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TARGET DETECTION ON SIDE-LOOKING RADAR WHEN IMAGE MOTION CAN BE TEMPORARILY DELAYED

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Foreword

This report was prepared in the Human Engineering Division of the Behavioral Sciences Laboratory, Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, Ohio. The work was performed jointly under Program 665A, "Precision Strike," headed by James E. Singer of the Research and Technology Division, and Project 7184, "Human Performance in Advanced Systems," Task 718404, "Advanced Systems Human Engineering Design Criteria." The authors are grateful for the administrative support, review, and comments of Mr. Charles Bates, Jr., Chief, Performance Requirements Branch, and for the administrative support of Mr. L. L. Griffin of the same branch. Thanks are also due to Messrs. Bob Roettele and Noel Schwartz, Research Instrumentation Branch of this laboratory, for their efficiency and skill in modifying the apparatus used in this study and to Mr. Don F. McKechnie for training the subjects on side-looking radar. The comments of Dr. M. J. Warrick, Assistant Chief of the Human Engineering Division, are also acknowledged as are the officers from the Strategic Air Command, who served as test subjects. This study was begun in January 1966 and was completed in November 1966.

This technical report has been reviewed and is approved.

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Abstract

This study was conducted to determine the effect, on the recognition of targets of opportunity, of permitting subjects to stop and, when behind, speed up the presentation of dynamically displayed, high-resolution, coherent side-looking radar. The radar film was projected onto a 14-inch square, rear-projection screen at a scale of 1:94,000. On the screen, 1-inch displayed approximately 1.29 nautical miles of terrain. The radar imagery moved from the top to the bottom of the screen at a simulated aircraft speed of 2000 Knots in the normal mode and 4000 Knots in the "catchup" mode. Thirty-eight radar navigator-bombardiers from the Strategic Air Command were randomly assigned to two groups. Subjects in group I were presented the radar imagery at a constant speed of 2000 Knots. Subjects in group II could view the radar imagery at a speed of 2000 Knots, stop the image movement for any length of time they desired up to a total accumulated "stop time" of 45 seconds and could eliminate any accumulated stop time by speeding up the image movement to 4000 Knots. There was no significant difference between the two groups in number of correct or number of false positive responses; nor was there a significant difference in response latency. These results do not justify providing equipment to stop image motion for the purpose of improving target detection in the presentation of side-looking radar imagery of the quality used in this study.

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SECTION I.
Introduction

To avoid enemy fire, aircraft on reconnaissance/strike missions are frequently flown at high speed and, if possible, their strike weapons are delivered on the first fly-by. In such situations, the crew member who is searching for targets on a sensor display has little time to search any one area on the terrain, and quite limited time to inspect objects of interest. This time limitation is likely responsible for at least part of the rather poor performance sometimes found in studies that have simulated reconnaissance/strike systems by use of a continuously moving pictorial display.

One suggestion often made for improving performance in real-time display systems is to permit the observer to momentarily stop the motion of the displayed image. Increased time for examining some areas of terrain might lead to the detection of more targets and/or to the elimination of some objects that, upon the basis of only a quick examination, would be mistaken for targets.

Side-looking-radar displays often utilize photographically recorded radar imagery that is either examined directly, presented to the observer by optical projection, or presented by a scanning system that displays the picture on a TV cathode ray tube (CRT). In such systems, it would be simple to momentarily stop the motion of the viewed imagery by allowing a slack loop to build up in the moving film while the film processor continues to develop film prior to its presentation to an observer. However, any system which allows an observer to drop behind in viewing the film will complicate weapon delivery. If excessively long delays are introduced by this technique, weapon delivery will be impossible without an undesirable second pass by the aircraft over the same target area.

In a system that permits occasional stopping of image motion, an operator must be given facilities for returning to "real" time, i.e., to catch up when behind. However, too rapid catching up allows very little time for viewing new (previously unexamined) film, so that the observer may momentarily become lost, i.e., lose track of where his aircraft is with respect to a map, or miss targets.

SECTION II.
Procedure

Experimental Design

Subjects were randomly divided into two groups. Group I, a control group, could not stop image movement. Group II had a foot control with which they could stop image motion for any period up to a total accumulated time of 45 seconds. Also, they could either cause the imagery to move at twice normal speed until they had used up the film in the slack loop, or return the film to normal speed and remain behind real time. A clock that registered the amount of accumulated delay in seconds was placed slightly above and to the right of the viewing screen so that subjects were able to readily ascertain how far behind they were. A strip of barren mountain terrain was added at the end of the film. The strip was long enough for all targets to move out of the scene, i.e., off the display, before the trial was over. This gave all subjects equal time to examine all targets, and it facilitated measurements on the Esterline paper tapes.

Dynamic Imagery Projector

A rear projection viewer with an adjustable speed film drive was used for presenting the radar film. This viewer, built for the Air Force by the Hughes Aircraft Company, was contained in the display console shown in figure 1. A continuous strip of radar film 5-inches in width was enlarged 2.8 times by projection onto the 14-inch square (360 by 360 mm) screen, completely filling the screen with a radar picture. The picture moved from the top to the bottom of the screen. The rate of image motion was 7 inches per minute, which simulated an aircraft speed of 1970 Knots (approximately Mach 3). Image motion during "catch-up," when the subject speeded up the motion, was at twice this rate, i.e., 14 inches per minute, simulating an aircraft speed of 3950 Knots (approximately Mach 6).

Performance Recording Equipment

The equipment for recording performance consisted of a response panel, an electrically operated single-frame data camera, and an Esterline Angus® pen recorder. Each operator was instructed to locate as many airfields, dams, large industries, railroad yards, tank farms and petroleum refineries as possible. In an earlier orientation lecture, operators were told that many nontargets looked more like targets than did some of the real targets. Hence, a compromise must be made between finding all possible targets (which would mean getting too many false targets) and being too cautious (which would result in missing too many real targets).

When the operator located a target, he placed the tip of an illuminated stylus upon it and pushed a target-type button, a confidence level button, and a record button. A 35 mm data camera located behind and to the left of the operator recorded the display screen scene, the position of the stylus point on the scene, and a readout display's indication of the name (target type) and the confidence level assigned by the operator.

The pen recorder indicated the number and length of stops, the number of times the operator shifted into the double-speed "catch-up" mode, the lengths of these periods of catching up, and the time spent in the normal mode. The recorder tape was synchronized with the radar film so that measurements on the tape corresponded with film travel.

The data camera permitted six target-finding performance measures for all operators:

1. *Number of correct responses:* A response was called a correct response when an operator

