

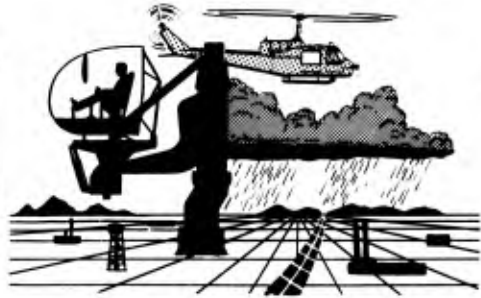
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# JANAIR

JOINT ARMY-NAVY AIRCRAFT INSTRUMENTATION RESEARCH

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TECHNICAL REPORT  
NO. D228-421-502



## LEGIBILITY OF ALPHA-NUMERIC INFORMATION AS A FUNCTION OF DISPLAY ROTATION

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JANA IR  
JOINT ARMY NAVY AIRCRAFT INSTRUMENTATION RESEARCH

LEGIBILITY OF ALPHA-NUMERIC INFORMATION  
AS A FUNCTION OF DISPLAY ROTATION

Technical Report  
D228-421-502

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This report presents work which was performed under the Joint Army Navy Aircraft Instrumentation Research (JANAIR) Project, a research and development program directed by the United States Navy, Office of Naval Research. Special guidance is provided to the program for the Army Material Command, the Office of Naval Research and the Bureau of Naval Weapons through an organization known as the JANAIR Committee. The Committee is currently composed of the following representatives:

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The goals of JANAIR are:

a. The Joint Army-Navy Aircraft Instrumentation Research (JANAIR) project, is a research project, the objective of which is to improve the state of the art of piloted aircraft instrumentation.

b. The JANAIR Project is to be responsive to specific problems assigned, and shall provide guidance for aircraft instrumentation research and development programs.

c. The JANAIR Project will conduct feasibility studies and develop concepts in support of service requirements.

d. These efforts shall result in reports and the knowledge to form the basis for development of improved instrumentation systems, components, and subsystems.

## ABSTRACT

This study was one of a series performed under the JANAIR program to examine the information requirements and the optimal presentation of navigation and horizontal position information.

Examination of the rotary wing pilot displays emphasizing the pictorial qualities has indicated the desirability of using a moving pictorial map display. Several reasons prompted this decision: (1) research indicated that for the critical maneuvering of the steep gradient vehicles at low level and slow speeds the use of a moving map was superior; (2) direct sensor information such as radar can best be superimposed on a moving map display; and (3) the moving elements of a moving map display are compatible with those of the pictorial vertical display.

The use of a moving map generates special problems. One of these is the requirement to read alpha-numeric information at various degrees of rotation, including inverted. This study examined the ability of subjects to read such data. Correctness of response and time to respond were the scores recorded during a presentation of the visual stimulus. The stimulus displays were words and numbers of various lengths taken from aeronautical charts.

It was concluded that (1) the legibility of word information is most difficult when displayed in an inverted or near inverted position, and (2) the legibility of numeric information does not pose a problem when displayed at any degree or rotation.

TABLE OF CONTENTS

	<u>Page</u>
I. INTRODUCTION	1
II. METHOD	3
III. RESULTS	7
IV. DISCUSSION	10
V. CONCLUSIONS	12
VI. SUMMARY	13
VII. REFERENCES	14
VIII. APPENDIX - Figures and Tables	15

LIST OF ILLUSTRATIONS

<u>Figure</u>		<u>Page</u>
1	Experimental Apparatus	15
2	Photographic Representation of Typical Slide	16
3	Graphical Representation of Angles of Slide Presentation (display angle)	17
4	Mean Response Latency Plotted as a Function of Sectors	18

LIST OF TABLES

<u>Table</u>		<u>Page</u>
1	Slides Represented in Tray A with Corresponding Display Angle per Session	19
2	Slides Represented in Tray B with Corresponding Display Angle per Session	20
3	Slides Represented in Tray C with Corresponding Display Angle per Session	21
4	Slides Represented in Tray D with Corresponding Display Angle per Session	22
5	Mean Response Latencies for Slides Presented in Tray A	23
6	Mean Response Latencies for Slides Presented in Tray B	24
7	Mean Response Latencies for Slides Presented in Tray C	25
8	Mean Response Latencies for Slides Presented in Tray D	26
9	Mean Response Latencies for Word, Number, and Combined Slides in Sectors I, II, III and IV	27
10	Analysis of Variance on Relative Scores of Response Latencies for Word Slides	27
11	Summary of Scheffe's Test for Multiple Comparisons Performed on the Treatment Sums of Relative Scores of Response Latencies for Word Slide Presentations	28
12	Percentage of Word, Number, and Combined Word and Number Slide Presentations Incorrectly Responded to Within Each Sector	28
13	Friedman Analysis of Variance Tests Applied to Response Errors for Word, Number, and Combined Word and Number Slide Presentations in Each Sector	29
14	Results of Wilcoxon Signed-Ranks Test Applied to Response Errors for Word and Combined Word and Number Slide Presentations in Each Sector	29

LIST OF TABLES (Cont'd)

<u>Table</u>		<u>Page</u>
15	Analysis of Variance on Relative Scores of Response Latencies for Number Slides	30
16	Summary of Scheffe's Test for Multiple Comparisons Performed on the Treatment Sums of Relative Scores of Response Latencies for Number Slide Presentations	30
17	Analysis of Variance on Relative Scores of Response Latencies for the Combined Words and Numbers	31
18	Summary of Scheffe's Test for Multiple Comparisons Performed on the Treatment Sums of Relative Scores of Response Latencies for Combined Word and Number Slide Presentations	31
19	Order of Tray Presentation	32

## I. INTRODUCTION

This study is one of a series of researches conducted under the Joint Army Navy Aircraft Instrumentation Research (JANAIR) program. This program is directed toward the development of a full instrument flight display system for rotary wing and steep gradient aircraft.

The flight display system centers around two primary pictorial displays, the vertical display or contact analog and the map display or pictorial position display. Studies have been conducted at Bell Helicopter to evolve an optimal display system. The study herein reported is one of these. It investigates one of the problem areas associated with the map display. This is the problem of legibility of rotated alpha-numeric information.

Previous researches on pictorial map displays presentations have indicated that one of the major problems was the specification of the proper moving elements. Payne, 1950 and 1952, and Narva, 1958, conducted studies which indicated that a display with a fixed map and a moving aircraft symbol was the preferred configuration. Bell research (Dougherty, et al, 1963) has re-examined this problem with reference to the specific application to rotary wing vehicles. The findings indicated that a moving map with a fixed symbol was equally good and at times superior to the fixed map. It was hypothesized that these findings were a result of the problems presented to the pilot-subjects not particularly to the moving elements of the display.

