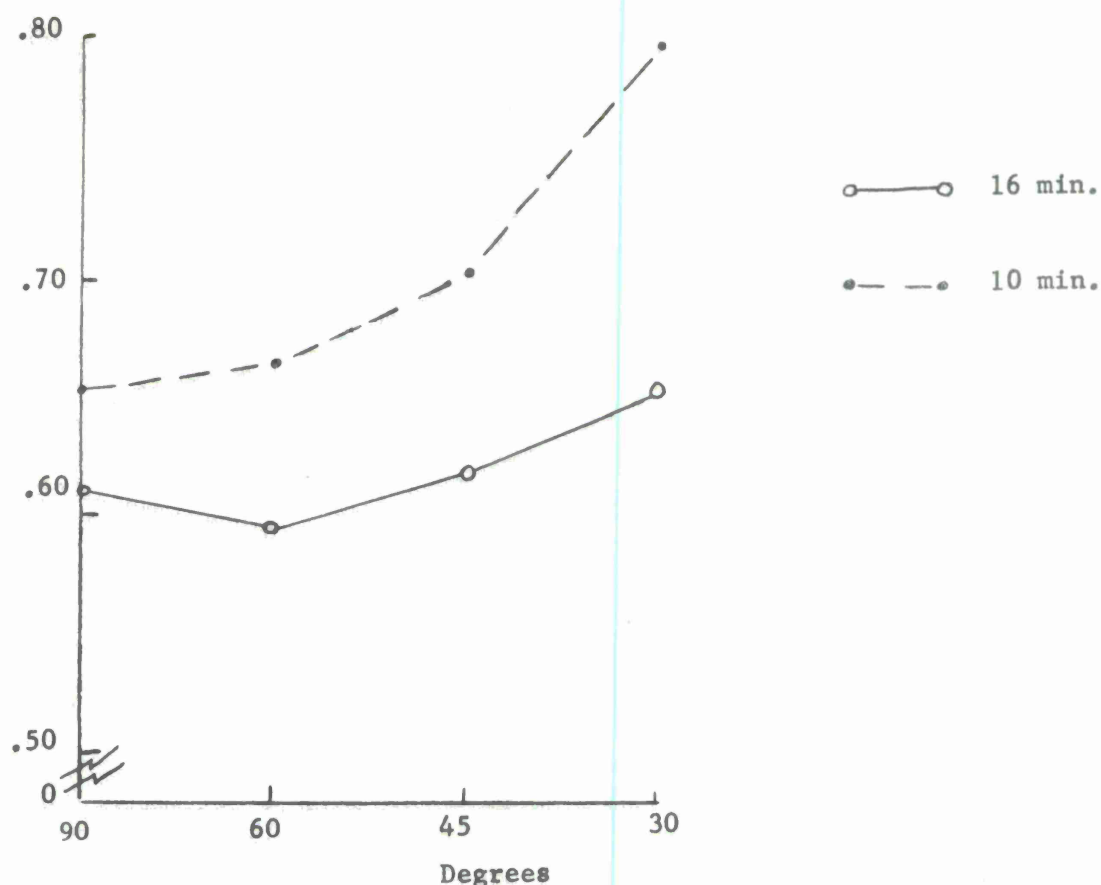


Fig. 3. Mean Reaction Time Plotted Against Viewing Angle for Both Symbol Sizes

A statistical analysis was also performed on the difference between reaction times to the two symbol sizes for each angle. For this analysis, each subject's median reaction time for the 16-minute size was subtracted from his median reaction time for the 10-minute size, but which yielded a sample of 12 differences for each angle of viewing. All but 3 of the 48 differences were greater than zero; two were less than zero, and one was zero. For each angle, the hypothesis that the group mean difference is equal to zero (i. e., the median reaction times for the 16-minute size are equal to the median reaction times for the 10-minute size) was tested statistically for each angle. For each angle, the

mean reaction time was larger for the 10-minute size than for the 16-minute size, the differences being statistically significant at the .01 level in all cases. In summary, the reaction time was slower for the smaller size for all viewing angles.