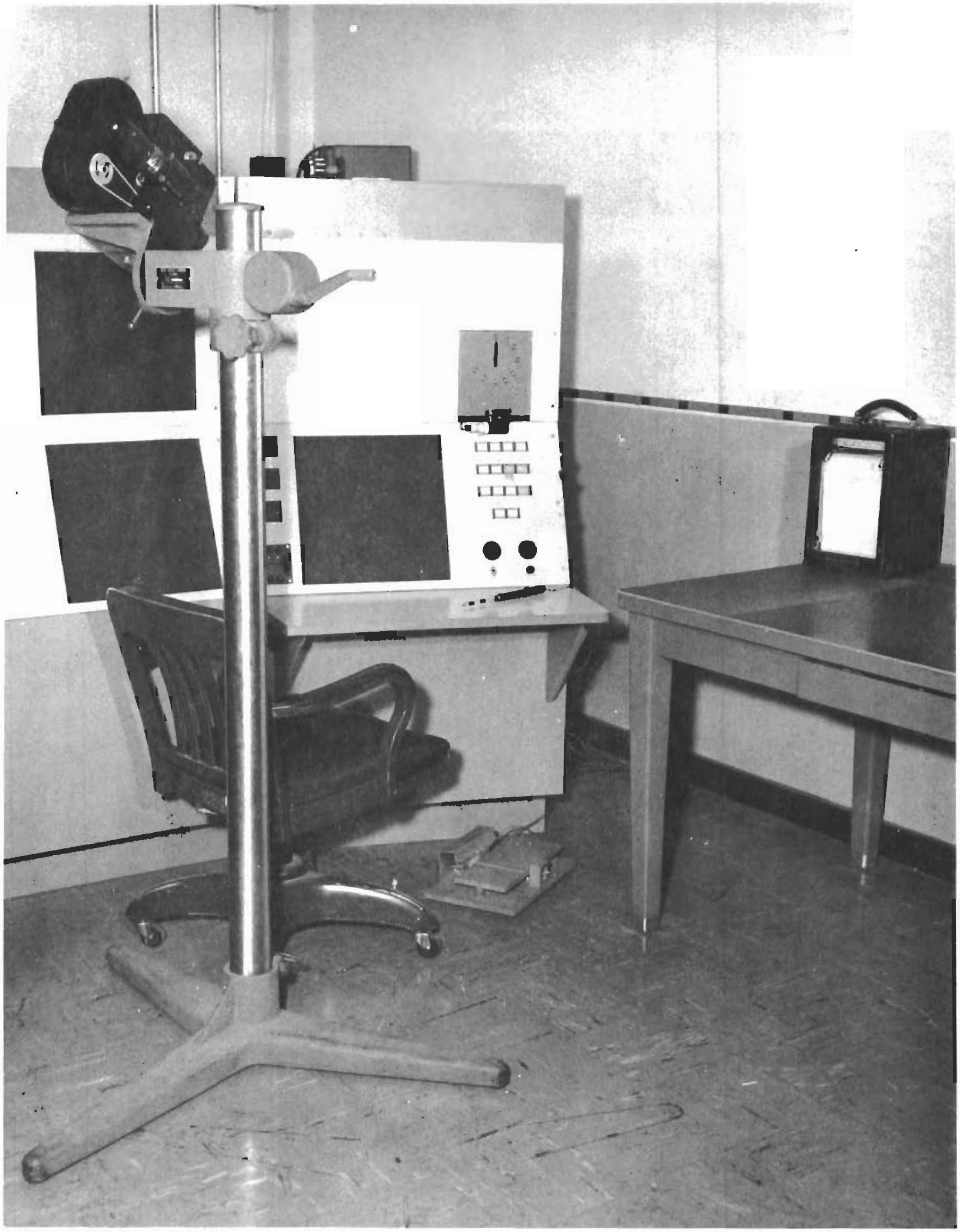
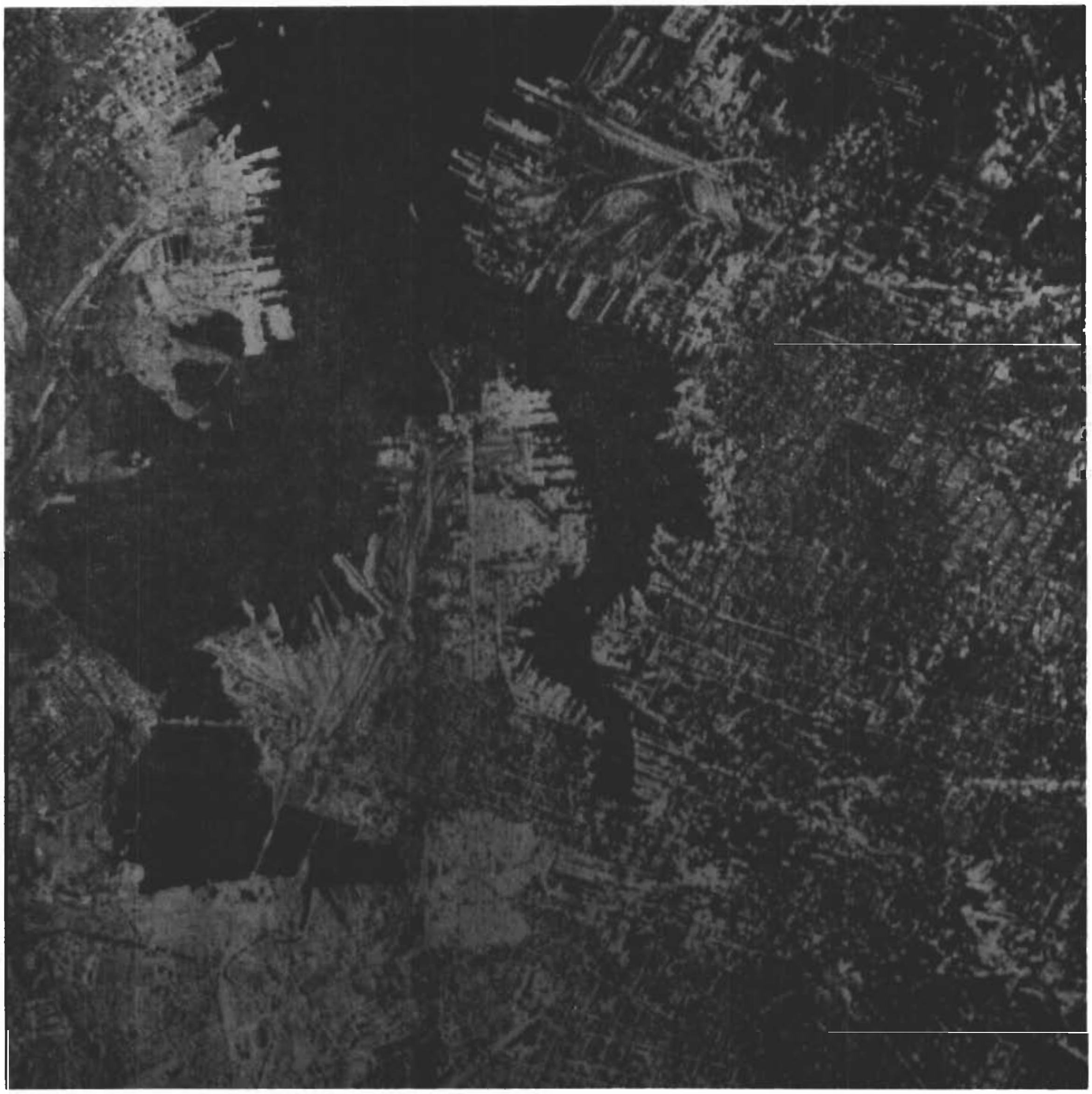


Figure 1. Rear Projection Display Apparatus



Picture by courtesy of the Westinghouse Corporation

Figure 2. Sample of SLR Imagery

placed the tip of the stylus upon one of ninety-seven targets (appendix I), determined by the investigators to be detectable, and depressed the correct target-type button and record button.

2. *False responses:* A false response was scored each time an operator depressed the record button while pointing to an area where there was no target, i.e., to a non-target.

3. *Number of incorrect responses:* An incorrect response was recorded each time an operator pointed to one of the detectable targets and pushed a target-type button whose label was different from the actual target type. Since misclassifying genuine targets was extremely uncommon (0.82% of all responses), and as the frequency of this type of error was approximately the same for both experimental groups, they were disregarded in the statistical tests.

4. *Screen distance traveled by an object before a response was made:* The distance traveled down the screen, in inches, by a target or non-target prior to being responded to by an operator was measured from the data camera pictures, and target detection time (response latency) was computed from this.

5. *Screen quadrant responses:* The screen was divided into four equal squares and the percentage of correct responses made in each quadrant of the screen was recorded. The percentage of false positive responses was also recorded by quadrants.

6. *Confidence level ratings:* Along with each response, each operator was asked to push one of three buttons: (1) low, (2) medium, or (3) high, indicating his confidence in the correctness of his response.

Radar Film

The strip of side-looking, airborne radar imagery collected with an APS-73 (XH-3) portrayed a ground area 18-nautical-miles wide. Image scale on the screen was 1:94,000. Figure 2 shows a side-looking radar picture similar to that used in this study.

Series 200 navigation charts, and various city and state maps were used by the experimentors in a thorough search for visible targets on the film; ninety-seven targets were determined to be visible. Distribution of targets along the flight-path is shown in figure 3.

Subjects

Thirty-eight USAF navigator-bombardiers from the Strategic Air Command served as subjects with each navigator being given three days of intensive training. It was known, however, that thorough training would not eliminate individual differences in target finding, as previous studies conducted at this laboratory have revealed large individual differences in the ability of trained navigators to detect the type of targets of opportunity used in this study.