The fixed wing map studies utilized experimental tasks with all problems involving compass information such as flight vectors, bearings, headings, commanded track in degrees, etc. All problem solutions and control manipulations were in response to compass information. In the Bell studies non-compass oriented problems were presented. It was ascertained that in standard Federal and Military aviation instrument flight terminology and techniques for controlling IFR traffic were at times completely impracticable, i.e., hovering directions and air taxi instructions (IFR) could not be given in speeds, vectors and times. It would be possible to control such traffic with pictorial displays and utilize control techniques similar to VFR flight. Here the pilot-subject could see on his map display the position to which he was to translate and proceed to that position without directions in terms of vectors, etc. With this type of map display the symbol was always oriented to be headed up-scope or with aircraft heading at the top of the scope. Thus, regardless of the vector or compass orientation the positions to the right of the aircraft were always presented on the map to the right of the aircraft symbol. Solutions of compass problems were not involved. It was hypothesized, therefore, that the moving map configuration was desirable when flight maneuvers

presented navigation problems involving the compass were not involved. The most critical of the maneuvers for the rotary wing aircraft were low altitude maneuvers, air taxi and terrain following or station keeping. This was the primary reason for selecting the moving map display for inclusion in the research helicopter instrumented under the JANAIR program.

Two other reasons were involved in this choice. These were (1) the possible future inclusion of a radar PPI (which is a moving map display) to be superimposed on the map display which would require that both the map and the PPI move in the same relationship for optimal display interpretation and (2) the movement of the contact analog is most compatible with a moving map display, i.e., a movement of the ship to the right is indicated by display elements in both displays moving to the left. A discussion of these points may be found in the Proceedings of the ANIP 1959 Symposium (Dougherty, 1959).

With a moving map there are associated problems of legibility of alpha-numeric information which is presented on maps and charts. At times this information will be rotated and inverted. This could offer a disadvantage to this type of display of position information. In order to examine these problems, this study was instigated.

## II. METHOD

### Subjects

The Ss were 16 undergraduates from Texas Christian University. They were obtained from the University Air Force ROTC unit and lacked both flying and map reading experience. Although the Ss were selected from a population which was somewhat physically superior (due to the AFROTC physical requirements) to the ordinary college population, possible effects from defective visual acuity or color blindness were controlled by employing each S as his own control. Each subject was paid for his participation in the experiment.

### Apparatus

The experimental apparatus is presented in Figure 1 and consisted of six basic components. These included the following:

- A. Translucent plastic screen (18" x 18")
- B. Yellow warning light
- C. Shutter
- D. Kodak Cavalcade automatic 35mm slide projector with General Electric 500 watt lamp
- E. .01 Standard electric timer
- F. Control panel

The S (Subject) sat at a distance of 18 inches from a translucent screen which contained a 15-1/2 in. x 10-1/4 in. image projected at eye level. The screen also served the further purpose of separating S from E (Experimenter).

The equipment was operated as follows: E loaded a tray of slides into the projector. After a slide had been positioned, E pushed the cycling switch on the control panel. This action introduced the warning light and five seconds later, simultaneously raised the shutter (exposing the image to the S) and started the timer. As soon as S made a verbal response, E closed shutter via a "voice-key" or "VOX" circuit. This circuit was energized when E blew a plosive puff of air into a handheld microphone. This action simultaneously closed the shutter and stopped the timer.

If an incorrect response was made, the slide was reintroduced by simply repeating the above procedure. When a correct response was made, S was presented the next slide.

The experimental room was located in the Bell Helicopter Company Experimental Laboratory at Texas Christian University. All extraneous light sources were eliminated by blacking the windows in the room.

### Instructions and Procedure

Before each experimental session, S was presented with the following instructions.

"We are interested in the readability of words and numbers projected at various angles on aerial maps. You will be presented 100 slides of various map segments and will be required to read aloud the number or word which will be indicated by an arrow. At no time should you tilt your head. Please maintain an upright position at all times."

"As soon as you respond to the slide, it will be turned off. If you should respond incorrectly, you will again be presented with the same slide and will be required to read it. When you do give the correct response, you will be allowed to proceed to the next presentation. Five seconds prior to each presentation, a yellow light will flash in the upper left hand corner of the screen. This will serve as a warning signal preceding each presentation."

"Do you have any questions?"

After the instructions were read, Ss were familiarized with a typical sectional aeronautical chart. These particular charts provide coverage at a size and scale (1:500,000) convenient for navigation by moderate speed aircraft.

The experiment was run in four sessions. A session consisted of the presentation of all 100 slides and lasted between 90 and 100 minutes. The inter-session interval was approximately seven days.

### Description of the Slide Series

One hundred 35mm Kodachrome slides were used in the present study. All slides were photographed from section aeronautical charts of the southern United States. Each slide contained a small black arrow, which pointed to a particular word or number. The words, which varied in size, indicated various cities, towns, and rivers, while the numbers designated elevations. Figure 2 illustrates a typical slide.

The words (N=67) and numbers (N=33) were displayed at various angles. For simplicity, the angle was designated the display angle and was defined as the angle between the word axis and the vertical axis (0°). The display angle is graphically represented in Figure 3.

Before each session, all slides were rotated 90 degrees in the slide trays. Thus, the display angle of each slide during a particular session could be conceived of as the display angle of the previous session plus 90 degrees. This procedure permitted a vast sampling of display angles.

Because of the limited capacity of the slide trays, it was necessary to divide the slides randomly into four equal trays which were labeled trays A, B, C, and D. Tables 1 through 4 present Trays A, B, C, and D, respectively and demonstrate the display angles represented by each tray over the four experimental sessions. There was an interval of 5 minutes between each tray presentation.

### Experimental Design

The experimental design was a 16 x 4 factorial, in which each S served as his own control. One experimental variable was the 16 Ss, while the other was the sector variable. This latter consisted of four levels, which were designated I, II, III and IV. Sector I represented all display angles between 45 degrees and 134 degrees; Sector II, display angles between 135 degrees and 224 degrees; Sector III, display angles between 225 degrees and 314 degrees, and Sector IV display angles between 315 degrees and 44 degrees.

The 16 Ss were randomly divided into four subgroups. Each group (N-4) received a different order of slide tray presentation at each session. The order of slide tray presentations was counter-balanced over sessions and groups and is given in Table 19. The purpose of this technique was to remove possible sequential effects.

### Response Measures

Two measures were recorded (1) response latency and (2) response error.

Response latency was defined as the total amount of time which elapsed before a correct response was elicited. For instance, when S made a verbal response, the shutter closed and the timer was stopped. If the response was incorrect, the slide was reintroduced and the timer continued from the point at which it had previously stopped. The time intervals during which the slides were exposed to S were cumulated and comprised the response latency for a particular slide.

