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HUMAN VIGILANCE INVESTIGATION
ANALYSIS OF THE PATTERN ARRAY TEST
(FURTHER DATA ANALYSIS)

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April 1979

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CALIFORNIA POLYTECHNIC STATE
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FINAL REPORT

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ANALYSIS OF THE PATTERN ARRAY TEST
(FURTHER DATA ANALYSIS)

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ABSTRACT

HUMAN VIGILANCE INVESTIGATION

ANALYSIS OF

THE PATTERN ARRAY TEST

Andrew C. Have

April 1979

This report analyzes a test which was designed to help solve problems of human vigilance encountered in a material safeguard system. The test was designed to determine the efficiency of an operator when processing large amounts of information from a video screen over extended periods of time. In the test eight objects, either circles, squares, or triangles, were set in a 5 X 5 matrix which appeared on a video screen. The eight objects were shown for a specified length of time, the screen blanked out for another specified period, then eight objects in the same 5 X 5 matrix were again shown. The observer was tested on his ability to discern changes in patterns and/or symbols from frame to frame. The testees were able to identify changes in pattern easier than changes in symbols.

TABLE OF CONTENTS

	PAGE
ABSTRACT	11
INTRODUCTION AND OBJECTIVE	4
The Vigilance Experiments	4
Pattern Array Test (Test III)	5
DISCUSSION	6
TEST RESULTS	7
Effect of Answer Type	7
Effect of Frame Viewing Time	7
Differences in Group Scores	9
Morning Vs. Afternoon Groups	9
Trend of Correct Responses by Answer Type	10
Percent Correct Vs. Distance of Symbol Movement	10
Effect of Seating Position	10
Effect of Distraction Markings	10
Effect of Sex of Monitor	11
Effect of Age	11
Effect of Vision	12
Effect of Medication	12
Effect of How Observer Feels	12
Effect of Previous Night's Hours of Sleep	13
Percent Correct Vs.	
Neatness of Testee's Handwriting	13
CONCLUSIONS	14
LIST OF REFERENCES	16
APPENDIX A (Figures)	17
APPENDIX B (Tables)	49
APPENDIX C (Errata Sheet for First Report)	61

INTRODUCTION AND OBJECTIVE

The Vigilance Experiments

Humans have been regularly used in safeguard systems from earliest times. This fact has been of great concern for the human element has been considered one of the vulnerable targets. Many studies have been made of this role, generally specific in nature, but little general knowledge applying to different systems has been produced. One area of concern in a safeguard system is human vigilance. From inspecting badges to sounding alarms, human vigilance is a basic factor. It has generally been assumed that one loses alertness after long work hours under low stress conditions and one becomes fatigued as a result of long work hours under high stress conditions. Both of these working environments represent reduction in performance that occurs over time and could become a hazard as the stress conditions move from their optimum levels. Psychological fatigue or mental tiredness is a very real complaint caused by a lack of arousal leading to a loss of vigilance. Stress leads to an increase of arousal resulting in poor performance. It can be shown that man is not well suited for the performance of vigilance work.

To further define some of the variables which are important in a safeguard situation, three tests were designed, video tapes made, and people tested, primarily in groups at Cal Poly. The test to be analyzed in this paper is the third of three vigilance tests, called the Pattern Array Test.¹

¹For more information on the design and test procedures for the Vigilance Experiments, including Test III, see reference 1.

Pattern Array Test (Test III)

A human monitor in a safeguard system must handle or process more more than one kind of information during the same time period. Test III was designed to see how well information could be reliably handled in this manner.

In Test III eight symbols, either circles, squares or triangles were set in an unmarked 5 X 5 matrix which appeared on a 19 inch video screen (see Figure 1). The eight symbols were shown for a specified length of time, the screen blanked out for another specified period, then eight symbols in the same 5 X 5 matrix were again shown. The sequential frame could differ from the previous frame in the following five ways:

- A. NO CHANGE
- B. ONE CHANGE IN PATTERN (Movement of one symbol to another position in the 5 X 5 matrix)
- C. ONE CHANGE IN SYMBOL (For example a circle changed to a square)
- D. COMBINATION OF ONE CHANGE IN PATTERN AND ONE CHANGE IN SYMBOL
- E. MORE THAN ONE CHANGE IN PATTERN OR MORE THAN ONE CHANGE IN SYMBOL

The observer was tested on how well he could discern the changes from frame to frame. The test was 172 questions long. There was approximately one hour and 45 minutes of test time not including a ten minute break which came after question number 88.

DISCUSSION

In the analysis of data for this test a computer statistical package called Minitab was used for most of the calculations. In measuring the effect of various variables on the results of the test, three indicators, computed by Minitab, are used. These are the correlation coefficient R , the correlation coefficient squared or R -SQUARED, and R -SQUARED ADJUSTED FOR DEGREES OF FREEDOM. R -SQUARED tells us what proportion of the variation of the dependent variable can be attributed to a linear relationship with the independent variable(s). As can be seen on the various PERCENT CORRECT VS. FRAME VIEWING TIME graphs, the R -SQUARED values in this experiment range from 0 percent (Figure 17) to 62.4 percent (Figure 24). The R -SQUARED ADJUSTED FOR D.F. term should be used when comparing the goodness-of-fit of two regression equations with different numbers of independent variables.

A regression equation is formulated for some variable relationships using the method of least squares. The regression equations are not used in this analysis due to the high variation in responses.

TEST RESULTS

Effect of Answer Type

As shown in Figure 2, there is a marked difference in percent correct for each different answer type. Answer type E (More than one Change in Pattern or Symbol) was correctly identified only 47.4 percent of the time. Obviously, a safeguard system needs higher reliability than 47.4 percent.

Using data generated from this experiment, a simplified alternative to identifying the five different answer types in this experiment was considered. In the alternate system the observer or guard must only determine whether or not a change has been made. If he decides that a change has been made he can alert another guard to investigate the situation. Using the same data that went into Figure 2 on a binary basis (State 0: No Change, State 1: Change), as before No Change was correctly determined 91 percent of the time; a change of any type (as opposed to No Change) was correctly detected approximately 93 percent of the time (see Table 3). Of course having had only two responses available to the testees would have affected the responses.