After completing training, but prior to each trial run, each operator was given a set of instructions (appendix II and III) which outlined the data recording process and informed him that he was to locate six types of targets: airfields, dams, large industrial complexes, railroad yards, tank farms, and petroleum refineries.

SECTION III.
Results

Correct and False Positive Responses

The total number of correct and false positive responses for the two experimental groups is shown in table I. Note that, although there are many more false positive responses than correct target identifications, from one experimental condition to the next, the number of correct or false responses is very similar. To determine if the small differences that were found between the means could be attributed to chance, statistical analysis by two-tailed t tests was conducted for the mean

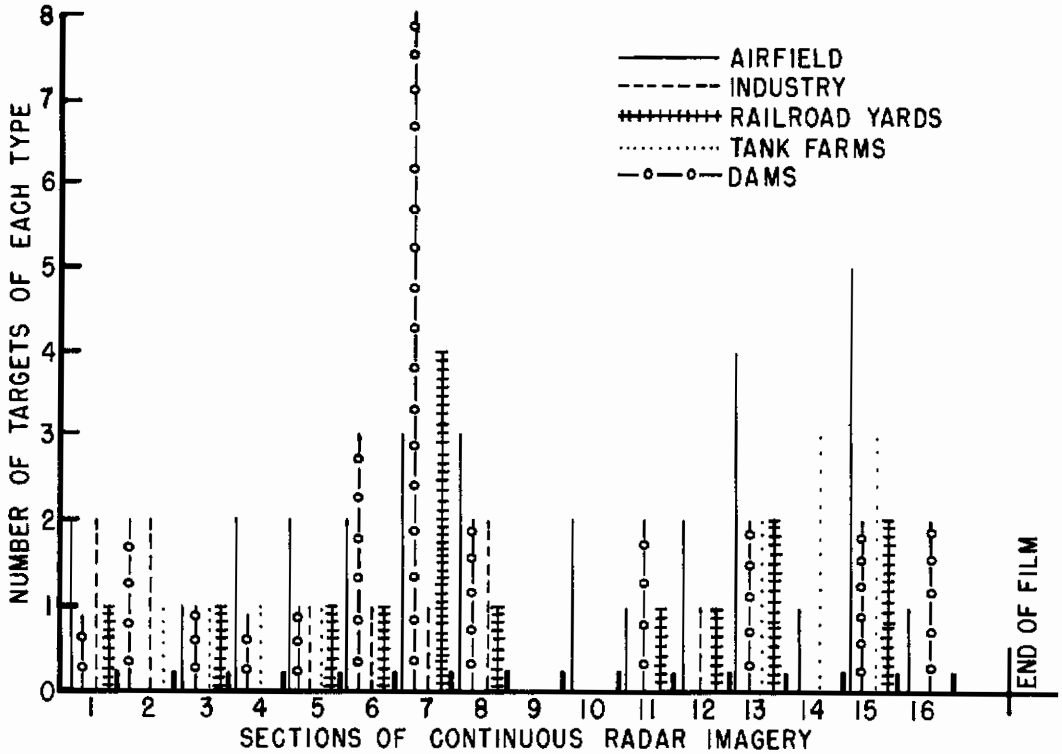


Figure 3. Target Distribution along the Flight Path. The flight path was arbitrarily divided into 16 target intervals of 5 inches each

number of correct identifications for each group, and for the mean number of false positive responses for each group. No significant differences were found (table II). This indicates that subjects who cannot stop image motion (group I) will obtain essentially the same number of correct identifications and number of false positive responses as subjects who can stop it, (group II). Thus, ability to stop or delay image motion has *not* been shown to be beneficial.

Stopping image motion might increase or decrease variability between subjects; i.e., it might enable some subjects to make a large number of correct identifications, and might cause other subjects to correctly identify only a few. Different variances might also be found in the number of false positive responses. To check on this possibility, a test for homogeneity of variance was

TABLE I.

NUMBER OF CORRECT AND FALSE POSITIVE RESPONSES

Experimental Condition	*I (No Motion Stopping)*		*II (Subjects Can Stop Picture Motion)*	
Type of Response	Correct	False Positive	Correct	False Positive
Total number	348	823	346	814
Average number	18.32	43.30	18.21	42.84
Standard Deviation (Variability of scores around the group mean)	4.099	19.942	5.168	18.041

TABLE II.

STATISTICAL ANALYSIS OF NUMBERS OF CORRECT AND FALSE POSITIVE RESPONSES FOR THE TWO EXPERIMENTAL GROUPS

Correct Identifications	
Difference between group means	t = 0.072
Ratio of sample variances of groups	F = 1.572
False Positive Responses	
Difference between group means	t = 0.090
Ratio of sample variances of groups	F = 1.246

t The obtained t scores are not different from what can be expected on the basis of chance. For two-tailed t tests at the .05 significance level, i.e., numbers of targets detected are not significantly different for the two groups, nor do they differ significantly in number of false positives.

F The variances ratios of the two groups does not differ from what can be expected on the basis of chance. For two-tailed F tests, at the .05 significance level, i.e., the two groups do not differ significantly in variability for number of detections or for number of false positives.

conducted on the number of correct target identifications, and on the number of false positive responses, for both experimental groups. This statistical analysis showed that the variances of the two experimental groups were not statistically significantly different (table II).

Screen Distances Traveled By Objects Prior to Responses: The average distance traveled down the screen by objects before they were responded to was measured for all correctly identified targets and for all false positives (table III). Statistical analysis by means of two-tailed t tests revealed no significant differences between the mean distance traveled by either correctly recognized targets or by false positives as a function of the experimental conditions (table IV). Thus, speed of responses for the two groups were not significantly different. To determine if the sample variances were significantly different, that is, if the variances of both experimental groups can be assumed to be estimates of the same population variance, two-tailed "F" tests for homogeneity were conducted on average distance traveled. The tests showed the two groups did not differ significantly in variance (table IV).

Correlations Between Correct Identifications and False Positives: Pearson product moment correlation coefficients were computed for the number of correct identifications and the number of false positive responses for each experimental group. A negative correlation of –0.5463, significant at the .05 level, was obtained for subjects in group II (foot control). This significant negative correlation indicated that subjects who had a greater number of correct identifications than the average for their group, also tended to have fewer false positive responses than the average for their group. Also, those with few correct target identifications tended to make many false positive responses. Contrarily, in group I (no motion stopping) there was no significant relationship ($r = +.0719$) between the number of correct identifications and the number of false positive responses. This lack of significant correlation shows that subjects who had a greater number of correct identifications than the average for their group, sometimes had a greater number of false positive responses and sometimes had a smaller number of false positive responses than the average for their group.

TABLE III.

SCREEN DISTANCES TRAVELED BY OBJECTS PRIOR TO RESPONSE

Experimental Condition	*I (No Stopping of Image Motion)*		*II (Subjects Can Stop Image Motion)*	
Responses	Correct	False Positive	Correct	False Positive
Mean Distance (Inches)	7.09	7.79	8.04	8.36
Standard Deviation (Variability around the mean)	1.747	1.438	2.250	2.692

Operator Accuracy Scores: Accuracy scores (number of correct identifications divided by the total number of responses) were computed for each operator (table V). Statistical analysis, by means of a two-tailed <u>t</u> test, and a two-tailed F test for homogeneity of variance, revealed no differences between average accuracy scores or variance of accuracy scores, as a function of the experimental conditions (table VI).

Confidence Level Ratings

Each subject's average confidence level for correct and for false positive responses was computed (table VII) and Pearson product moment correlation coefficients were computed for each group. Table VIII shows the correlation coefficients for the two experimental conditions and for combined experimental conditions. All three correlations are positive and statistically significant at the .05 level. Thus, operator's confidence level for correctly identified targets and his confi-

TABLE IV.