A source of variance in the response latency was contributed by E, since it was his task to close the shutter when a response was made. While the magnitude of the error attributable to this procedure is unknown, it is assumed to be inconsequential to the conclusions derived from the data, since the same procedure was employed for all Ss.

Response error was defined as the number of incorrect responses which were elicited at the first exposure of each slide presentation. Repetitive errors to the same slide presentation were not included in this measure.

### III. RESULTS

In Tables 5 through 8, mean response latencies of all subjects are presented for each slide under each sector.

Response latencies for each slide were analyzed in the following manner. Four response latencies were obtained from each S for each slide (one response per slide per session) and were categorized according to the particular sector which the display angle represented. Thus, a 16x4 matrix was determined for each slide.

The latency scores were then converted to relative scores. The purpose of this procedure was to remove the variance due to the differential difficulty between slides. The relative score thus provides an index of the difficulty due to angle of presentation alone. This was accomplished by summing the latencies of the 16x4 matrix of each slide. Each latency score for a particular slide was then divided by the sum total, thereby producing a matrix of relative scores. The relative scores for each sector of all slides were then combined and all analyses were performed using these measures.

#### Word Slide Presentation

##### Response Latencies

In Figure 4, the mean response latencies for word, number and the combined (word and number) slides have been plotted as a function of the sector in which the display angle occurred. It can be seen that the response latencies to word slides showed greater error than the response latencies to either number slides or number and word slides combined.

An analysis of variance performed on the relative scores of the response latencies for the word slides yielded significant differences for the sector variable ( $F = 14.56, p < .01$ ) and for the subject variable ( $F = 2.00, p < .05$ ). A summary of the analysis of variance is reported in Table 10.

Scheffe's test for multiple comparisons (Edwards, 1960) was performed on the treatment sums for the sectors variable. The results of this test are summarized in Table 11. Sector III (inverted) produced greater response latencies than the other sectors. These differences were found to be statistically reliable.

##### Response Errors

Table 12 represents the percentage of word, number, and combined word and number slide presentations which were incorrectly responded to within each sector. By this table, Sector I (upright) is clearly superior to the other sectors. Furthermore, Sector III

(inverted) is inferior to all other sectors. A Friedman analysis of variance was performed on the response errors for the four sectors. The results of this analysis are given in Table 13 and indicate a significant difference between the sectors. A Wilcoxon signed-ranks test performed on the response errors corroborated the above findings. Sector I (upright) was statistically superior to Sectors II, III or IV. Sector III (inverted) on the other hand, was statistically inferior to Sectors I, II, or IV. The results of the Wilcoxon test are summarized in Table 14.

#### Number Slide Presentations

##### Response Latencies

An analysis of variance performed on the relative scores of the response latencies for the number slides is summarized in Table 15. In spite of the scant graphical differences depicted in Figure 4, there were reliable differences between Sectors ( $F = 3.42, p < .05$ ). Again the Subjects effect was significant ( $F = 14.60, p < .01$ ).

A Scheffe's test for multiple comparisons performed on the treatment sums for the Sectors variable yielded reliable differences. Sector I (upright) was significantly superior to Section IV. A summary of this analysis is given in Table 16.

##### Response Errors

A Friedman analysis of variance performed on the response errors for the four sectors did not reveal any significant differences.

#### Word and Number Slide Presentations (Combined)

##### Response Latencies

An analysis of variance was performed on the relative scores based upon the response latencies of the combined words and numbers. A summary of this analysis is reported in Table 17. It can be seen that the Sectors variable was highly significant ( $F = 13.33, p < .01$ ), while the Subjects effect was also significant ( $F = 3.79, p < .05$ ).

A Scheffe's test for comparison of treatment sums (Table 18) indicated that Sector III (inverted) was vastly inferior to the other sectors. While the preceding comparisons were significant at the .01 level, Sector I (upright) was found to be superior to Sector IV at the .05 level.

##### Response Errors

The response errors elicited under the total slide presentations were analyzed via the Friedman analysis of variance. The sectors variable was found to produce reliable differences in response errors ( $X^2_r = 31.93, p < .01$ ). A summary of the analysis is presented in Table 13.

A Wilcoxon signed-ranks test was performed on the response errors to assess between-Sector comparisons. These results are summarized in Table 14 and establish the following findings: (1) Sector I (upright) produces superior performance to the other sectors (2) Sector III (inverted) produces inferior performance to the other sectors and (3) Sector II is superior to Sector III, but not to Sector IV. All of the preceding comparisons were significant at the .01 level.

#### IV. DISCUSSION

##### Word Slide Presentations

It is evident from Table 9 that with the exception of Sector I (upright), the magnitude of the mean response latencies to word slides were substantially greater than the response latencies to number slides. This may be explained by a tendency of Ss to make implicit verbal responses, while attempting to recognize the words. This may have conceivably resulted in a longer latency before an actual overt response was elicited. A response to number slides, on the other hand, would require less covert rehearsal, and consequently, small response latencies.

Inspection of Figure 5, together with the statistical significance revealed by the Scheffe tests, demonstrate that words displayed in Sector III (inverted) were most difficult to read. From Table 9 it is apparent that the magnitude of the ratio of the mean response latencies for the word slides of Sector I (upright) to Sectors II, III and IV were 1.91, 3.60 and 1.70 seconds, respectively. Consequently, the differences between the Sectors may be considered as following an orderly fashion, i.e., words displayed in an inverted manner require nearly four times as much time to respond to as words displayed upright. Furthermore, words displayed sideways required nearly twice as much time as words displayed upright.

Although significant differences were found in the analysis of response errors for word slide presentations, it is evident that the magnitude of the error was slight. It is apparent from Table 12 that out of a possible 1027 word slide presentations within each sector, there were total response errors of 12 (1 per cent), 55 (5 per cent), 128 (12 per cent) and 59 (6 per cent) for Sectors I, II, III and IV, respectively.

##### Number Slide Presentations

The results of the statistical analysis of the response latencies for number slides failed to exhibit an effect analogous to that found with word slides. In view of the fact that the differences between Sector I (upright) and II (sideways) and I and III (inverted) were found to be without statistical significance suggests that the statistically significant difference obtained between Sectors I and IV (also sideways) is to be regarded continuously. If the difference were of unimpeachable validity one would have expected a similarly significant difference to be found in the comparison of Sector I with Sector II and Sector I with III. Since these events did not occur, the reader is left with the option of believing either that there is a small but highly variable difference between the upright presentation of numerals and the other than (inverted or sideways) upright presentation or of believing that the differences as obtained for position in this study were spurious.

The percentage of number slide presentations incorrectly responded to is shown in Table 12. In general, it is reasonable to conclude that numbers displayed in any of the four sectors may be read with apparent ease. This is suggested not only by: (1) the small percentage of number slides incorrectly responded to but (2) by the lack of statistical difference yielded by the Friedman analysis of variance test. These findings are particularly important when one considers that the numeric information contained within sectional aeronautical charts represents elevation values, radio frequencies, runway lengths, etc.