One item of particular interest shown in Figure 2 is that the percent correct depends not only on the answer type of that frame, but also is related to the answer type of the previous frame.

Effect of Frame Viewing Time

The frame viewing time for each frame was randomly chosen between 1 and 50 seconds. The interframe time during which the matrix was

blanked out was held constant at ten seconds.

In analyzing the effect of frame viewing time on the percent correct, it was noticed that there was a slight relationship but it did not appear to be linear. By taking the natural log of the frame viewing times a better correlation was established. The analysis which follows uses the natural log of the frame viewing time as the independent variable.

Looking at the 3 graphs titled ALL ANSWER TYPES (Figure 15-17), notice that the percent correct on the PREVIOUS FRAME VIEWING TIME graph reaches a peak at viewing time $\ln(t) = 1.75$ or $t = 6$ seconds. The percent correct on the SAME FRAME VIEWING TIME GRAPH continues to increase slightly all the way up to viewing time $\ln(t) = 3.25$ or $t = 26$ seconds. A possible explanation for this is that if an observer is given more viewing time than is needed on the same frame, he will probably mark his answer for that frame before he starts daydreaming and becoming inattentive. On the next frame however, the observer may find that during his attention lapse he has forgotten what the previous frame looks like and has lost the basis for comparison necessary to detect changes.

In the subsequent graphs (Figures 18 - 32) the same information is shown broken down into the five different answer types: A, B, C, D, and E. In trying to distinguish the optimal viewing time, the graphs for answer types A, C, and E provide the best indication. Using the SAME FRAME VIEWING TIME graph for A, C, and E we see that there is an initial rise in percent correct with increases in viewing time. This rise continues for A, C, and E up to $\ln(t) =$ respectively

1.75, 2.75, 2.75 or $t = 6, 16, 16$ seconds. As would be expected, it takes longer to mentally process a frame in which a change has been made.

From the data collected, it would appear that the optimal viewing time for processing the type of information in this experiment is somewhere between 15 and 25 seconds. This estimate is based on answer types B, C, D, and E and allows more than enough time for answer type A. Since the monitor has no control over the viewing time, sufficient time would have to be allowed for the worst possible case.

An alternative that should be considered for a task of this nature is to let the observer or guard control the monitor and the viewing time. Since the viewing time does appear to have an effect on some of the answer types presented in this experiment, this alternative would appear to provide the optimal viewing time for each observer.

Differences in Group Scores

Test III was administered to eight different groups. A few variables were thrown into the group scoring such as playing music during the test. Since there was not a significant difference in the group scores as shown in Table 1, these factors will not be analyzed in this report. The trend of correct responses by group is given in Figures 12-14.

Morning Vs. Afternoon Groups

As can be seen in Figure 3, the morning groups scored lower in the first period and in the period directly following the break. The afternoon groups scored lower in the period before the break

and in the last period. It would appear that in the morning it was harder to get going, but once started the afternoon group's scores declined at a faster rate.

Trend of Correct Responses by Answer Type

In Figures 6-11 the trend of correct responses is given for each answer type. Answer type A appears to follow the same trend as the data as a whole. For answer types B, C, D, and E there is too much variation in the response to draw a conclusion.

Percent Correct Vs. Distance of Symbol Movement

In answer type B, D, and some of type E there was a movement of one of the symbols to another position in the 5 X 5 matrix. In Figures 4 and 5 these movements are analyzed to see if there is any relationship between the distance of movement and the percent correct. A log transformation gives slightly better results, but there still is no significant correlation shown.

Effect of Seating Position

As shown in Table 2 there is no significant relation between where a person sat and his score.

Effect of Distraction Markings

For some of the frames in this experiment a large dot or an X was inscribed inside one or two of the symbols. Before the test the observers were instructed to ignore these markings. Since the frames which contained these markings do not have the same proportion of each answer type as the general population, they are broken down by answer type. Two types of distractions were considered. Distraction Present

indicates that a distraction marking was present in a frame. Distraction Change indicates an appearance, disappearance or movement of a distraction marking in a frame with respect to the previous frame.

The results were as follows:

Answer Type	Distraction Present % Correct N = 70	Distraction Change % Correct N = 46	Total Population % Correct N = 172
A	92 %	No Data	91 %
B	80 %	78 %	80 %
C	75 %	70 %	66 %
D	70 %	73 %	70 %
E	43 %	47 %	47 %

Conclusion: No significant distraction effect was made.

Effect of Sex of Monitor

Male	N = 91	Mean = 81.7	Std. Dev. = 10.2
Female	N = 60	Mean = 81.9	Std. Dev. = 7.79

Conclusion: Slightly higher variations in scores were experienced among the male monitors. The difference is not significant at a level of significance of $\alpha = .05$.

Effect of Age

17-18	N = 24	Mean = 81.1	S = 9.88
19-20	N = 74	Mean = 82.4	S = 8.66
21-22	N = 30	Mean = 79.9	S = 9.13
Over 22	N = 17	Mean = 82.5	S = 12.0

Conclusion: No significant differences were shown.

Effect of Vision

Testees were asked to rate their vision excellent, good, fair or poor. If testee wore glasses or contact lenses, his corrected vision was rated.

Excellent	N = 83	Mean = 80.8	S = 9.88
Good	N = 59	Mean = 83.5	S = 8.37
Fair	N = 7	Mean = 79.6	S = 9.88
Poor	N = 0		

Conclusion: No significant differences were shown.

Effect of Medication

On Medication	N = 15	Mean = 83.8	S = 9.30
Not On Medication	N = 134	Mean = 81.7	S = 9.30

Conclusion: No significant differences were shown.

Effect of How Observer Feels

Testees were asked to rate how they felt.