STATISTICAL ANALYSIS OF SCREEN DISTANCES TRAVELED BY OBJECTS PRIOR TO RESPONSES

Differences between mean travel (in inches) for Correctly Identified targets for the two groups	t = 1.547
Differences between mean travel (in inches) for False Positives for the two groups	t = 0.696
Differences between sample variance for Correct Identifications for the two groups	F = 1.29
Differences between sample variance for False Positives for the two groups	F = 1.87

t = Two-tailed student's t tests for the significance of obtained differences was used. The obtained t scores are not different (at the .05 level) from what can be expected on the basis of chance, i.e., neither group responded significantly faster than the other for either targets or false positives.

F = The ratio between variances, F, was used. The obtained variances of the two groups does not differ (at the .05 level) from what can be expected on the basis of chance, i.e., group variabilities were not significantly different for either targets or false positives.

TABLE V.

ACCURACY SCORES AS A FUNCTION OF EXPERIMENTAL CONDITION

Experimental Condition	*I (No Stopping of Image Motion)*	*II (Subjects Can Stop Image Motion)*
Average Accuracy	32.79	32.26
Standard Deviation (Variability of scores around the group mean)	12.144	12.699

dence level for false positive responses are positively related, i.e., operators who have a higher than average mean confidence level for one type of response tend to be high on the other, and similarly for low confidence.

Accuracy Scores and Confidence Level: The Pearson product moment correlation between operators' accuracy scores and average confidence levels for all responses (operators in group I and II combined) was +0.1121. The correlation was +0.024 for operators in group I, and +0.196 for operators in group II. None of these three correlations are larger than that which can be expected on the basis of chance. Thus, an operator's average confidence in the correctness of his

TABLE VI.

STATISTICAL ANALYSIS OF ACCURACY SCORES FOR THE EXPERIMENTAL CONDITIONS

	Obtained
Difference between mean accuracy scores, **t**	0.038
Difference between sample variances of accuracy scores, F	1.092

No differences past chance were obtained at the .05 level of significance, i.e., neither accuracy or variability in accuracy scores were significantly different for the two groups.

TABLE VII.

MEAN CONFIDENCE LEVELS FOR CORRECT AND FALSE POSITIVE RESPONSES

	Correct	*False Positive*	*Overall*
Group I	2.74	2.41	2.58
Group II	2.75	2.47	2.61

TABLE VIII.

CORRELATIONS BETWEEN CONFIDENCE LEVELS FOR CORRECT AND FOR FALSE POSITIVE RESPONSES FOR INDIVIDUAL SUBJECTS

Value of the Product Moment Correlation Coefficient

	Group I	*Group II*	*Combined I and II*
r	+0.675*	+0.599*	+0.621

*Significant relationship exceeding chance expectation at the .05 level of significance; i.e., for both Group I and Group II, there was a statistically significant relationship between confidence levels for correct and false positive responses: those who were highly confident of their detections were also confident of their false positives, and those whose confidence was low for detections also had low confidence for false positives.

response is not related to how accurate he is. Operators who express high average confidence in what they report as targets are not necessarily more accurate, and operators whose average confidence is low are not necessarily more inaccurate.

Confidence Level Categories: For each experimental condition a separate count was made of those targets correctly identified and those false positive responses given a confidence rating by subjects of categories 1 (low confidence), of 2 (medium confidence), and of 3 (high confidence) (figures 4, 5, and 6). Under both experimental conditions, separately and combined, there was a higher percentage of the responses that were target identifications at the highest confidence

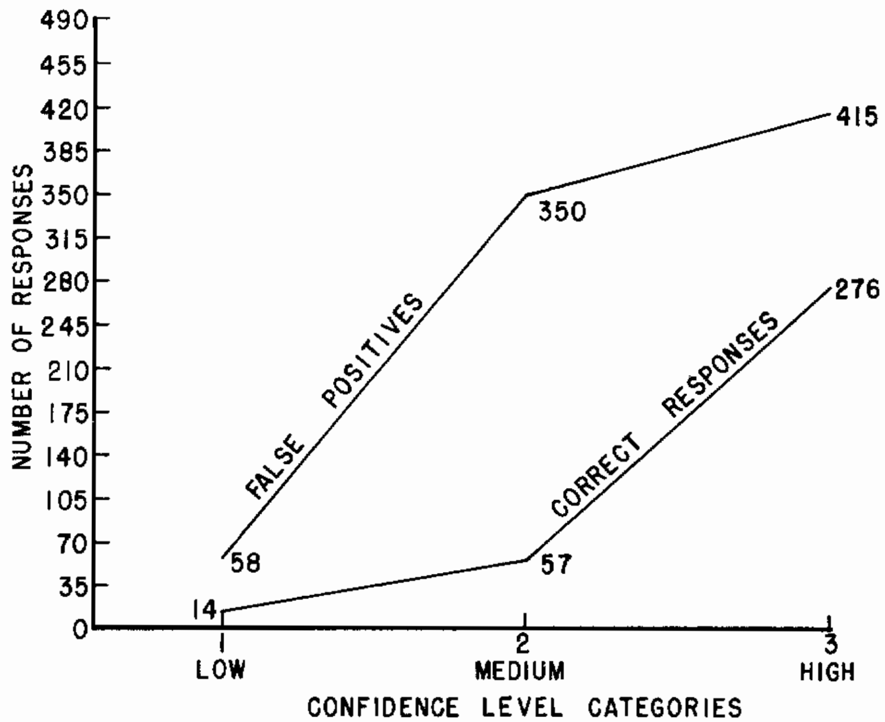


Figure 4. Correct and False Positive Responses Given Various Confidence Level Ratings by Subjects in Group I (No Foot Control)

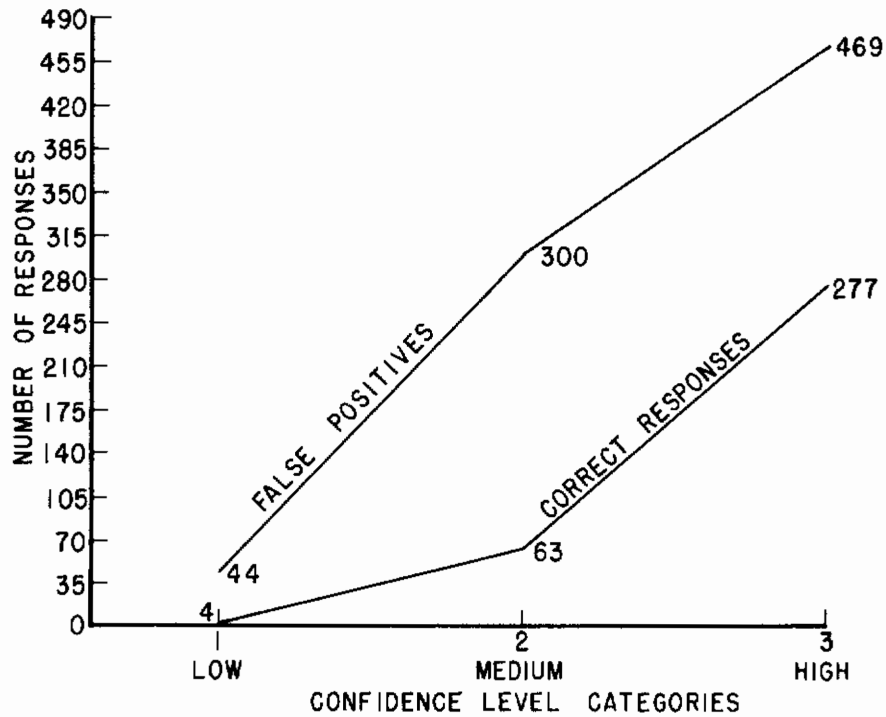


Figure 5. Correct and False Positive Responses Given Various Confidence Level Ratings by Subjects in Group II (Foot Control)