#### Word and Number Slide Presentations (Combined)

When the latencies for both word and number slide presentations were combined, Sector III (inverted) was found to be inferior to the other sectors. Sector I (upright) was found to be superior to Sector IV (sideways). This demonstrates that the legibility of alpha-numeric information is most difficult when displayed in an inverted position.

The analysis of response errors further substantiates the above notion. Sector III (inverted) was inferior to the other sectors and Sector I (upright) was superior to the other sector. Sector II (sideways) and IV (sideways) did not differ significantly from each other. Most surprising were the percentage of slide presentations incorrectly responded to. Of a total 1600 slide presentations for each sector, the percentage of slide presentations incorrectly responded to were as follows: Sector I (2 per cent), Sector II (5 per cent), Sector III (9 per cent), and Sector IV (5 per cent).

## V. CONCLUSIONS

The conclusions which may be made from the present study are as follows.

1. The legibility of word information in sectional aeronautical charts is most difficult when displayed in an inverted position. The appearance of words in this position represents the southerly heading problem in static form.
2. The legibility of numeric information in aeronautical charts does not pose a problem when displayed at a variety of angles. Inverted numeric information was as legible as numeric information displayed upright.

Although these results will come as no surprise to persons who have attempted to read inverted alpha-numeric information, the experiment is justified since the data will be of use in determining the degree of degradation that will be encountered in the use of the moving map display. While it is believed that this obvious disadvantage is amply compensated for by the improved movement relationship between display and control, the degree of degradation will be of interest to those responsible for determining the design criteria of the horizontal display.

The results of this experiment suggest that it should be feasible and profitable to analyze further the factors of practice, color contrast, lighting, word and number size, and symbol shapes. Finally, it would be tenable further to investigate the various factors under a dynamic open loop situation.

## VI. SUMMARY

This study examined the ability of subjects to read words and numbers when they were displayed in an aeronautical chart setting and at various degrees of rotation. The 360 degrees of possible rotation were divided into four sectors of 90 degrees each. The visual stimuli were displayed to the subjects by means of a color slide. A total of 1600 presentations were made to each subject in each sector. This consisted of 528 presentations of numbers per sector and 1072 presentations of various words per sector.

Two measures of performance were recorded. These were time to respond and accuracy of response. Data were subjected to an analysis of variance and Scheffe's test for multiple comparisons or Wilcoxon signed-ranks test.

Results indicate that the use of a moving map in which alphanumeric information is presented will offer no increased error in reading numbers, however, when words are in the inverted or near inverted position they may be greater error and longer reading time required.

## VII. REFERENCES

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VIII. APPENDIX  
FIGURES AND TABLES

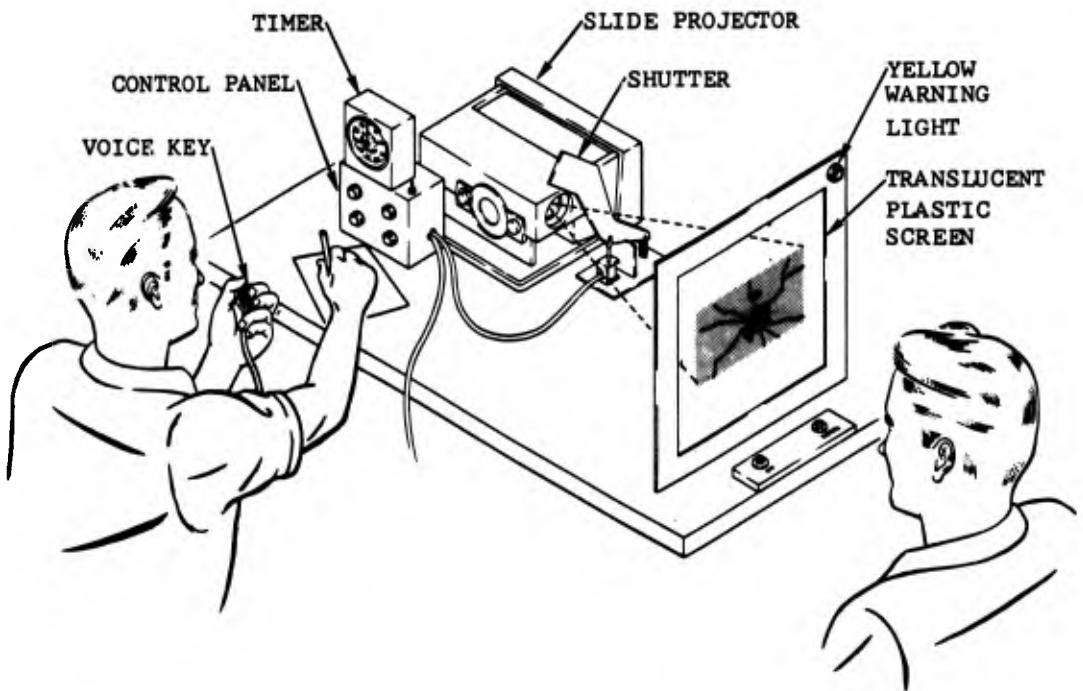


Figure 1. Sketch of Experimental Apparatus. Experimenter is shown at left and subject is shown at right.

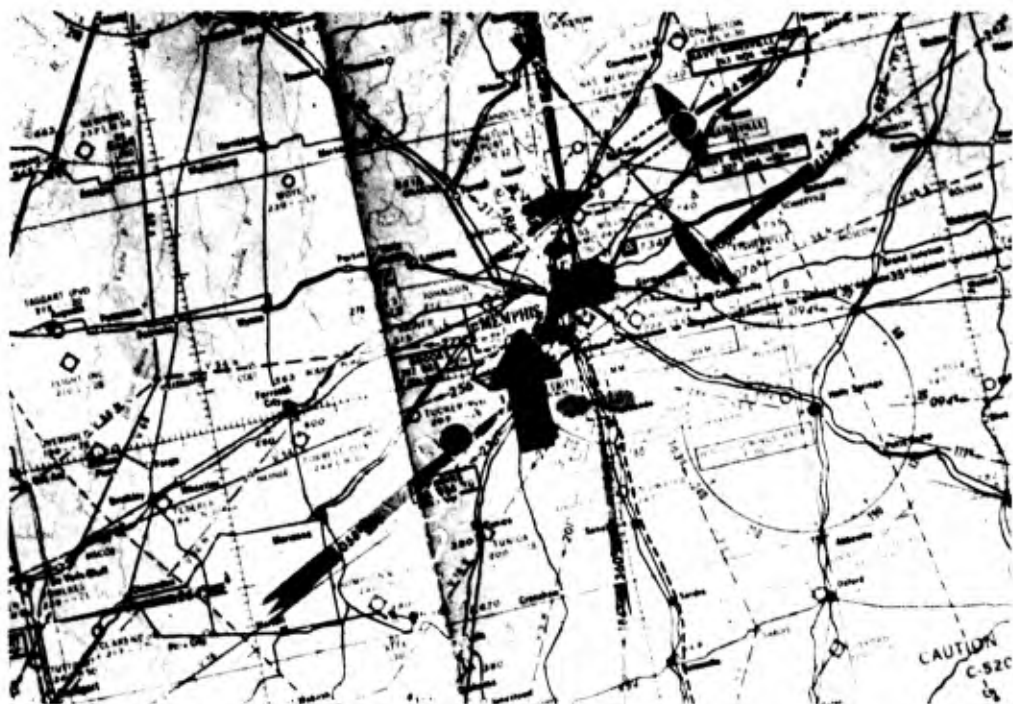


Figure 2. Photograph of typical slide (word to be responded to is MEMPHIS and is indicated by the black arrow.)