Excellent	N = 20	Mean = 78.2	S = 11.1
Good	N = 56	Mean = 81.8	S = 9.30
Fair	N = 23	Mean = 82.9	S = 8.37
Poor	N = 43	Mean = 83.6	S = 8.49
"Rotten"	N = 7	Mean = 77.0	S = 11.2

Conclusion: No significant differences were shown

Effect of Previous Night's Hours of Sleep

Under 5	N = 24	Mean = 79.3	S = 9.94
5-7	N = 88	Mean = 82.6	S = 9.42
7.5-9	N = 29	Mean = 81.3	S = 9.24
Over 9	N = 9	Mean = 81.3	S = 6.28

Conclusion: No significant differences were shown.

Percent Correct Vs. Neatness of Testee's Handwriting

Testee's handwriting was rated good, fair or poor by testor.

Good	N = 81	Mean = 81.5	S = 9.48
Fair	N = 41	Mean = 82.6	S = 8.84
Poor	N = 29	Mean = 81.6	S = 9.04

Conclusion: No significant differences were shown.

CONCLUSIONS

Although the results of Test III were not very conclusive, there are a few conclusions which can be made. The answer type of the frame being viewed and the previous frame showed a definite effect on the results. The scores ranged from an average of 91 % for answer type A down to 47 % for answer type E. The low scores for type E information indicate that the human would not be of much use for processing information under the test conditions used in this experiment. Other relationships between variables are noted in the results.

It should be noted that the observers used in the Cal Poly Vigilance Experiments were college students and thus were not representative of the general population as a whole.

If another experiment of this nature is run, the following suggestions might be helpful:

In Test III, due to the effect of the previous frames, as well as the one being answered, on the percent correct, allowing the viewing time to vary randomly increased the number of viewing time variables. The experimental viewing time should be fixed over certain intervals. For example, the test could be divided up into four sections of equal length. A fixed viewing time could be set for each section of the test. The viewing time might be 10 seconds for section 1, 15 seconds for section 2, 20 seconds for section 3, and 25 seconds for section 4. By making several video tapes of the experiment with the sections in different orders, the experimental variables

could be even further isolated.

The design of this experiment was of a very general nature. As actual safeguard systems are proposed, more specific testing should be done to ensure that system failure due to human error is kept to a minimum. It would be naive and even dangerous not to fully consider the factor of human error.

LIST OF REFERENCES

1. Kaiser, Charles, Management and Supervision of the Human Vigilance Experiment. San Luis Obispo, CA. December 1978
2. Davies, D. R., and Tune, G. S., Human Vigilance Performance. London: Staples Press, 1970
3. Buckner, Donald N., and McGrath, James J., Vigilance: A Symposium. United States: McGraw Hill, 1963

APPENDIX A

PATTERN OF ORIGINAL ARRAY

FIGURE 1

ANSWER TYPE OF SAME FRAME

ANSWER TYPE OF PREVIOUS FRAME

- A. No Change
- B. 1 Change in Pattern
- C. 1 Change in Symbol
- D. Combination of 1 Change in Pattern and 1 Change in Symbol
- E. More than 1 Change in Pattern or More than 1 Change in Symbol

FIGURE 2

TREND OF CORRECT RESPONSES

19

FIGURE 3

PERCENT CORRECT VS. DISTANCE OF SYMBOL MOVEMENT

20

-- CORRELATION C2,C42

CORRELATION OF C2 AND C42 = 0.122

C2 = Percent Correct

C42 = ln(distance of movement in inches)

-- REGRESS C2 WITH 1 PREDICTOR IN C42

THE REGRESSION EQUATION IS

$Y = 79.00 + 1.640 X1$

	COLUMN	COEFFICIENT	ST. DEV. OF COEF.	T-RATIO = COEF/S.D.
X1	C42	1.64	2.35	0.70

THE ST. DEV. OF Y ABOUT REGRESSION LINE IS

$S = 6.98$
WITH (34-2) = 32 DEGREES OF FREEDOM

R-SQUARED = 1.5 PERCENT

ADJUSTED R-SQUARED = 1.0 PERCENT, ADJUSTED FOR D.F.

FIGURE 4

PERCENT CORRECT VS. DISTANCE OF SYMBOL MOVEMENT

21

C4 = Percent Correct

C44 = ln(distance of movement in inches)

CORRELATION OF C4 AND C44 = 0.050

-- REGRESS C4 WITH 1 PREDICTOR IN C44

THE REGRESSION EQUATION IS
 $Y = 67.28 + 1.510 X1$

	COLUMN	COEFFICIENT	ST. DEV. OF COEF.	T-RATIO = COEF/S.D.
X1	C44	67.3 1.51	15.0 7.86	4.47 0.19

THE ST. DEV. OF Y ABOUT REGRESSION LINE IS
 $S = 14.3$
 WITH 17-2 = 15 DEGREES OF FREEDOM

R-SQUARED = 0.2 PERCENT
 R-SQUARED = -0.4 PERCENT, ADJUSTED FOR D.F.

FIGURE 5

21

TREND OF CORRECT RESPONSES
FOR ALL GROUPS COMBINED
ALL ANSWER TYPES

TREND OF CORRECT RESPONSES

ANSWER TYPE A (No Change)

FIGURE 7

TREND OF CORRECT RESPONSES

ANSWER TYPE B (1 Change in Pattern)

FIGURE 8

TREND OF CORRECT RESPONSES

ANSWER TYPE C (1 Change in Symbol)

FIGURE 9

TREND OF CORRECT RESPONSES

ANSWER TYPE D (1 Change in Pattern & 1 Change in Symbol)

FIGURE 10

TREND OF CORRECT RESPONSES

ANSWER TYPE E (More than 1 Change in Pattern or Symbol)

FIGURE 11

FIGURE 12

FIGURE 13

TREND OF CORRECT RESPONSES

FIGURE 14

32

% CORRECT VS. SAME FRAME VIEWING TIME

ALL ANSWER TYPES

Independent Variable:

C20 = ln(Same Frame Viewing Time)
With Time in Seconds.