The hypothesis that the difference in reaction time is the same for all four angles (i. e. , there is no interaction between viewing angle and symbol size) was tested by subjecting the sample of differences to an analysis of variance. The test revealed that the differences among means for the four angles were statistically significant at the .01 level of confidence (F equalled 9.02). Duncan's Range Test revealed that the differences for angles of 90, 60 and 45 degrees were not distinguishable from each other, but each was statistically distinguishable from the difference for 30 degrees, all at the .01 level. This test confirms the statement made above that the difference in reaction time to the two sizes depends upon the viewing angle.

The curves plotted in Fig. 3 show that reaction times for the 16-minute size are approximately equal for 90-, 60- and 45-degree viewing angles, and that the reaction time is slower (but not significant statistically, as stated earlier) at 30 degrees. The progression of increasing reaction time as the viewing angle is decreased is seen clearly in the curve for the 10-minute symbol size. The curves are in agreement with the results of the earlier study of reading errors and viewing angle.^[1]

In summary, the three questions asked in Section I are answered as follows:

- (1) The reaction time did depend upon the viewing angle for 10-minute size symbols when the angle was 30 degrees.

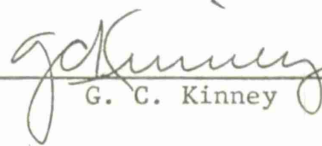
- (2) The reaction time did depend upon the visual angle subtended by the symbol height at the viewer's eyes, the time being greater for the smaller size.
- (3) The effect of viewing angle on reaction time did depend upon the symbol size, the effect being a greater increase in reaction time at 30 degrees for the smaller symbol.

SECTION V

DISCUSSION AND RECOMMENDATIONS

The results of this experiment are in agreement with the results of previous work.^[1] The effect of the viewing angle upon reading ease, especially for 30 degrees, and to a lesser extent at 45 degrees, is to increase the error and/or the time of reading common five-letter words. In addition, the effects of small viewing angle and small symbol sizes appear to be additive. The possibility that practice will enable a subject to partially overcome the effects of size and angle on reading ease is presently being investigated.

For displays whose viewers do not enjoy frequent practice at reading text at small viewing angles, and when it is desired to retain easy reading for all viewers, it is recommended that no viewer be seated at a viewing angle smaller than 45 degrees, or at a distance from which the height of the smallest symbol subtends an angle much smaller than 16 minutes of arc.


G. C. Kinney


S. Manning


L. Smith

APPENDIX

NOTE ON THE PROCEDURE

The experiment was carried out with three subjects at each angle; three were shown words projected through a red filter, three were shown green words, three were shown blue, and three were shown the words with the light from the projector unfiltered, which was typical, incandescent white. The brightnesses of the four colors were matched with a Spectra Brightness Spot Meter. The colors were included in order to compare the results of this experiment with the results of a pilot study of visual acuity (unpublished) using the same colors and being conducted at the same time.

The effect of color on the legibility of the words in this experiment would occur only with relatively narrow-band colors seen at distances of 10 feet or more, if any effect were to occur at all. The colors used were broad-band colors (Wratten Filters No. 38, No. 24, and X2), and the greatest viewing distance was 7 feet (see Section III). There is no theoretical reason, therefore, to expect differences among the reaction times for the various colors.

The data were analyzed to test the statistical significance of the differences among the median reaction times for the four colors. The results of the analysis for the 16-minute symbol size are shown in Table II, and the results for the 10-minute size are in Table III. The variances attributable to color and to the color by angle interaction are both small, and neither is statistically significant.

Accordingly, the color of the light is of no theoretical or practical interest in this study. In the interests of clarity, the presence of color in the experimental procedure was disregarded in the main report, and the conclusions reached there are unaffected by the results shown in this appendix.

Table II
Analysis of Variance for Reaction Times for Symbol
Size of 16 Minutes of Arc

	Sum of Sq.	df	Mean Sq.	F
Total	2666.49	47		
Angles	14.05	3	4.68	0.071
Colors	256.51	3	85.50	1.29
Colors x Angles	280.60	9	31.18	0.47
Replicates	2115.33	32	66.10	

Table III
Analysis of Variance of Reaction Times for Symbol
Size of 10-Minutes of Arc

	Sum of Sq.	df	Mean Sq.	F
Total	6552.81	47		
Angles	1591.19	3	530.40	4.60*
Colors	563.77	3	187.92	1.63
Colors x Angles	709.52	9	78.84	0.68
Replicates	3688.33	32	115.26	

*Significant at .01 level.

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