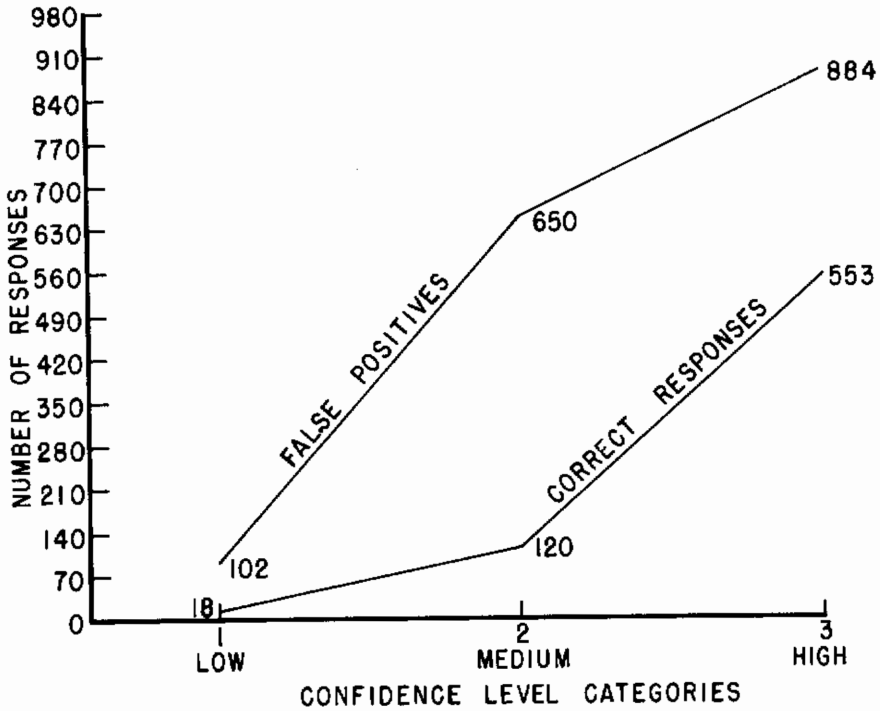


Figure 6. Correct and False Positive Responses Given Various Confidence Level Ratings by All Subjects Regardless of Experimental Condition

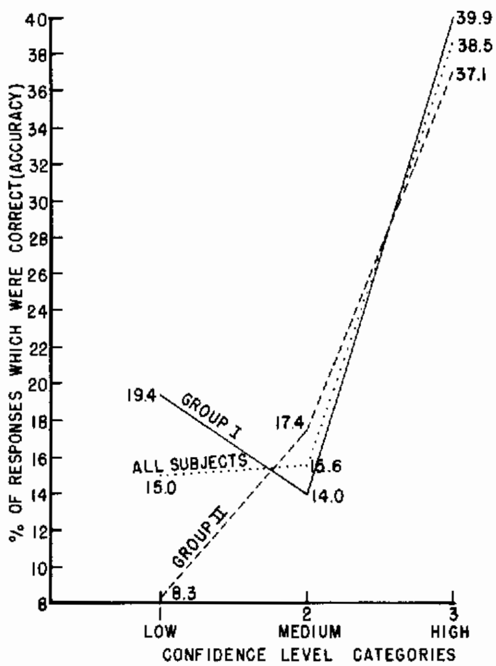


Figure 7. Percentage of Responses which were Correct for Given Confidence Level Categories

category of 3 (see figure 7). This suggests that an improvement in a subject's accuracy would be brought about by accepting, as targets, just those responses given a confidence level rating of 3 (high).

Location of Targets and Probability of Responses

The imagery on the radar film traveled from the top to the bottom of the screen; therefore, any predominance of responses in the vertical dimension of the screen was not due to the location of targets on the imagery. It is possible, however, that targets were not distributed equally across the width of the screen. Tabulation of the position on the film of all targets found by one or more subjects revealed that there were nearly twice as many different targets found on the left half of the screen as there were on the right half. However, there were more total responses on the right side of the screen than on the left. Whether this reversal is due to differences in average target difficulty on the two sides, or peculiarities or habits of search behavior that favor one side, or to some combination of them, is not known.

Screen Quadrant Analysis for Correctly Identified Targets: It may be noted from figure 8 that the percentage of correct identifications is not uniform for the four parts (quadrants) of the screen.

To determine whether the same screen quadrants were favored under all conditions, an arc sin transformation was performed on the percentage of the total responses that were correct for each subject for each screen quadrant. This transformation was performed in accordance with suggestions by Snedecor (1956) and Li (1957) as a method for normalizing data that is in the form of proportions.

Group I (Control Group): Statistical analysis by means of Duncan's New Multiple Range Test (Duncan, 1957) revealed no significant differences at the .05 level of significance between the percentage of correct responses made in the various quadrants of the screen.

Group II (Foot Pedal): Subjects in experimental group II made a higher percentage of correct responses in the upper part of the screen than in the lower part. Duncan's test revealed that there was a significantly higher percentage of correct identifications in the upper right quadrant than in the lower left or lower right quadrants. No difference significant at the .05 level was found between the percentage of correct identifications in the upper right quadrant and the upper left quadrant of the screen.

Combined Scores for Group I and II: Duncan's test revealed that, regardless of the experimental condition, a significantly higher ($P<.05$) percentage of correct identifications was made in the upper-right quadrant of the screen than in the lower-left quadrant. No other significant differences in the percentage of correct identifications were found between any other portions of the screen.

Screen Quadrant Analysis for False Positives: Figure 9 shows that higher percentages of false positive responses were made in the lower-right quadrant of the screen than in any other quadrant. The same statistical analysis by Duncan's New Multiple Range Test was conducted on percentage of false positive responses, with the following results:

Group I (Control Group): A significantly higher ($P<.05$) percentage of false positive responses was made in the lower-right quadrant than in the upper-right or upper-left quadrants; and a significantly higher ($P<.05$) percentage was made in the lower-left than in the upper-left quadrants.

TOTAL CORRECT IDENTIFICATIONS

(a) Total Both Groups (I and II)

I	23.63%	28.10%	III
II	22.77%	25.50%	IV

(b) Group I

I	23.28%	23.85%	III
II	26.15%	26.72%	IV

(c) Group II

I	23.99%	32.37%	III
II	19.36%	24.28%	IV

Figure 8. Distribution of Correctly Identified Targets by Screen Quadrant for Each Experimental Group Separately and Combined. All Numbers Represent Percentages of Responses.

TOTAL FALSE POSITIVES

(a) Total Both Groups (I and II)

I	17.80%	22.99%	III
II	25.00%	34.21%	IV

(b) Group I

I	17.50%	20.65%	III
II	27.95%	33.90%	IV

(c) Group II

I	18.12%	25.33%	III
II	22.03%	34.52%	IV

Figure 9. Distribution of False Positive Responses by Screen Quadrant for Each Experimental Group Separately and Combined. All Numbers Represent Percentages of Responses.

Group II (Foot Pedal): Significantly higher ($P<.05$) percentage of false positive responses was made in the lower-right quadrant than in any other portion of the screen.

Combined Scores for Group I and II: Scores were combined for all experimental conditions; a significantly higher ($P<.05$) percentage of false positive responses was made in the lower-right quadrant of the screen than in any other quadrant, and a significantly higher percentage ($P<.05$) was made in the lower-left than were made in the upper-left quadrant.

Type of Foot Pedal Operation and Response Correctness

Correlation coefficients were computed between various measures of foot pedal operation and number of correct identifications for the number of false positive responses (table IX). Two positive correlations were found to be significantly greater than chance:

TABLE IX.

CORRELATION COEFFICIENTS BETWEEN IMAGE MOTION CONTROL MEASURES AND TARGET RESPONSE BEHAVIOR

Stop Mode	*Variables Correlated*	*Correlation, r*
Number of stops and Accuracy		+0.109
Number of stops and Number of Correct Identifications		–0.159
Number of stops and Number of False Responses		+0.149
Average length of stops and Accuracy Scores		–0.046
Average length of stops and Number of Correct Identifications		–0.097
Average length of stops and Number of False Responses		+0.116
Total length of accumulated stop or catch time and Accuracy Scores		–0.294
Total length of accumulated stop or catch time and Number of Correct Identifications		–0.256
Total length of accumulated stop or catch time and Number of False Responses		+0.495*
Catch Mode		
Number of times catch mode used and Accuracy scores		–0.252
Number of times catch mode used and Number of Correct Identifications		–0.101
Number of times catch mode used and Number of False Responses		+0.347*
Average length of catch mode and Accuracy scores		–0.195
Average length of catch mode and Number of Correct Identifications		+0.064
Average length of catch mode and Number of False Responses		+0.179

*Indicates a greater than chance correlation coefficient (relationship), found by using a two-tailed test of significance at the .05 level.