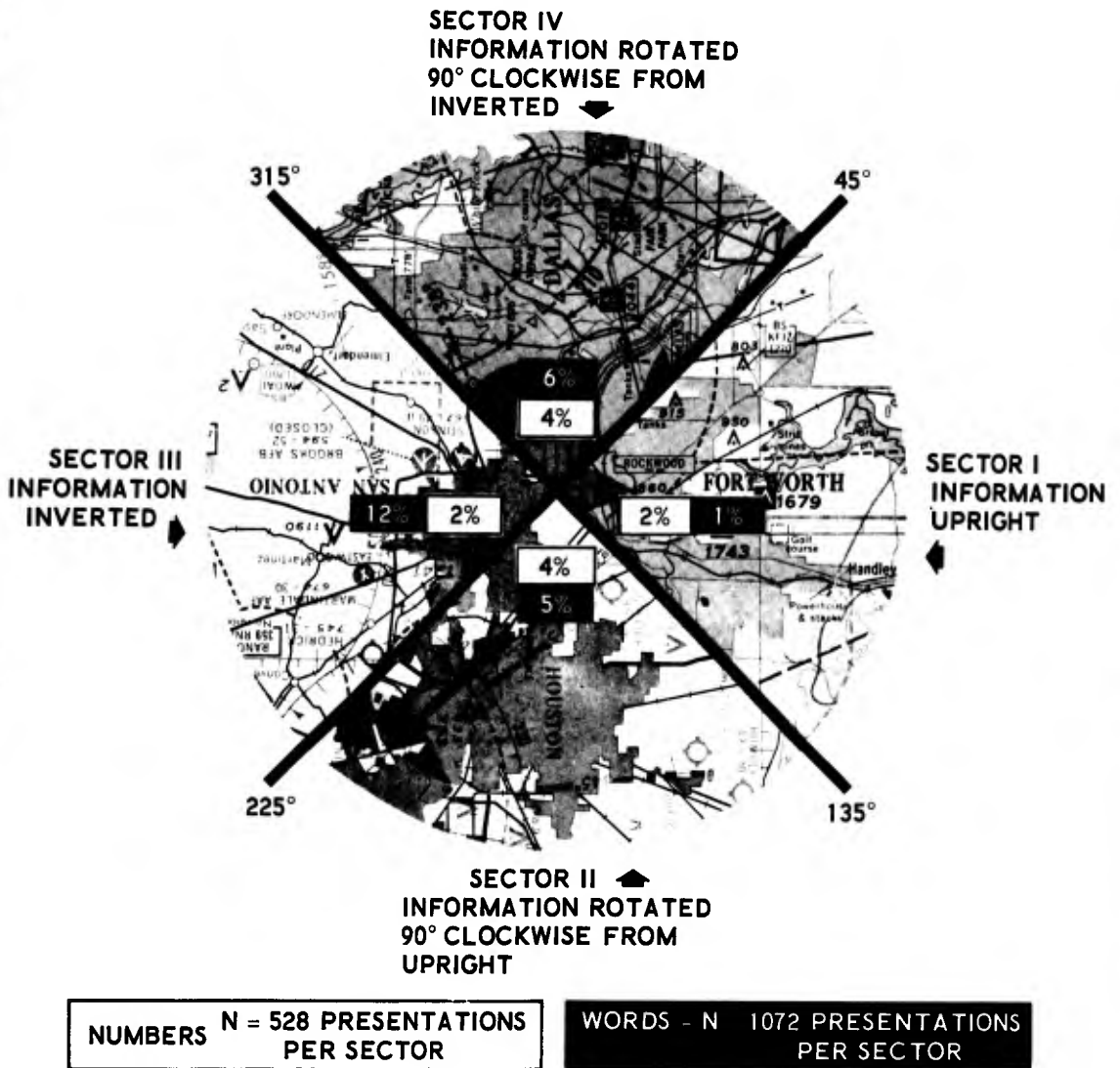


Figure 3. Geographical representation of angles of slide presentation (display angle). Clockwise, the display angle is defined as the angle between the word axis and the vertical axis. Each of the four sectors are noted on the figure. Percent errors are indicated in the figure as are total word and number presentations.