Dependent Variable:

C6 = % Correct

N = 172

-- CORRELATION C6,C20

CORRELATION OF C6 AND C20 = 0.241

-- REGRESS C6 WITH 1 PREDICTOR IN C20

THE REGRESSION EQUATION IS

$$Y = 70.15 + 4.075 X1$$

	COLUMN	COEFFICIENT	ST. DEV. OF COEF.	T-RATIO = COEF/S.D.
<1	C20	70.15 4.08	3.80 1.26	18.19 3.24

THE ST. DEV. OF Y ABOUT REGRESSION LINE IS

(172 - 2) = 170 DEGREES OF FREEDOM

FIGURE 16

32

% CORRECT VS. COMBINED FRAME VIEWINGALL ANSWER TYPES

Independent Variables:

C10 = ln(Previous Frame Viewing Time)

C20 = ln(Same Frame Viewing Time)

With Time in Seconds.

Dependent Variable:

C6 = % Correct

N = 172

C20 Value Indicators:

0 DENOTES VALUES L.T. 2.00624
 . DENOTES VALUES L.T. 2.92830
 / DENOTES VALUES L.T. 3.85036
 x DENOTES VALUES G.T. 3.85036

-- REGRESS C6, 2 PREDICTORS IN C10, C20

THE REGRESSION EQUATION IS

$$Y = 67.80 + 0.8349 X1 + 4.043 X2$$

COLUMN	COEFFICIENT	ST. DEV. OF COEF.	T-RATIO = COEF/ST. DEV.
X1 C10	0.83	1.26	0.66
X2 C20	4.04	1.26	3.21

THE ST. DIV. OF Y ABOUT REGRESSION LINE IS

$$S = \sqrt{15.2 / (172 - 3)} = 169 \text{ DEGREES OF FREEDOM}$$

FIGURE 17

% CORRECT VS. PREVIOUS FRAME VIEWING TIME

ANSWER TYPE A

Independent Variable:

C11 = ln(Previous Frame Viewing Time)
With Time in Seconds.

Dependent Variable:

C3 = % Correct

N = 96

-- CORRELATION C1,C11

CORRELATION OF C1 AND C11 = 0.398

-- REGRESS C1 WITH 1 PREDICTOR IN C11

THE REGRESSION EQUATION IS

Y = 83.24 + 2.815 X1

	COLUMN	COEFFICIENT	ST. DEV. OF COEF.	T-RATIO = COEF/S.D.
X1	C11	83.24 2.815	1.95 0.669	42.64 4.21

THE ST. DEV. OF Y ABOUT REGRESSION LINE IS

S = 6.51
WITH (96 - 2) = 94 DEGREES OF FREEDOM

R-SQUARED = 15.8 PERCENT

R-SQUARED = 14.9 PERCENT, ADJUSTED FOR D.F.

FIGURE 18

% CORRECT VS. SAME FRAME VIEWING TIME

ANSWER TYPE A

Independent Variable:

C21 = ln(Same Frame Viewing Time)
With Time in Seconds.

Dependent Variable

C1 = % Correct

N = 96

-- CORRELATION C1,C21

CORRELATION OF C1 AND C21 = -0.010

-- REGRESS C1 WITH 1 PREDICTOR IN C21

THE REGRESSION EQUATION IS

Y = 91.19 - 0.07619 X1

COLUMN	COEFFICIENT	ST. DEV. OF COEF.	T-RATIO = COEF/S.D.
X1	-0.076	0.799	-0.10

THE ST. DEV. OF Y ABOUT REGRESSION LINE IS

S = 7.09

WITH (96 - 2) = 94 DEGREES OF FREEDOM

R-SQUARED = 0.0 PERCENT

R-SQUARED = -1.1 PERCENT, ADJUSTED FOR D.F.

FIGURE 19

C21 Value Indicators:

0	DENOTES VALUES L.T.	2.07118
.	DENOTES VALUES L.T.	2.98215
/	DENOTES VALUES L.T.	3.89312
x	DENOTES VALUES G.T.	3.89312

-- REGRESS C1, 2 PREDICTORS IN C11, C21

THE REGRESSION EQUATION IS
 $Y = 82.62 + 2.830 X1 + 0.1949 X2$

	COLUMN	COEFFICIENT	ST. DEV. OF COEF.	T-RATIO = COEF/S.D.
X1	C11	2.830	0.675	4.19
X2	C21	0.195	0.739	0.26

THE ST. DEV. OF Y ABOUT REGRESSION LINE IS
 $S = 6.54$
 WITH (96 - 3) = 93 DEGREES OF FREEDOM

R-SQUARED = 15.9 PERCENT
 R-SQUARED = 14.1 PERCENT, ADJUSTED FOR D.F.

FIGURE 20

% CORRECT VS. PREVIOUS FRAME VIEWING TIME

ANSWER TYPE B

Independent Variable:

C12 = ln(Previous Frame Viewing Time)
With Time in Seconds.

Dependent Variable:

C2 = % Correct

N = 32

ln(t)
with t in seconds

-- CORRELATION C2,C12

CORRELATION OF C2 AND C12 = 0.012

-- REGRESS C2 WITH 1 PREDICTOR IN C12

THE REGRESSION EQUATION IS

Y = 79.94 + 0.1158 X1

	COLUMN	COEFFICIENT	ST. DEV. OF COEF.	T-RATIO = COEF/ST. DEV.
X1	C12	79.94 0.12	5.59 1.72	14.29 0.07

THE ST. DEV. OF Y ABOUT REGRESSION LINE IS

S = 7.03

WITH 1 (34 - 2) = 32 DEGREES OF FREEDOM

FIGURE 21

% CORRECT VS. SAME FRAME VIEWING TIME

ANSWER TYPE B

Independent Variable:
C22 = ln(Same Frame Viewing Time)
With Time in Seconds.