(1) A significant (P<.05) positive correlation was found between the total time spent in catch-up mode and the number of false positive responses. Since the total time spent in catch-up mode is approximately equal to the total time spent in the stop mode, this correlation with the number of false positive responses holds true for both catch-up and stop time. Figure 10[1] shows that with increased total time spent in stop or catch-up mode, the number of false positive responses tends to increase, while the number of correct identifications tends to decrease.

(2) There was a significant (P<.05) positive correlation between number of times the catch-up mode was used and the number of false positive responses. The number of false positive responses increased rapidly with increase in the number of times the "catch-up" mode was used (see figure 11[2]).

Thus, the number of false positive responses increased as the total time spent by an operator in the stop or catch-up mode increased. They also increased as the number of times an operator used the foot pedal to catch up increased. Table X lists the type, number of times, and length of times each speed mode was used.

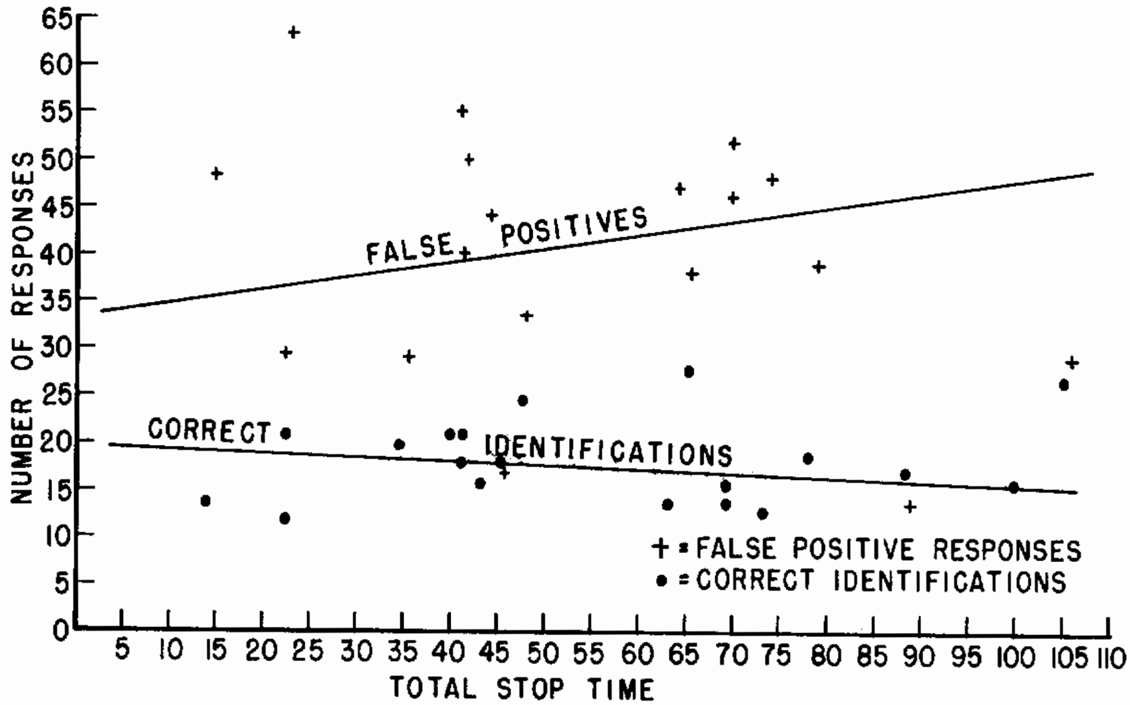


Figure 10. Group II: Total Time Each Subject Spent in Stop or Catch Mode, and Number of Correct or False Positive Responses.

[1] One subject, whose total stop time was 258.4 seconds, has been omitted from this graph, but was included in the calculations involved. He scored 9 correct and 97 false positive responses.

[2] One subject, who had 9 correct identifications and 97 false positive responses, has been omitted from this graph, but not from the calculations. He used the "catch-up" mode 32 times.

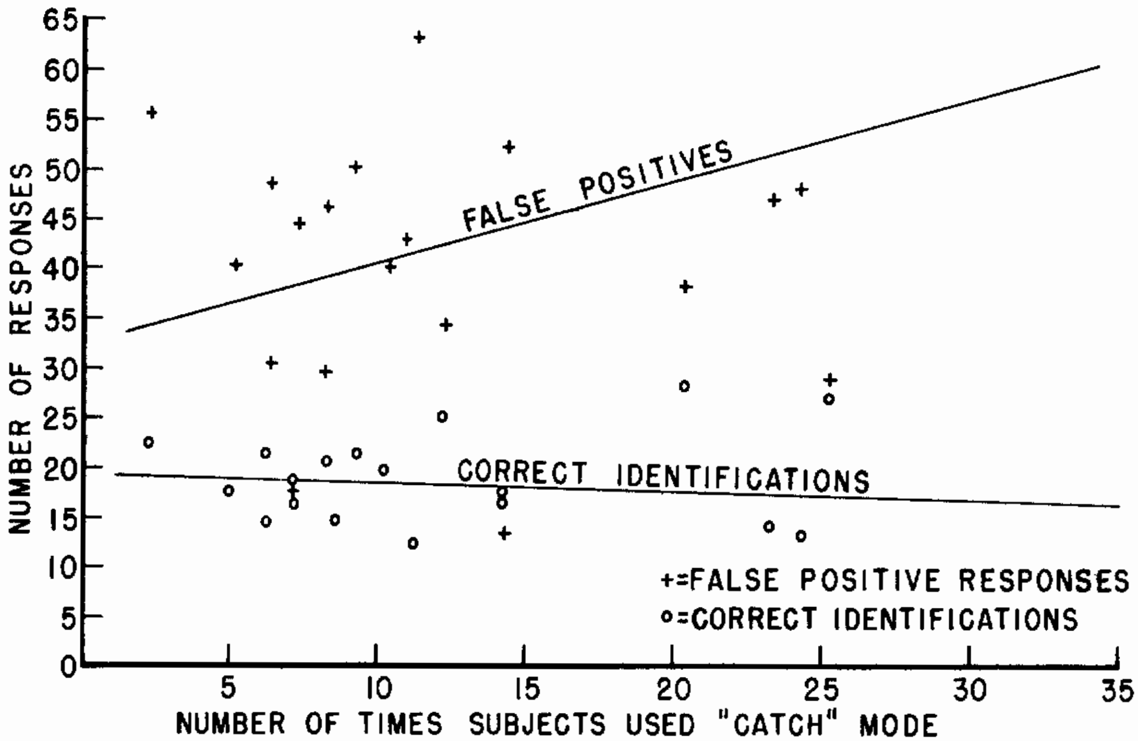


Figure 11. Group II: Number of Correct and False Positive Responses as a Function of the Number of Times Catch Mode was Used.

TABLE X.

STOP AND CATCH-UP BEHAVIOR: FREQUENCY OF USE AND VARIABILITY OF USE

	Total Stop Time (seconds)	*Total Catch Time (seconds)*	*Number of Times Stop mode used*	*Number of Times Catch mode used*
Mean	5.70	5.70	12.84	12.79
Standard Deviation (Variability around the mean)	3.205	3.822	8.846	8.425

SECTION IV.
Discussion

Dynamic versus Static Presentation Modes

There have been a number of studies which have compared target acquisition with a moving and with a static presentation mode. In a study by Erickson (1964), using Landolt C's, target acquisition was compared under a moving and under a static presentation mode. Performance deteriorated as available search time was reduced, regardless of whether the imagery was moving or static. When image motion rate was increased to 5 degrees per second, significantly more detections were made in the moving mode than in the static mode. Simon (1964) used targets whose exact appearance (but not orientation or location) was known in advance. He showed that if there is any superiority of one presentation over the other, it is in favor of a moving display. For example, while the results of his study showed no significant differences in the number of correct or false positive responses, there was significantly less time required to find a target on the moving imagery display.

