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Effects of Image Exposure Time and Size on Ship Identification on Television

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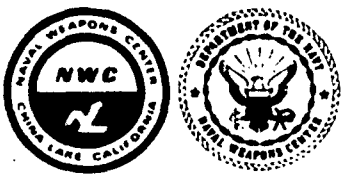

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FOREWORD

This report documents a study conducted in 1979 at the Naval Weapons Center, China Lake, Calif. The work was carried out under an imaging infrared design support program supported by the Naval Air Systems Command under Airtask A503503E/008E/8W06600000, and under the direction of Thomas J. Schmitt (AIR 526E).

The Naval Weapons Center is conducting analysis and experimentation on several aspects of imaging infrared sensor use on missile and aircraft platforms. This report describes a laboratory experiment on ship identification on a raster-type display. The results will be used to determine future research needs and to improve current imaging system specifications.

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(U) *Effects of Image Exposure Time and Size on Ship Identification on Television*, by Hugh O. Whitehurst and Jeffrey D. Grossman. China Lake, Calif., Naval Weapons Center, February 1980. 28 pp. (NWC TP 6169, publication UNCLASSIFIED.)

(U) Human operators' ability to identify a ship on a television display was tested in a simulation experiment. The primary objective was to measure how well the operators could identify a single target from among several alternatives with different image exposure times and image sizes. A second objective was to evaluate two response strategies. In one the observer would view all ships in a set before making an identification response. In the other, he would designate the target when it was first seen.

(U) Image size had a far stronger effect on identification performance than exposure time. Identification probabilities were low at the smallest image size (7 TV lines) at all exposure times tested. With 10 or 13 lines across the image, the percentage of correct identifications increased between 2 and 4-sec exposure times, but the increase was slight between 4 and 6 sec. Giving the observer the opportunity to view all ships in the set before responding did not improve performance.

(U) The data suggests that exposure times should be at least 4 sec to maintain a high level of performance. Correct identifications can be made at the time the target is on the display (whether the target appears first or last in the set) without viewing all ships in a set.

CONTENTS

INTRODUCTION

BACKGROUND

The development of an anti-ship missile equipped with an imaging seeker, a data link, and an operator-missile control link has raised several issues related to the capability of an operator to perform certain required functions. One of the functions that is likely to be allocated to the system operator is the identification of the target prior to the decision to attack.

While experimental data are available for use in estimating the operator's identification ability as a function of the system quality,[1] and as a function of several ship and environmental factors,[2] little is known about identification performance as a function of time. For a multiple ship scenario, where the missile is closing and a target must be designated from among several candidates, the time available to the operator may be insufficient for him to make a correct designation.

Erickson[3] performed an analysis of an anti-ship missile in a multiple ship scenario and concluded that a "surgical" strike mission is not possible against five widely separated ships. In many cases, given the conditions used in the analysis, it was found that only two or three ships out of groups of five can be identified before a decision to attack must be made. A key element in this analysis was the inspection time required by the missile operator. The study assumed 3-, 4-, and 5-sec inspection times with a median of 4-sec as a baseline. It was recommended that these assumptions be validated, however.

OBJECTIVES

This report describes an investigation of ship identification performance using imagery simulating a forward-looking infrared (FLIR) sensor being employed against

[1] Naval Weapons Center. *Warship Identification with Electro-Optical Imaging Systems*, by P. R. Decker. China Lake, Calif., NWC, September 1976. (NWC TP 5895, publication UNCLASSIFIED.)

[2] Naval Weapons Center. *Ship Acquisition on Television: Three Laboratory Experiments*, by H. O. Whitehurst. China Lake, Calif., NWC, August 1977. (NWC TP 5978, publication UNCLASSIFIED.)

[3] Naval Weapons Center. *Imaging Infrared Seeker Study Post-Detection Phase: Man-in-the-Loop Operation*, by R. A. Erickson. China Lake, Calif., NWC, November 1979. (NWC TP 6112, publication UNCLASSIFIED.)

several ships. The primary objective of the experiment was to assess operators' abilities to identify a designated "target" from among several alternatives, given variable lengths of image exposure time and image size. A second objective was to examine identification performance when the identification was made after all ships in the set had been viewed, and compare it to performance when the identification was made at the time the prebriefed target image was on the display. (The target could appear at any time in the sequence of ship exposures.)

METHOD

DESIGN

The experimental design, shown in Table 1, was a completely crossed, 3 × 3 factorial. Twelve aircrewmen participated in the experiment.