Dependent Variable:
C2 = % Correct

N = 34

-- CORRELATION C2,C22

CORRELATION OF C2 AND C22 = -0.093

-- REGRESS C2 WITH 1 PREDICTOR IN C22

THE REGRESSION EQUATION IS
Y = 83.37 - 0.9781 X1

COLUMN	COEFFICIENT	ST. DEV. OF COEF.	T-RATIO = COEF/S.D.
X1 C22	-0.98	5.91	-0.53

THE ST. DEV. OF Y ABOUT REGRESSION LINE IS
S = 7.00
WITH (34 - 2) = 32 DEGREES OF FREEDOM

FIGURE 22

% CORRECT VS. COMBINED FRAME VIEWING TIMEANSWER TYPE B

Independent Variables:

C12 = ln(previous Frame Viewing Time)

C22 = ln(Same Frame Viewing Time)

Dependent Variable:

C2 = % Correct

N = 34

C22 Value Indicators:

O DENOTES VALUES L.T. 2.47788

/ DENOTES VALUES L.T. 3.13845

X DENOTES VALUES L.T. 3.79901

X DENOTES VALUES C.T. 3.79901

-- REGRESS C2, 2 PREDICTORS IN C12, C22

THE REGRESSION EQUATION IS

Y = 82.74 + 0.2289 X1 - 1.008 X2

	COLUMN	COEFFICIENT	ST. DEV. OF COEF.	T-RATIO = COEF/S.D.
X1	C12	82.74	7.72	10.72
X2	C22	-1.01	1.76	0.13
			1.89	-0.53

THE ST. DEV. OF Y ABOUT REGRESSION LINE IS

S = 7.11
WITH (34 - 3) = 31 DEGREES OF FREEDOM

R - SQUARED = 0.9 PERCENT

FIGURE 23

% CORRECT VS PREVIOUS FRAME VIEWING TIMEANSWER TYPE C

Independent Variable:

C13 = $\ln(\text{Previous Frame Viewing Time})$
With Time in Seconds.

Dependent Variable:

C3 = % Correct

N = 15

-- CORRELATION C3, C13

CORRELATION OF C3 AND C13 = 0.676

-- REGRESS C3 WITH 1 PREDICTOR IN C13

THE REGRESSION EQUATION IS

$$Y = 1.089 + 21.02 X1$$

	COLUMN	COEFFICIENT	ST. DEV. OF COEF.	T-RATIO = COEF/S.D.
X1	C13	21.02	1.1 19.9 0.36	0.05 3.30

THE ST. DEV. OF Y ABOUT REGRESSION LINE IS

S = 12.5
WITH (15 - 2) = 13 DEGREES OF FREEDOM

R-SQUARED = 45.6 PERCENT

FIGURE 24

% CORRECT VS. SAME FRAME VIEWING TIME

ANSWER TYPE C

Independent Variable:
C23 = $\ln(\text{Same Frame Viewing Time})$
With Time in Seconds.

Dependent Variable:
C3 = % Correct

N = 15

-- CORRELATION C3, C23

CORRELATION OF C3 AND C23 = 0.763

-- REGRESS C3 WITH 1 PREDICTOR IN C23

THE REGRESSION EQUATION IS

$$Y = 39.10 + 10.65 X1$$

	COLUMN	COEFFICIENT	ST. DEV. OF COEF.	T-RATIO = COEF/S.D.
X1	C23	10.65	2.51	4.25

THE ST. DEV. OF Y ABOUT REGRESSION LINE IS

11.0
WITH (15 - 2) = 13 DEGREES OF FREEDOM

COEFFICIENT = 54.2 PERCENT

FIGURE 25

% CORRECT VS. COMBINED FRAME VIEWING TIME

ANSWER TYPE C

Independent Variables:

C13 = ln(Previous Frame Viewing Time)

C23 = ln(Same Frame Viewing Time)
With Time in Seconds.

Dependent Variable:

C3 = % Correct

N = 15

G23 Value Indicators:

O DENOTES VALUES L.T.
/ DENOTES VALUES L.T.
X DENOTES VALUES G.T.

-- REGRESS C3, 2 PREDICTORS IN C13, C23

THE REGRESSION EQUATION IS
Y = 18.27 + 9.010 X1 + 7.884 X2

COLUMN	COEFFICIENT	ST. DEV. OF	T-RATIO = COEF/S.D.
X1 C13	18.53	18.57	0.98
X2 C23	9.51	7.52	1.20
	7.88	3.38	2.35

THE ST. DEV. OF Y ABOUT REGRESSION LINE IS 10.8
WITH (15 - 3) = 12 DEGREES OF FREEDOM

FIGURE 26

% CORRECT VS. PREVIOUS FRAME VIEWING TIME

ANSWER TYPE D

Independent Variable:

$C14 = \ln(\text{Previous Frame Viewing Time})$
With Time in Seconds.

Dependent Variable:

$C4 = \% \text{ Correct}$

$N = 17$

-- CORRELATION $C4, C14$

CORRELATION OF $C4$ AND $C14 = 0.560$

-- REGRESS $C4$ WITH 1 PREDICTOR IN $C14$

THE REGRESSION EQUATION IS

$$Y = 48.91 + 6.846 X1$$

	COLUMN	COEFFICIENT	ST. DEV. OF COEF.	T-RATIO = COEF/ST. DEV.
$X1$	$C14$	6.85	2.61	2.62

THE ST. DEV. OF Y ABOUT REGRESSION LINE IS

$S = 11.9$
WITH $(17 - 2) = 15$ DEGREES OF FREEDOM

R-SQUARED = 31.4 PERCENT

R-SQUARED = 26.8 PERCENT, ADJUSTED FOR D.F.

FIGURE 27

% CORRECT VS. SAME FRAME VIEWING TIME

ANSWER TYPE D

Independent Variable:

C24 = ln(Same Frame Viewing Time)
With Time in Seconds.