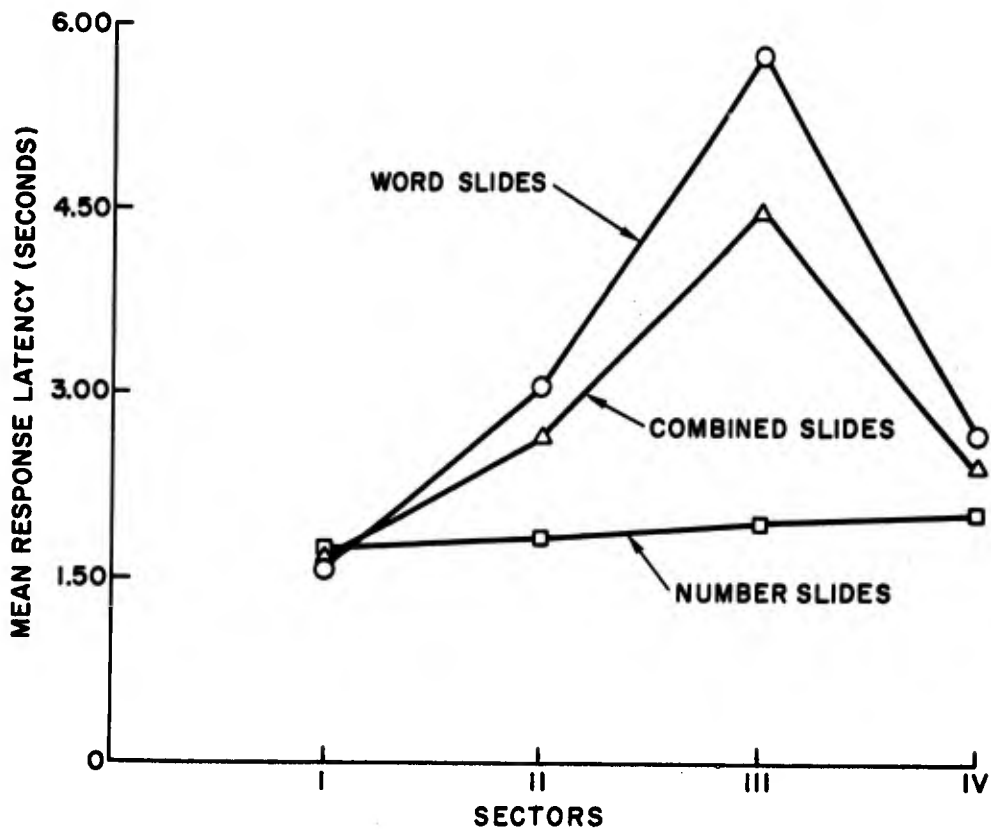


Figure 4. Mean response latency (sec.) plotted as a function of sectors.

TABLE 1  
 SLIDES REPRESENTED IN TRAY A WITH  
 CORRESPONDING DISPLAY ANGLE PER SESSION

TRAY A

Slide	Title	Display Angles (Degrees)			
		Session 1	Session 2	Session 3	Session 4
1.	Memphis	348	78	168	258
2.	P	20	110	200	290
3.	Washita	226	316	46	136
4.	Patricia	220	310	40	130
5.	190	142	232	322	52
6.	R	127	217	307	37
7.	Whitefield	295	25	115	205
8.	Alabama	322	52	142	232
9.	1575	285	15	105	195
10.	Grenada	52	142	232	322
11.	Brownsville	0	90	180	270
12.	Oxford	319	49	139	229
13.	075°	224	314	44	134
14.	Wister	180	270	0	90
15.	Goodfellow	38	128	218	308
16.	443	148	238	328	58
17.	McPherson	285	15	105	195
18.	380	270	0	90	180
19.	Matador	300	30	120	210
20.	Oil Tanks	302	32	122	212
21.	Herrington	287	17	107	197
22.	Hallbrook	248	338	68	158
23.	1481	78	168	258	348
24.	V 77	270	0	90	180
25.	Menard	90	180	270	0

TABLE 2

SLIDES REPRESENTED IN TRAY B WITH  
CORRESPONDING DISPLAY ANGLE PER SESSION

TRAY B

Slide	Title	Display Angles (Degrees)			
		Session 1	Session 2	Session 3	Session 4
1.	Gail	39	129	219	309
2.	237°	243	333	63	153
3.	Fort Riley	115	205	295	25
4.	Hillsboro	307	37	127	217
5.	Sweetwater	121	211	301	31
6.	1980	180	270	0	90
7.	Woodson	190	280	10	100
8.	N	12	102	192	282
9.	Washington	281	11	101	191
10.	Hutchinson	235	325	55	145
11.	Pipe Line	90	180	270	0
12.	330	10	100	190	280
13.	Edinburg	310	40	130	220
14.	Coldwater	90	180	270	0
15.	750	20	110	200	290
16.	Ellsworth	253	343	73	163
17.	1425	113	203	293	23
18.	35	241	331	61	151
19.	Oklahoma City	76	166	256	346
20.	Tishomingo	282	12	102	192
21.	R	150	240	330	60
22.	1357	302	32	122	212
23.	Brazos River	46	136	226	316
24.	617	315	45	135	225
25.	Bell Helicopter	124	214	304	34

TABLE 3

SLIDES REPRESENTED IN TRAY C WITH  
CORRESPONDING DISPLAY ANGLE PER SESSION

TRAY C

Slide	Title	Display Angles (Degrees)			
		Session 1	Session 2	Session 3	Session 4
1.	Whiteman	86	176	266	356
2.	5 Span Bridge	228	318	48	138
3.	Okemah	142	232	322	52
4.	Radio	108	198	288	18
5.	240	118	208	298	28
6.	Tanks	293	23	113	203
7.	Wilson	261	351	81	171
8.	771	301	31	121	211
9.	Moore	84	174	264	354
10.	Van Camp	348	78	168	258
11.	Corning	33	123	213	303
12.	18	336	66	156	246
13.	Valley View	358	88	178	268
14.	WBAP	294	24	114	204
15.	180	76	166	256	346
16.	2450	163	253	343	73
17.	150	267	357	87	177
18.	Cimarron	122	212	302	32
19.	El Dorado	176	266	356	86
20.	Kingman	197	287	17	107
21.	Waco	307	37	127	217
22.	028	37	127	217	307
23.	Benbrook	115	205	295	25
24.	Okla	161	251	341	71
25.	School	39	129	219	309

TABLE 4

SLIDES REPRESENTED IN TRAY D WITH  
CORRESPONDING DISPLAY ANGLE PER SESSION

TRAY D

Slide	Title	Display Angles (Degrees)			
		Session 1	Session 2	Session 3	Session 4
1.	0	237	327	57	147
2.	Westminster	221	311	41	131
3.	Graham Ranch	119	209	299	29
4.	Goree	17	107	197	287
5.	054	64	154	244	334
6.	Bald Knob	301	31	121	211
7.	Lincoln	356	86	176	266
8.	Ark	15	105	195	285
9.	C-198	98	188	278	8
10.	Military	0	90	180	270
11.	Havana	291	21	111	201
12.	School Craft	95	185	275	5
13.	1655	13	103	193	283
14.	Spur	200	290	20	110
15.	Sonora	90	180	270	0
16.	Prairie Dog Town	78	168	258	348
17.	Tracy	303	33	123	213
18.	2875	144	234	324	54
19.	Olpe	180	270	0	90
20.	Enid	260	350	80	170
21.	Wilroads Gardens	337	67	157	247
22.	Elevators	243	333	63	153
23.	286°	354	84	174	264
24.	18	323	53	143	233
25.	Mills Ranch	244	334	64	154

TABLE 5  
 MEAN RESPONSE LATENCIES FOR SLIDES  
 PRESENTED IN TRAY A (SCORES HAVE  
 BEEN CATEGORIZED ACCORDING TO SECTORS)