The independent variables were the length of time the ship image was visible (exposure time) and the number of lines of the raster that carried information about the ship image (image size).

There were two dependent variables. Both were measures of the percentage of correct identifications of the ship that had been designated the target. Sets of five ship images were presented individually and sequentially to the observer. The observer could voluntarily respond by saying "target" at the time the ship image was present on the display. Each observer was instructed that a voluntary response committed him to attack that ship. After all five ships in a set had been presented the observer was required to respond by pressing one of five buttons which corresponded to the sequence number of the designated target. Consequently, there was a voluntary dependent measure and a forced-choice dependent measure for each trial.

TABLE 1. Experimental Design.

Image size, TV lines	Exposure time, sec		
	2	4	6
7 10 13	12 Observers		

OBSERVERS

Twelve Navy aircrewmen (pilots and bombardier/navigators) served as operators for this experiment. All had at least 20/20 visual acuity based on a recent annual Navy flight physical examination.

APPARATUS

Electronic Equipment

The electronic equipment used to record and display the ship images consisted of the following items:

1. Two Sony U-matic, videotape-recorders, model VO-2860.
2. A solenoid controlled by an interval timer that was used to start and stop one of the videotape-recorders at a constant interval.
3. A Sony video camera with a zoom lens.
4. An S C Electronics, Inc. television monitor (model 10M915) with 9-inch display and 525 nominal TV lines.
5. Five push-push type switches which operated a paper recorder.
6. Headphones with a microphone attached.
7. A tape recorder used to record and play instructions.

Background

A calm sea state was simulated with dark cloth attached to a wall and draped over a table on which the ships were placed for video-taping.

Ships

The ships were eleven 1:1250 scale-model combatants and merchant ships. Table 2 gives the length and visual angle of the smallest and largest ship image for each level of image size. Approximate simulated ranges for a system with a 5-deg horizontal field of view (HFOV) are also given. Photographs of the ships taken at the bearing used in the experiment (30-deg off the bow) are presented in Figure 1. The horizontal resolution of the videotaped images was about 250 TV lines.

TABLE 2. Ship Image Dimensions as Seen on the Display, and Simulated Range.

Image size, TV lines	Image length		Visual angle,[a] min	Simulated range,[b] km
	Inches	mm		
7	0.16-0.24	4.0- 6.1	39-59	26
10	0.22-0.34	5.6- 8.6	57-83	18
13	0.28-0.44	7.1-11.2	69-108	15

[a] Based on viewing distance of 14 inches.
[b] Approximate ranges for system with a 5-deg HFOV.