Dependent Variable:

C4 = % Correct
N = 17

-- CORRELATION C4,C24

CORRELATION OF C4 AND C24 = 0.564

-- REGRESS C4 WITH 1 PREDICTOR IN C24

THE REGRESSION EQUATION IS

$Y = 52.97 + 8.663 X1$

COLUMN	COEFFICIENT	ST. DEV. OF COEF.	T-RATIO = COEF/S.D.
X1 C24	52.97 8.663	7.07 2.52	7.49 2.65

THE ST. DEV. OF Y ABOUT REGRESSION LINE IS

S = 11.8
WITH (17 - 2) = 15 DEGREES OF FREEDOM

R-SQUARED = 31.8 PERCENT

R-SQUARED = 27.3 PERCENT, ADJUSTED FOR D.F.

FIGURE 28

% CORRECT VS. COMBINED FRAME VIEWING TIMEANSWER TYPE D

Independent Variables:

C14 = $\ln(\text{Previous Frame Viewing Time})$ C24 = $\ln(\text{Same Frame Viewing Time})$
With Time in Seconds.

Dependent Variable:

C5 = % Correct

N = 17

C24 Value Indicators:

0 DENOTES VALUES L.T. 1.39433
 . DENOTES VALUES L.T. 2.56974
 / DENOTES VALUES L.T. 3.74515
 x DENOTES VALUES G.T. 3.74515

-- REGRESS C5, 2 PREDICTORS IN C14, C24

THE REGRESSION EQUATION IS

Y = 42.26 + 4.903 X1 + 4.815 X2

	COLUMN	COEFFICIENT	ST. DEV. OF COEF.	T-RATIO = COEF/S.D.
X1	C14	4.903	2.62	1.87
X2	C24	4.815	2.53	1.90

THE ST. DEV. OF Y ABOUT REGRESSION LINE IS

S = 11.0
WITH 17 - 31 = 14 DEGREES OF FREEDOMR-SQUARED = 45.5 PERCENT
R-SQUARED = 37.7 PERCENT, ADJUSTED FOR D.F.

FIGURE 29

% CORRECT VS. PREVIOUS FRAME VIEWING TIMEANSWER TYPE E

Independent Variable:

C15 = ln(Previous Frame Viewing Time)
With Time in Seconds.

Dependent Variable:

C5 = % Correct

N = 10

-- CORRELATION C5,C15

CORRELATION OF C5 AND C15 = 0.056

-- REGRESS C5 WITH 1 PREDICTOR IN C15

THE REGRESSION EQUATION IS

 $Y = 42.19 + 1.625 X1$

	COLUMN	COEFFICIENT	ST. DEV. OF COEF.	T-RATIO = COEF/S.D.
X1	C15	42.2 1.6	33.0 10.2	1.28 0.16

THE ST. DEV. OF Y ABOUT REGRESSION LINE IS

S = 16.0
WITH (10 - 2) = 8 DEGREES OF FREEDOMR-SQUARED = 0.3 PERCENT
R-SQUARED = -12.1 PERCENT, ADJUSTED FOR D.F.

FIGURE 30

% CORRECT VS SAME FRAME VIEWING T1

ANSWER TYPE E

Independent Variable:

C25 = ln(Same Frame Viewing Time)
With Time in Seconds.

Dependent Variable:

C5 = % Correct

N = 10

+C25 ln(t)
t in seconds

-- CORRELATION C5,C25

CORRELATION OF C5 AND C25 = 0.532

-- REGRESS C5 WITH 1 PREDICTOR IN C25

THE REGRESSION EQUATION IS

Y = 12.54 + 11.94 X1

	COLUMN	COEFFICIENT	ST. DEV. OF COEF.	T-RATIO = COEF/S.D.
X1	C25	11.94	6.72	1.78

THE ST. DEV. OF Y ABOUT REGRESSION LINE IS

S = 14.1
WITH 10 - 2 = 8 DEGREES OF FREEDOM

R-SQUARED = 28.3 PERCENT

R-SQUARED = 19.3 PERCENT, ADJUSTED FOR D.F.

FIGURE 31

% CORRECT VS COMBINED FRAME VIEWING TIANSWER TYPE E

Independent Variables:

C15 = ln(Previous Frame Viewing Time)

C25 = ln(Same Frame Viewing Time)
With Time in Seconds.

Dependent Variable:

C5 = % Correct

N = 10

C25 Value Indicators:

O DENOTES VALUES L.T. 2.22068
 / DENOTES VALUES L.T. 2.91854
 x DENOTES VALUES L.T. 3.61638
 X DENOTES VALUES G.T. 3.61638

-- REGRESS C5, 2 PREDICTORS IN C15, C25

THE REGRESSION EQUATION IS

$$Y = -23.16 + 8.762 X1 + 14.56 X2$$

	COLUMN	COEFFICIENT	ST. DEV. OF COEF.	T-RATIO = COEF/S.D.
X1	C15	-23.2	43.4	-0.53
X2	C25	14.56	7.34	1.98

THE ST. DEV. OF Y ABOUT REGRESSION LINE IS

S = 14.2
With (10-3) = 7 DEGREES OF FREEDOMR-SQUARED = 36.2 PERCENT
R-SQUARED = 18.0 PERCENT, ADJUSTED FOR D.F.

FIGURE 32

APPENDIX BTABLE 1ANALYSIS OF VARIANCE FOR GROUPS 1 - 8

DUE TO	DF	SS	MS=SS/DF	F-RATIO
FACTOR	7	721.4	103.1	1.20
ERROR	157	13455.2	85.7	
TOTAL	164	14176.5		

LEVEL	N	MEAN	ST. DEV.
C1	22	84.46	7.90
C2	11	82.66	11.31
C3	14	85.13	9.00
C4	25	79.72	8.55
C5	28	81.40	9.75
C6	23	78.82	11.48
C7	17	85.58	7.75
C8	25	83.12	8.23

POOLED ST. DEV. = 9.26

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)

TABLE 2% CORRECT VS. SEATING

C30 = % Correct (Test Score)

C40 = Viewing Angle in Degrees
Measured from Center

C50 = Distance From Screen

CORRELATION OF C30 AND C40 = -.092

CORRELATION OF C30 AND C50 = .036

-- 7 REGRESS C30 WITH 2 PREDICTORS IN C40, C50

THE REGRESSION EQUATION IS

Y = 83.62 - .1324 X1 - .00178 X2

	COLUMN	COEFFICIENT	ST. DEV. OF COEF.	T-RATIO = COEF/S.D.
	---	83.62	3.92	21.34
X1	C40	-.132	.128	-1.03
X2	C50	-.0018	.0156	-.11

THE ST. DEV. OF Y ABOUT REGRESSION LINE IS

S = 9.35

WITH (150 - 3) = 147 DEGREES OF FREEDOM

R-SQUARED = .8 PERCENT

R-SQUARED = .5 PERCENT, ADJUSTED FOR D.F.