Tray A		Sector			
Slide	Title	I (45°-134°)	II (135°-224°)	III (225°-314°)	IV (315°-44°)
1.	Memphis	1.33	1.40	1.35	4.19
2.	P	1.62	1.97	1.72	4.75
3.	Washita	1.88	1.49	26.07	10.00
4.	Patricia	1.48	24.68	6.19	1.74
5.	190	1.50	2.44	1.72	4.16
6.	R	1.65	1.41	1.28	1.26
7.	Whitefield	1.42	3.35	21.40	2.18
8.	Alabama	1.30	1.25	1.34	2.27
9.	1575	1.44	1.93	2.92	1.76
10.	Grenada	3.78	2.46	4.94	2.34
11.	Brownsville	1.30	1.41	1.69	2.59
12.	Oxford	1.32	1.22	1.54	4.63
13.	075°	1.34	2.17	1.56	1.38
14.	Wister	1.48	3.71	3.19	2.27
15.	Goodfellow	1.48	1.86	1.93	2.10
16.	443	1.37	2.08	1.53	1.59
17.	McPherson	1.29	1.62	4.72	1.84
18.	380	1.30	1.33	1.90	1.40
19.	Matador	1.40	2.27	20.64	3.61
20.	Oil Tanks	1.26	1.42	7.16	1.70
21.	Herrington	1.31	1.76	4.66	2.19
22.	Hallbrook	1.50	1.61	4.62	5.36
23.	1481	5.92	3.45	3.09	3.72
24.	V77	1.53	1.53	3.05	2.06
25.	Menard	1.99	2.33	4.42	2.20

TABLE 6  
 MEAN RESPONSE LATENCIES FOR SLIDES  
 PRESENTED IN TRAY B (SCORES HAVE  
 BEEN CATEGORIZED ACCORDING TO SECTORS)

Slide	Tray B Title	Sector			
		I (45°-134°)	II (135°-224°)	III (225°-314°)	IV (315°-44°)
1.	Gail	2.34	1.79	2.09	3.49
2.	237°	1.34	1.41	2.59	1.69
3.	Fort Riley	1.73	1.81	1.60	1.54
4.	Hillsboro	1.33	1.61	2.72	1.48
5.	Sweetwater	1.50	1.90	1.49	1.35
6.	1980	1.32	2.00	1.69	1.47
7.	Woodson	1.21	2.58	1.95	1.47
8.	N	1.61	1.68	1.63	3.06
9.	Washington	1.30	1.64	34.21	1.88
10.	Hutchinson	1.30	1.30	3.84	1.84
11.	Pipe Line	1.63	1.56	1.54	1.39
12.	330	1.34	1.34	1.25	1.64
13.	Edinburg	1.30	3.90	1.72	1.44
14.	Cold Water	1.81	3.67	5.51	2.05
15.	750	1.68	2.21	1.59	2.90
16.	Ellsworth	1.28	1.41	3.74	2.21
17.	1425	3.98	5.57	5.24	2.04
18.	35	1.27	1.28	2.07	1.47
19.	Oklahoma City	1.52	1.43	1.30	1.34
20.	Tishomingo	1.84	1.78	9.97	3.37
21.	R	1.29	1.77	1.46	1.50
22.	1357	1.37	1.43	2.07	1.54
23.	Brazos River	1.63	1.39	1.57	1.74
24.	617	1.94	1.54	1.87	2.65
25.	Bell Helicopter	1.98	2.14	1.77	1.41

TABLE 7

MEAN RESPONSE LATENCIES FOR SLIDES  
PRESENTED IN TRAY C (SCORES HAVE  
BEEN CATEGORIZED ACCORDING TO SECTORS)

Tray C		Sector			
Slide	Title	I (45°-134°)	II (135°-224°)	III (225°-314°)	IV (315°-44°)
1.	White Man	1.97	2.31	2.36	1.83
2.	5 Span Bridge	1.56	1.59	10.22	5.47
3.	Okemah	1.77	2.88	5.04	2.56
4.	Radio	1.63	1.99	1.72	1.42
5.	240	1.60	1.47	1.38	1.29
6.	Tanks	1.47	1.61	11.32	1.94
7.	Wilson	1.29	1.42	4.73	1.65
8.	771	1.23	1.29	2.11	1.35
9.	Moore	1.92	1.61	1.64	1.50
10.	Van Camp	1.42	1.45	1.71	2.87
11.	Corning	1.41	5.30	2.39	2.28
12.	18	1.84	1.81	2.47	3.55
13.	Valley View	1.31	1.35	1.47	2.11
14.	WBAP	1.49	1.56	3.20	1.67
15.	180	1.51	1.33	1.26	1.30
16.	2450	1.31	1.73	1.41	1.40
17.	150	1.16	1.22	1.45	1.29
18.	Cimarron	1.54	1.93	1.42	1.23
19.	El Dorado	1.21	2.06	1.61	1.65
20.	Kingman	1.24	3.35	3.55	1.59
21.	Waco	1.20	1.21	1.98	1.26
22.	028	1.56	1.47	1.40	2.02
23.	Benbrook	2.10	7.84	5.69	1.81
24.	Okla.	1.24	1.74	1.50	1.40
25.	School	1.28	1.62	1.43	1.77

TABLE 8

MEAN RESPONSE LATENCIES FOR SLIDES  
PRESENTED IN TRAY D (SCORES HAVE  
BEEN CATEGORIZED ACCORDING TO SECTORS)

Tray D		Sector			
Slide	Title	I (45°-134°)	II (135°-224°)	III (225°-314°)	IV 315°-44°)
1.	0	1.35	1.35	2.17	1.55
2.	Westminster	1.44	19.12	15.98	1.48
3.	Graham Ranch	2.89	3.37	2.65	1.83
4.	Goree	1.89	2.74	2.56	13.56
5.	054	2.88	1.99	1.92	1.48
6.	Bald Knob	1.43	1.80	7.74	1.96
7.	Lincoln	1.28	1.31	1.40	1.87
9.	Ark	1.31	1.21	1.22	1.89
9.	C-198	1.94	1.35	1.31	1.30
10.	Military	1.24	1.30	1.54	1.96
11.	Havana	2.10	1.68	25.03	3.24
12.	School Craft	1.59	2.17	2.70	1.49
13.	1655	1.43	1.67	1.52	2.21
14.	Spur	1.28	1.99	1.84	1.39
15.	Sonora	1.81	2.28	3.53	1.50
16.	Prarie Dog Town	2.32	1.99	2.21	1.56
17.	Tracy	1.29	1.48	3.46	1.35
18.	2875	1.31	1.90	1.57	1.45
19.	Olpe	2.51	30.08	19.41	10.03
20.	Enid	1.52	1.36	3.18	1.94
21.	Wilroads Gardens	2.44	2.58	4.79	12.60
22.	Elevators	1.84	1.79	32.24	6.62
23.	286°	1.52	1.63	1.51	2.45
24.	18	1.70	1.41	1.53	2.35
25.	Mills Ranch	1.28	1.35	3.27	2.28

TABLE 9

MEAN RESPONSE LATENCIES (SEC.) FOR WORD, NUMBER  
AND COMBINED SLIDES IN SECTORS I, II, III AND IV

	Sector I	Sector II	Sector III	Sector IV
Words	1.61	3.08	5.80	2.74
Numbers	1.73	1.82	1.92	2.03
Combined	1.65	2.66	4.52	2.51

TABLE 10

ANALYSIS OF VARIANCE ON RELATIVE SCORES  
OF RESPONSE LATENCIES FOR WORD SLIDES

Source	SS	df	MS	F
Sectors	5.7693	3	1.9231	14.56**
Subjects	3.9541	15	.2636	2.99*
Sectors x Subjects <sup>b</sup>	3.9743	45	.0883	
Pooled Error Term <sup>a</sup>	7.9284	60	.1321	
Total	13.6977	63	.2174	

a. Based on the combined sums of squares of the Subjects and the Sectors x Subjects effects, this is the appropriate error term for testing the effects of Sectors.

b. This is the error term for testing the Subject's effect.