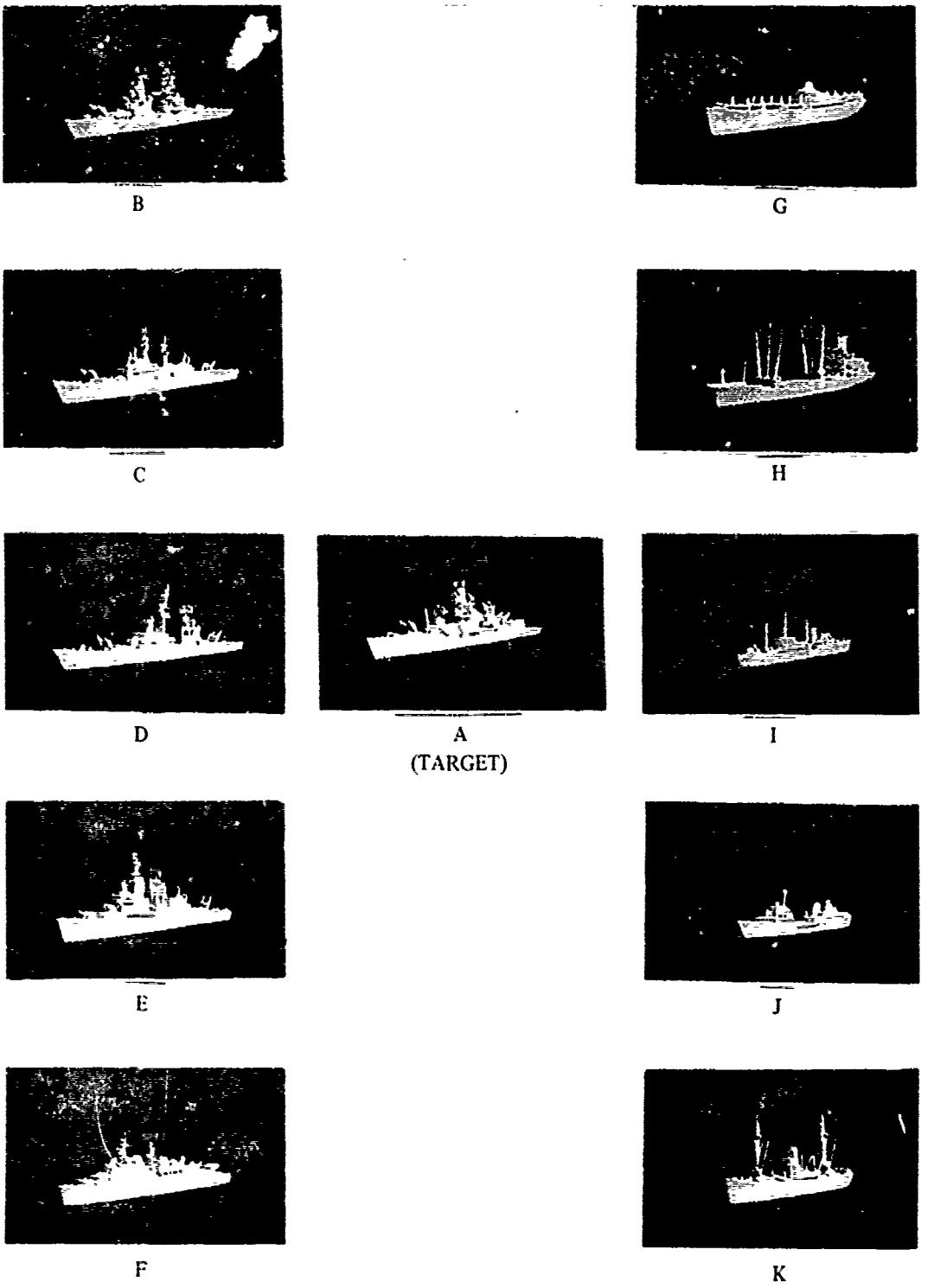

FIGURE 1. Photographs of the Scale-Model Ships.

Lighting

The ship and background were front-lighted by a Mole-Richardson lamp with a single 1000-watt bulb.

The luminance of the videotaped ship images was 16.2 ft-L and the background luminance was 13.5 ft-L on the display seen by the observers. The target/background contrast was 20 percent.*

Test Room

The observers were tested in a noise-free room. The equipment in the room included a television monitor, five push-push switches, headphones with a microphone attached, and a reference card with a picture of each of the 11 ships. The videotape-recorder, paper response recorder, and an additional television monitor for use by the experimenter were located in an adjacent room. The playback configuration during the experimental trials is shown in Figure 2.