0.8 % of the Variation in Scores can be
accounted for by seating.

ANALYSIS OF VARIANCE

CONCLUSION: No Significant Effect

DUE TO	DF	SS	MS=SS/DF
REGRESSION	2	109.7	54.9
RESIDUAL	147	12858.2	87.5
TOTAL	149	12967.9	

TABLE 3LIST OF RESPONSES FOR EACH ANSWER TYPE

For correct answer type A the responses were:	A	91.0 %
	B	4.9 %
	C	1.8 %
	D	1.0 %
	E	0.5 %
	No Response	0.8 %
For correct answer type B the responses were:	A	4.8 %
	B	80.3 %
	C	2.0 %
	D	6.2 %
	E	6.0 %
	No Response	0.7 %
For correct answer type C the responses were:	A	11.0 %
	B	7.3 %
	C	65.9 %
	D	9.7 %
	E	4.1 %
	No Response	2.0 %
For correct answer type D the responses were:	A	2.4 %
	B	9.1 %
	C	5.0 %
	D	70.1 %
	E	11.2 %
	No Response	2.3 %
For correct answer type E the responses were:	A	2.2 %
	B	12.1 %
	C	7.2 %
	D	29.9 %
	E	47.4 %
	No Response	1.2 %

TABLE 4

TEST SCORES LISTED BY GROUP (Groups 1 - 4 in C1 - C4)

	COLUMN C1	C2	C3	C4
	COUNT 22	11	14	25
ROW				
1	84.8837	61.6279	91.2791	81.9767
2	90.6977	75.5814	86.6279	77.3256
3	80.2326	75.0000	87.7907	80.8140
4	89.5349	72.0930	92.4419	85.4651
5	90.6977	93.0233	68.0233	83.1395
6	81.3953	93.6047	66.0465	67.4419
7	75.0000	91.2791	83.1395	67.4419
8	87.2093	75.0000	93.0233	90.6977
9	87.7907	77.0930	78.4884	76.1628
10	94.7674	87.7907	97.6744	71.8605
11	92.4419	87.2093	86.6279	81.3953
12	94.7674		83.7209	85.4651
13	83.7209		66.2791	90.6977
14	77.3256		90.6977	77.3256
15	83.7209			58.7209
16	91.8605			79.6512
17	77.3256			71.5116
18	81.3953			71.5116
19	68.6047			71.5116
20	90.1163			73.8372
21	66.2791			77.9070
22	88.3721			84.8837
23				87.2093
24				89.5349
25				89.5349

TABLE 4 (continued)

TEST SCORES LISTED BY GROUP (Groups 5 - 8)

ROW	COLUMN COUNT	CS 28	CS 23	CS 17	CS 26
1	90.6977		62.2093	87.2093	78.4884
2	90.6977		86.0465	85.4651	72.6744
3	71.5116		65.1163	75.5814	81.9767
4	90.6977		55.2326	87.2093	85.4851
5	96.6279		82.5581	87.2093	91.2791
6	75.5314		77.6744	71.5116	94.7674
7	65.1163		73.2558	88.9535	83.5721
8	89.5349		83.7209	91.2791	90.6977
9	87.3093		93.1395	89.5749	91.8605
10	88.9535		78.4884	85.4651	92.3419
11	84.8337		72.6744	95.9302	85.7209
12	75.6090		62.2093	77.3256	73.8372
13	88.9535		79.6512	71.5116	93.6047
14	70.9302		88.9535	85.4651	76.1628
15	80.9130		88.9535	86.6047	46.2791
16	65.1163		73.2558	68.6047	80.8130
17	65.1163		87.2093	86.0465	79.5512
18	94.7674		85.4651		95.9302
19	95.5308		67.4419		92.4419
20	77.6744		75.4884		77.2070
21	93.6047		70.9302		77.3256
22	83.7209		94.1850		73.8372
23	81.2767		95.9502		80.2326
24	72.0230				81.5823
25	70.9302				73.8372
26	77.3256				
27	91.8605				
28	70.3483				

TABLE 5

TEST RESULTS
FOR EACH QUESTION

Question Number	Answer Type	Viewing Time (Sec.)	Percent Correct
1 .	2	46	70.7091
2 .	3	44	72.1212
3 .	1	45	90.9091
4 .	2	16	78.7879
5 .	3	31	71.5152
6 .	2	35	63.0303
7 .	2	32	74.5455
8 .	3	26	73.7374
9 .	1	12	92.7273
10 .	1	32	89.697
11 .	2	17	74.5455
12 .	1	20	80
13 .	1	41	90.9091
14 .	3	4	71.5152
15 .	1	15	72.3239
16 .	1	36	92.7273
17 .	1	34	94.5455
18 .	3	42	77.5758
19 .	1	43	56.7697
20 .	2	44	78.1818
21 .	2	50	80.6061
22 .	1	26	91.5152
23 .	1	5	92.7273
24 .	1	42	89.697
25 .	4	2	73.3333

TABLE 5 (continued)