Both Erickson and Simon found that, at the greater speeds (Erickson at 5 degree/second, and Simon at 7 degree/second), the subjects had difficulty in restricting their target searching to only the lead edge of the moving display (to minimize detection time) because of blur effects. Neither Erickson nor Simon were able to ascertain where this searching difficulty occurred, but Simon speculated that "... It could be related to the velocity at which blur begins to have a noticeable effect and the observer attempts to track the image to compensate for the movement."

Brown (1960) pointed out that until speeds in excess of approximately 5 degree/second are reached, blur is not an important consideration. The average angular rate of image motion for subjects in the present experiment may only be estimated, since operators were allowed to view the screen from any position or distance that they desired. An estimate based upon an average eye distance of 16 inches from the screen was one-half degree/second. Therefore, there was no blur effect due to image movement in this experiment.

Results from the foregoing studies indicate that, if all other experimental controls are equal, an advantage would seem to favor a display in which imagery is continuously moving, rather than one consisting of a series of static pictures.

If allowing the operators some control over the presentation of moving imagery has some beneficial effects upon target response behavior (e.g., by increasing an operator's interest or motivation), these beneficial effects are offset by detrimental effects associated with static displays. This may partially explain why there was no significant difference, as a function of experimental condition, between the number of correct responses, number of false positive responses, or the average response time.

Operator Control Over Image Presentation

In a study concerned with man's ability to recognize geographic landmarks from a spacecraft (Simon and Craig, 1964), subjects were allowed to slew a simulated telescopic view of the ground forward, backward, or sideward. The authors concluded that (1) Pacing can be used without increasing the total time required to find target areas, and (2) "Observer pacing (allowing operators to partially control the image presentation by slewing a telescope), increases observer confidence."

The report by Simon and Craig does not discuss the empirical evidence on which their conclusions were based. Therefore, it is not possible to more than point out that, while the results of the present study support their first conclusion, a somewhat converse conclusion also seems justified. That is, within the experimental parameters investigated in the present study, observer pacing neither hinders nor improves a subject's response behavior.

The present study does not support the second conclusion of Simon and Craig. Table VII shows that the overall mean confidence level for group I is almost identical to group II, 2.58 versus 2.61. Thus, allowing operators to have some control over the presentation of moving imagery has no effect upon the relationship between their confidence level and their objectively measured target response behavior.

Screen Quadrant Analysis

In a study conducted with aerial photographs, Fry and Enoch (1957) performed a quadrant analysis of eye fixations across a screen and found that most eye fixations occurred in the lower-right quadrant and that the fewest occurred in the upper-left quadrant (figure 12).

Buswell (1948) conducted a study of the same general type as Fry and Enoch's, but instead of using aerial photographs, he used paintings taken from the Art Institute of Chicago. His data indicate that most eye fixations occur in the upper-right quadrant, and that fewest occur in the lower-left quadrant of the picture (figure 13). However, artists use principles of composition such as arranging picture detail to cause the observer's eyes to cross the picture diagonally, that might influence eye movements.

Brandt (1945) used nonsense patterns (a symmetrical arrangement of squares on a background divided into twenty-five cells) and found that most eye fixations occur in the upper-left and fewest in the lower-right quadrant of the screen (figure 14).

If the percentage of the targets detected is low, as it was in this study, then the number of eye fixations is assumed to be related to target response behavior. Thus, if a person spends more time looking in certain quardants of a screen, he will also make more responses in these quadrants. Regardless of the validity of the assumption, the studies just cited are inconsistent. Possible generalizations are further complicated because the foregoing studies were presented in the static mode and the imagery in the present study was presented in a dynamic mode. Also, the targets used in the present study were not distributed evenly across the width of the film: There were more

FRY AND ENOCH DATA

11.52%	22.38%
31.01%	35.09%

Figure 12. Quadrant Analysis of Distribution of Percentage of Eye Fixations.

BUSWELL DATA

26.1%	30.4%
19.9%	23.6%

Figure 13. Quadrant Analysis of the Distribution of Percentage of Eye Fixations.

BRANDT DATA

41%	20%
25%	14%

Figure 14. Quadrant Analysis of the Distribution of Percentage of Eye Fixations.

targets located on the left half of the screen (quadrants 1 and 2). In view of these inconsistencies and differences, conclusions from these studies about display design are unwarranted. In the present study, little differences were noted in group I, but subjects in group II correctly identified significantly more targets in the upper-right quadrant of the screen than in the lower-right or lower-left quadrants of the screen, and made significantly more false positive responses in the lower-right quadrant of the screen than in any other quadrant. What there was in experimental condition II of the present study to cause this response behavior has not been determined.

Measures of Image Motion Control by Subjects and their Detection Performance

Although there were no significant differences in the number of correct identifications or of false positives between the two experimental conditions, the data reveals a way in which performance might be improved in group II. Two positive significant correlations were found between the number of false positive responses and (1) the total time spent in stop or catch mode, and (2) the number of times the catch-up mode was used. An improvement in operator performance might be brought about by:

1. Reducing the total number of times the operator is allowed to use the stop mode (while maintaining average stop times), or by reducing the average stop time (while maintaining the total number of stops), or by some combination of both which results in a decrease in total stop time; or

2. By forcing the operators to stay in the catch-up mode for longer periods of time than they normally did in this study (average 5.82 seconds).

SECTION V.
Conclusions

The experimental parameters under which the results of the present study were obtained are an important factor influencing the application of the results. Generalizations must not be overextended to situations where they do not apply. For example, given a different scale, simulated aircraft speed, etc., the results might have been different. However, the experimental conditions in this study are considered to be somewhat representative of visual display conditions found in actual reconnaissance/strike missions. Experimental controls were selected so that the results would have some generality. There were 38 experimental subjects. The subjects were thoroughly briefed and familiarized with target signatures on side-looking radar. There was a large number of different targets on the radar film, and probability of identification of the various targets ranged from 2.67% to 97.4% with a fairly uniform distribution of target difficulties in between (appendix I). It is, thus, unlikely that a replication of the experiment, using another sample of subjects selected from experienced radar operators would, under approximately the same experimental conditions, yield results appreciably different from those obtained. Therefore, the incorporation of an image motion control device which allows an observer to momentarily stop, speed up, or return to normal speed the image motion on a side-looking radar display is not warranted. Such control of image motion does not increase the number of targets of opportunity detected, does not reduce the number of non-targets mistaken for targets, and does not lead to more rapid detection, i.e., reduce response latency.

APPENDIX I.

Target List with Probability of Detections

Target #–Target Name	*Number of Times Identified*	*Probability of Identification*
1–Airfield	0	0.00%
2–Industry	1	2.63%
3–Airfield	0	0.00%
4–Railroad Yard	10	26.32%
5–Industry	9	23.68%
6–Dam	24	63.16%
7–Tank Farm	5	13.16%
8–Industry	7	18.42%
9–Dam	4	10.53%
10–Industry	13	34.21%
11–Dam	3	7.89%
12–Railroad Yard	3	7.89%
13–Railroad Yard	14	36.84%
14–Airfield	6	15.79%
15–Dam	0	0.00%
16–Tank Farm	18	47.37%
17–Tank Farm	20	52.63%
18–Tank Farm	8	21.05%
19–Airfield	1	2.63%
20–Dam	1	2.63%
21–Airfield	32	84.21%
22–Tank Farm	7	18.42%
23–Airfield	1	2.63%
24–Dam	0	0.00%
25–Industry	1	2.63%
26–Airfield	3	7.89%
27–Railroad Yard	12	31.58%
28–Industry	5	13.16%
29–Dam	2	5.26%
30–Airfield	0	0.00%
31–Dam	3	7.89%
32–Airfield	0	0.00%
33–Dam	6	15.79%
34–Railroad Yard	28	73.68%
35–Dam	6	15.79%
36–Dam	8	21.05%
37–Dam	0	0.00%
38–Airfield	0	0.00%
39–Railroad Yard	13	34.21%
40–Railroad Yard	8	21.05%
41–Dam	22	57.89%