\*  $p < .05$

\*\*  $p < .01$

TABLE 11

Summary of Scheffe's Test for Multiple Comparisons Performed on the Treatment Sums of Relative Scores of Response Latencies for Word Slide Presentations

	Sector I	Sector II	Sector III	Sector IV
Sector I	-	N.S.	p < .01	N.S.
Sector II		-	p < .01	N.S.
Sector III			-	p < .01
Sector IV				-

Sector I produced less error than Sector III  
 Sector II produced less error than Sector III  
 Sector IV produced less error than Sector III

TABLE 12

Percentage of Word, Number, and Combined Word and Number Slide Presentations Incorrectly Responded to Within Each Sector

Slides	Sectors			
	I	II	III	IV
Numbers	.02	.04	.02	.04
Words	.01	.05	.12	.06
Total (Combined)	.02	.05	.09	.05

TABLE 13

Friedman Analysis of Variance Tests Applied  
To Response Errors for Word, Number, and  
Combined Slide Presentations in Each Sector

Condition	Sum of Ranked Scores				$\chi^2_r$	P
	I	II	III	IV		
Words	18	41.0	60.0	41.0	33.22	$p < .01$
Numbers	35	46.5	35.0	43.5	3.92	-
Combined	18	40.5	59.0	42.5	31.93	$p < .01$

TABLE 14

Results of Wilcoxon Signed Ranked Test Applied  
To Response Errors for Word, and Combined  
Word and Number Slide Presentations in Each Sector

Condition	I vs II	I vs III	I vs IV	II vs III	II vs IV	III vs IV
Words	$p < .01$	$p < .01$	$p < .01$	$p < .01$	-	$p < .01$
Combined	$p < .01$	$p < .01$	$p < .01$	$p < .01$	-	$p < .01$

TABLE 15

Analysis of Variance on Relative Scores  
of Response Latencies for Number Slides

Source	SS	df	MS	F
Sectors	.0677	3	.0226	3.42*
Subjects	.3291	15	.0219	14.60**
Sectors X Subjects <sup>b</sup>	.0677	45	.0015	
Pooled Error Term <sup>a</sup>	.3968	60	.0066	
Total	.4645	63	.0074	

<sup>a</sup> Based on the combined sums of squares of the Subjects and the Sectors X Subjects effects, this is the appropriate error term for testing the effects of Sectors.

<sup>b</sup> This is the error term for testing the Subjects effect.

\* p .05

\*\*p .01

TABLE 16

Summary of Scheffe's Test for Multiple Comparisons  
Performed on the Treatment Sums of Relative Scores  
of Response Latencies for Number Slide Presentations

	Sector I	Sector II	Sector III	Sector IV
Sector I	-	N.S.	N.S.	p < .05
Sector II		-	N.S.	N.S.
Sector III			-	N.S.
Sector IV				-

Sector I produced less error than Sector IV.

TABLE 17

Analysis of Variance on Relative Scores of Response  
Latencies for the Combined Words and Numbers

Source	SS	df	MS	F
Sectors	6.5373	3	2.1791	13.33**
Subjects	5.4744	15	.3650	3.79*
Sectors X Subjects <sup>a</sup>	4.3326	45	.0963	
Pooled Error Term <sup>b</sup>	9.8070	60	.1635	
Total	16.3443	63	.2594	

<sup>a</sup> Based on the combined sums of squares of the subjects and the Sectors X Subjects effects, this is the appropriate error term for testing the effects of Sectors

<sup>b</sup> This is the error term for testing the Subjects effect.

\* p .05

\*\* p .01

TABLE 18

Summary of Scheffe's Test for Multiple Comparisons  
Performed on the Treatment Sums of Relative Scores  
of Response Latencies for Combined Word and Number  
Slide Presentations

	Sector I	Sector II	Sector III	Sector IV
Sector I	-	N.S.	p < .01	p < .05
Sector II		-	p < .01	N.S.
Sector III			-	p < .01
Sector IV				-

Sector I produced less error than Sector III  
 Sector II produced less error than Sector III  
 Sector IV produced less error than Sector III  
 Sector I produced less error than Sector IV

TABLE 19  
ORDER OF TRAY PRESENTATION

Subject	Session			
	1	2	3	4
1	ABCD	BDAC	CADB	DCBA
2	ABCD	BDAC	CADB	DCBA
3	ABCD	BDAC	CADB	DCBA
4	ABCD	BDAC	CADB	DCBA
5	BDAC	CADB	DCBA	ABCD
6	BDAC	CADB	DCBA	ABCD
7	BDAC	CADB	DCBA	ABCD
8	BDAC	CADB	DCBA	ABCD
9	CADB	DCBA	ABCD	BDAC
10	CADB	DCBA	ABCD	BDAC
11	CADB	DCBA	ABCD	BDAC
12	CADB	DCBA	ABCD	BDAC
13	DCBA	ABCD	BDAC	CADB
14	DCBA	ABCD	BDAC	CADB
15	DCBA	ABCD	BDAC	CADB
16	DCBA	ABCD	BDAC	CADB

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13. ABSTRACT This study was one of a series performed under the JANAIR program to examine the information requirements and the optimal presentation of navigation and horizontal position information. Examination of the rotary wing pilot displays emphasizing the pictorial qualities has indicated the desirability of using a moving pictorial map display. Several reasons prompted this decision: (1) research indicated that for the critical maneuvering of the steep gradient vehicles at low level and slow speeds the use of a moving map was superior; (2) direct sensor information such as radar can best be superimposed on a moving map display and (3) the moving elements of a moving map display are compatible with those of the pictorial vertical display. The use of the moving map generates special problems. One of these is the requirement to read alpha-numeric information at various degrees of rotation, including inverted. This study examined the ability of Ss to read such data. Correctness of response and time to respond were the scores recorded during a presentation of the visual stimulus. The stimulus displays were word and number of various lengths taken from aeronautical charts. It was concluded that (1) the legibility of word information is most difficult when displayed in an inverted or near inverted position and (2) the legibility of numeric information does not pose a problem when displayed at any degree or rotation.		

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Alpha-Numeric Information Pictorial Map Display Aeronautical Charts JANA IR Displays						

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