TEST RESULTS
FOR EACH QUESTION

Question Number	Answer Type	Viewing Time (Sec.)	Percent Correct
26 .	1	16	93.0303
27 .	1	37	94.5455
28 .	1	42	93.9697
29 .	1	14	95.1515
30 .	1	47	93.1818
31 .	4	40	77.3939
32 .	4	30	84.2424
33 .	1	22	95.1515
34 .	5	17	60
35 .	4	5	65.4545
36 .	1	19	75.7576
37 .	3	26	85.4545
38 .	1	38	89.597
39 .	1	23	96.2626
40 .	2	21	85.0606
41 .	1	3	86.6667
42 .	1	3	90.303
43 .	1	35	96.9697
44 .	2	45	83.6364
45 .	5	17	50.303
46 .	2	20	84.2424
47 .	2	10	73.5353
48 .	4	4	84.2424
49 .	2	39	69.0909
50 .	1	20	89.0709

TABLE 5 (continued)

TEST RESULTS
FOR EACH QUESTION

Question Number	Answer Type	Viewing Time (Sec.)	Percent Correct
51 .	5	49	54.5455
52 .	2	30	80
53 .	2	25	81.8182
54 .	2	5	83.8384
55 .	1	23	80.6061
56 .	1	41	93.5836
57 .	1	18	93.3333
58 .	2	26	93.9394
59 .	2	14	84.8485
60 .	2	2	84.2424
61 .	2	31	83.8384
62 .	1	23	93.3333
63 .	1	45	96.9697
64 .	1	37	96.3636
65 .	1	36	96.3636
66 .	5	10	55.7576
67 .	1	35	67.2727
68 .	5	15	64.2424
69 .	1	11	75.7576
70 .	1	30	90.9091
71 .	1	6	92.1212
72 .	1	12	96.3636
73 .	1	2	93.3333
74 .	4	46	76.5636
75 .	2	35	81.2121

TABLE 5 (continued)

TEST RESULTS
FOR EACH QUESTION

Question Number	Answer Type	Viewing Time (Sec.)	Percent Correct
76 .	1	40	89.0907
77 .	3	17	80
78 .	1	45	95.1515
79 .	2	20	87.8788
80 .	3	11	72.1212
81 .	3	3	60.6061
82 .	1	20	75.7576
83 .	2	25	86.6667
84 .	3	40	61.2121
85 .	2	35	81.8182
86 .	1	21	92.1212
87 .	1	33	90.9091
88 .	1	42	95.1515
89 .	4	12	53.9394
90 .	5	34	41.2121
91 .	4	17	61.2121
92 .	3	13	64.8485
93 .	1	1	83.6364
94 .	1	50	90.9091
95 .	1	26	91.5152
96 .	1	31	89.697
97 .	1	30	93.9394
98 .	4	14	71.5152
99 .	1	26	83.0303
100 .	1	50	89.697

TABLE 5 (continued)

TEST RESULTS
FOR EACH QUESTION

Question Number	Answer Type	Viewing Time (Sec.)	Percent Correct
101 .	1	2	86.6667
102 .	1	24	95.1515
103 .	3	17	83.6364
104 .	5	28	54.5455
105 .	1	32	76.9697
106 .	1	2	93.9374
107 .	1	30	74.5455
108 .	1	43	96.3636
109 .	4	45	83.6364
110 .	1	46	93.3333
111 .	5	5	12.1212
112 .	1	35	80
113 .	1	40	92.7273
114 .	1	6	94.5455
115 .	1	48	93.3333
116 .	4	41	77.5758
117 .	1	3	92.7273
118 .	1	15	95.7576
119 .	1	29	95.1515
120 .	4	23	75.1515
121 .	2	12	67.8788
122 .	1	35	91.5152
123 .	2	17	81.8182
124 .	1	28	91.5152
125 .	2	35	88.4849

TABLE 5 (continued)

TEST RESULTS
FOR EACH QUESTION

Question Number	Answer Type	Viewing Time (Sec.)	Percent Correct
126 .	2	45	83.6364
127 .	2	43	85.4546
128 .	1	37	90.303
129 .	1	20	94.5455
130 .	1	7	98.7879
131 .	1	45	97.5758
132 .	1	37	96.9697
133 .	1	20	96.9697
134 .	1	3	97.5758
135 .	2	26	86.6667
136 .	2	23	86.6667
137 .	3	10	95.9594
138 .	5	12	30.303
139 .	5	2	41.8182
140 .	1	44	69.697
141 .	1	10	96.9697
142 .	1	20	96.9697
143 .	1	37	93.2333
144 .	4	19	86.0606
145 .	1	24	91.5152
146 .	2	27	73.5353
147 .	3	22	69.0909
148 .	1	40	87.8788
149 .	1	8	93.1212
150 .	1	38	94.5455

TABLE 5 (continued)

TEST RESULTS
FOR EACH QUESTION

Question Number	Answer Type	Viewing Time (Sec.)	Percent Correct
151 .	1	12	94.5455
152 .	1	1	93.3333
153 .	1	30	88.4817
154 .	4	5	75.7576
155 .	1	30	90.9091
156 .	1	43	93.3333
157 .	1	13	93.3333
158 .	1	10	94.5455
159 .	1	14	84.8485
160 .	1	7	93.3333
161 .	1	12	95.7576
162 .	1	12	96.9697
163 .	1	43	93.1818
164 .	4	0	76.3636
165 .	3	1	23.6364
166 .	4	1	30.303
167 .	1	35	60
168 .	5	32	50.9091
169 .	1	12	83.3337
170 .	1	5	91.5152
171 .	1	30	93.3337
172 .	2	33	70.7091

APPENDIX C

FINAL REPORT
HUMAN VIGILANCE INVESTIGATION (UCRL 13891)
SEPTEMBER 1978

ERRATA SHEET:

The words symbol and pattern should be interchanged on Chart 3 in the morning, afternoon, and cumulative. Also, on page 8, 11th line, symbol change to pattern; line 12, pattern change to symbol; page 17, last line change shape to pattern and pattern to symbol; page 18, line 3 change patterns to symbols, and line 5, patterns to symbols.

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