APPENDIX I.—Continued

Target List with Probability of Detections

Target #—Target Name	*Number of Times Identified*	*Probability of Identification*
42—Airfield	4	10.53%
43—Dam	4	10.53%
44—Dam	9	23.68%
45—Dam	14	36.84%
46—Railroad Yard	3	7.89%
47—Railroad Yard	34	89.47%
48—Airfield	0	0.00%
49—Dam	1	2.63%
50—Industry	0	0.00%
51—Airfield	0	0.00%
52—Airfield	0	0.00%
53—Railroad Yard	6	15.79%
54—Airfield	1	2.63%
55—Dam	0	0.00%
56—Dam	2	5.26%
57—Industry	0	0.00%
58—Industry	1	2.63%
59—Airfield	37	97.37%
60—Airfield	1	2.63%
61—Dam	30	78.95%
62—Railroad Yard	12	31.58%
63—Dam	12	31.58%
64—Airfield	1	2.63%
65—Airfield	1	2.63%
66—Industry	4	10.53%
67—Railroad Yard	22	57.89%
68—Airfield	2	5.26%
69—Tank Farm	15	39.47%
70—Railroad Yard	1	2.63%
71—Railroad Yard	34	89.47%
72—Dam	30	78.95%
73—Airfield	2	5.26%
74—Airfield	12	31.58%
75—Tank Farm	35	92.10%
76—Airfield	0	0.00%
77—Dam	1	2.63%
78—Airfield	2	5.26%
79—Tank Farm	3	7.89%
80—Tank Farm	1	2.63%
81—Airfield	0	0.00%
82—Tank Farm	0	0.00%

APPENDIX I.—Continued

Target List with Probability of Detections

Target #—Target Name	*Number of Times Identified*	*Probability of Identification*
83—Airfield	0	0.00%
84—Airfield	1	2.63%
85—Airfield	0	0.00%
86—Airfield	1	2.63%
87—Dam	0	0.00%
88—Tank Farm	2	5.26%
89—Railroad Yard	17	44.74%
90—Tank Farm	0	0.00%
91—Tank Farm	1	2.63%
92—Dam	1	2.63%
93—Railroad Yard	1	2.63%
94—Airfield	4	10.53%
95—Dam	8	21.05%
96—Airfield	1	2.63%
97—Dam	17	44.47%
Total Number of Targets		97
Total Number of Targets Recognized One or More Times		76
Total Number of Recognitions		694

APPENDIX II.

Instructions for Subjects in Experimental (Control) Group I

Delayed Image Motion Study

The purpose of this study is to determine your ability to correctly identify certain targets of opportunity imaged on a film strip of high resolution side-looking coherent radar.

The radar film will be projected onto the screen in front of you at a scale of 1:94,000 (18 nautical miles wide), 1-inch on the screen is equal to approximately 1.29 nautical miles.

The imagery will move by you from the top to the bottom of the screen as a consistent simulated aircraft speed of 1974 Knots (Mach 3). This experiment will last 20 minutes.

Your targets are as follows:

- Airfields
- Dams
- Industry
- Railroad Yards
- Tank Farms and Petroleum Refineries

When you locate a target push the buttons indicating target TYPE and CONFIDENCE level; then place the tip of your light pencil on the target and push the button marked RECORD.

QUESTIONS?

APPENDIX III.

Instructions for Subjects in Experimental Group II

The purpose of this study is to determine your ability to correctly identify certain targets of opportunity imaged on a film strip of high resolution side-looking coherent radar.

The radar film will be projected onto the screen in front of you at a scale of 1:94,000 (18 nautical miles wide), 1-inch on the screen is equal to approximately 1.3 nautical miles.

To aid you in identifying targets you have been supplied with a foot pedal. Until you either press on the heel or the toe of the foot pedal, the imagery will continue to move by you from the top to the bottom of the screen at a simulated aircraft speed of 1970 Knots (Mach 3). By pressing on the heel of the pedal, you can stop the image motion as often and as long as you desire up to a total *accumulated* time of 45 seconds, after which you will be automatically overridden, and image movement will return to normal. By pressing on the toe of the foot pedal you can speed up the film movement to a simulated aircraft speed of 3950 Knots (Mach 6); as often and as long as you desire, until any accumulated stop time is eliminated. You will be automatically overridden and speed will return to normal when all accumulated stop time has been eliminated. You can easily ascertain how far behind "real" time you are by observing the clock located slightly above and to the right of your viewing screen. This experiment will last 20 minutes.

Your targets are as follows:

Airfields
Dams
Industry
Railroad Yards
Tank Farms and Petroleum Refineries

When you locate a target push the buttons indicating target TYPE and CONFIDENCE level; then place the tip of your light pencil on the target and push the button marked RECORD.

QUESTIONS?

References

Brandt, H. F., *The Psychology of Seeing,* Philosophical Press, New York, 1945.

Brown, R. H., *The Visual Discrimination of Velocity as a Function of the Rate of Movement and Other Factors,* NRL Report 4299, Psychology Branch Radio Division III, Naval Research Laboratory, Washington, D. C., January 26, 1954.

Buswell, G. T., *How People Look at Pictures,* University of Chicago Press, Chicago, Illinois, 1935.

Duncan, D. B., "Multiple Range Tests for Correlated and Heteroskedastic Means," *Biometrics,* 1957, pp. 164-176.

Erickson, Ronald A., *Visual Search for Targets: Laboratory Experiments,* NAVWEPS REPORT 8406 NOTS TP 3328, Aviation Ordnance Department U. S. Naval Ordnance Test Station, China Lake, California, October 1964. AD 448 468.

Erickson, Ronald A., *Visual Detection of Targets: Analysis and Review,* NAVWEPS REPORT 8617 NOTS TP 3645, Aviation Ordnance Department U. S. Naval Ordnance Test Station, China Lake, California, February 1965. AD 612 721.

Fry, Glenn A., and Enoch, Jay M., *Human Aspects of Photographic Interpretation,* Fourth Interim Technical Report, Mapping and Charting Research Laboratory, Ohio State University Research Foundation, Columbus, Ohio, February-April 1957.

Li, J. C. R., *Introduction to Statistical Inference,* Edwards Brothers, Inc., Ann Arbor, Michigan, 1957.

Simon, Charles W., and Craig, David W., *Man's Ability to Recognize Landmarks from a Spacecraft: Considerations and Recommendations for Equipment and Training,* TM 801, Aerospace Group, Hughes Aircraft Company, Culver City, California, December 1, 1964.

Simon, C. W., *Rapid Acquisition of Radar Targets from Moving and Static Displays,* Technical Memorandum TM-783, Aerospace Group, Hughes Aircraft Company, Culver City, California, 15 June 1964.

Snedecor, G. W., *Statistical Methods,* Iowa State University Press, Ames, Iowa, 1956.

Van Ausdall, Barbara A., and Self, Herschel C., *Effects of Display Polarity on Target Detection with Side-Looking Radar,* AMRL-TR-64-82, Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, Ohio, October 1964.

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13. ABSTRACT

This study was conducted to determine the effect, on the recognition of targets of opportunity, of permitting subjects to stop and, when behind, speed up the presentation of dynamically displayed, high-resolution, coherent side-looking radar. The radar film was projected onto a 14-inch square, rear-projection screen at a scale of 1:94,000. On the screen, 1-inch displayed approximately 1.29 nautical miles of terrain. The radar imagery moved from the top to the bottom of the screen at a simulated aircraft speed of 2000 Knots in the normal mode and 4000 Knots in the "catchup" mode. Thirty-eight radar navigator-bombardiers from the Strategic Air Command were randomly assigned to two groups. Subjects in group I were presented the radar imagery at a constant speed of 2000 Knots. Subjects in group II could view the radar imagery at a speed of 2000 Knots, stop the image movement for any length of time they desired up to a total accumulated "stop time" of 45 seconds and could eliminate any accumulated stop time by speeding up the image movement to 4000 Knots. There was no significant difference between the two groups in number of correct or number of false positive responses; nor was there a significant difference in response latency. These results do not justify providing equipment to stop image motion for the purpose of improving target detection in the presentation of side-looking radar imagery of the quality used in this study.

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