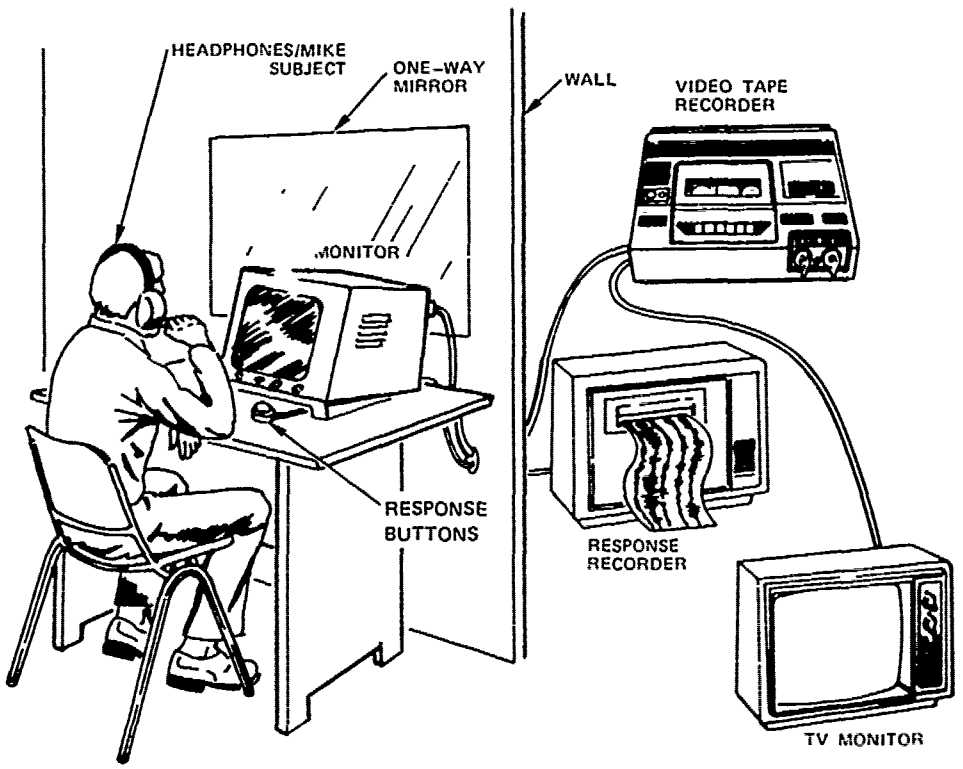

FIGURE 2. Playback Configuration.

$$* \% \text{ Contrast} = \frac{L_t - L_b}{L_b} \times 100$$

PROCEDURE

Videotape Recording

Each of the 11 ships was videotape-recorded with the zoom lens adjusted for image sizes of 7, 10, or 13 TV lines. These images were then dubbed onto the test tape for the correct test image durations and orders.

A total of 450 ship images were recorded on videotape for use in the actual data trials. Ten trials were recorded at each of the nine exposure time X image size conditions. A trial consisted of five individual ship presentations. The target ship was always among the five ship images.

Four of the five ships which constituted one trial were selected from five combatants and five merchant ships. Each set of five ships consisted of two combatants, two merchant ships, and the target. All ten combinations of the five combatants taken two at a time were randomly paired with the ten combinations of the five merchant ships taken two at a time. Thus, each combatant and each merchant ship were videotaped an equal number of times (four times) under each exposure time X image size condition.

The exposure times of 2, 4, and 6 sec were videotaped in blocks; the 30 trials in each block (10 trials at each of the three levels of image size) were randomized. The sequence of the five ships which constituted a trial was also randomized for each trial.

A blank interval of 2 sec was recorded after each of the first four ship image presentations in each trial. The interval gave the observer additional time to respond before the next ship image was presented, and simulated slew time between ships. The interval between the last ship image presentation of a trial and the first ship presentation of the next trial was 6 sec.

When all of the imagery had been recorded, the numbers one through five, corresponding to the image sequence during a trial, were recorded on the audio channel of the tape to aid the observer in keeping track of the ship sequence.

Practice trials were also recorded. The 60 practice trials were similar to the data trials except that the images were composed of 10, 20, and 30 TV lines, the exposure times were 2 and 5 sec, and the ship's bearing was 20 deg or 40 deg off the bow. The word "target" was played over the earphones at the time the ship target was present on the display for the first 20 trials. For the next 20 trials, the sequence number of the target was played after the set of five ship images was presented. The final 20 trials were recorded without feedback (as in the actual data trials).

Experimental Trials

Each observer was seated in the experimental room, the instructions were given and questions were answered. The 60 practice trials were then administered. During the first 20 practice trials the observer simply sat with the headphones on and watched the monitor. No response was required. Each time the target was presented the observer heard the recorded word "target." During the second 20 practice trials the

observer was instructed to respond as he would during the data trials (i.e., say "target" at the time a ship believed to be the target was presented and press the button that corresponded to the sequence number of the ship believed to be the target after all five had been presented). During these trials, the observer was given the sequence number of the target about 4 sec after the last ship in the set had been presented. He could therefore tell if his response had been correct. The observer was instructed to continue responding in the same way during the last 20 practice trials, but no feedback was given. Completion of the practice trials ended one session with the observer. The entire practice session lasted about one hour.

Most observers were given the practice trials during the morning and then returned for the data trials the afternoon of the same day. These observers were given a few additional practice trials just prior to the data trials. The remaining observers were given the data trials after a 15-minute break following the practice trials. During this break, or just prior to the presentation of the data trials, the ship and background luminances on the display were adjusted to obtain a 30 percent contrast.

Presentation of the three blocks of 30 trials (3 different exposure times) was completely counterbalanced between observers. A break of 5 min was given after each 30-trial block. The entire data collection phase lasted just over one hour.

RESULTS

DATA REDUCTION

The data consisted of 90 forced-choice target identification responses and 90 voluntary responses (or omissions) for each observer. The percentages of correct and incorrect identifications were computed for each observer under each of the nine exposure time/image size conditions. The percentages were computed for (1) the forced-choice responses, (2) voluntary responses with omissions counted as errors, and (3) for voluntary responses with omissions not counted. These percentages were used in the following data descriptions and analyses. The percentage of correct responses for each observer under each condition are given in Appendix B.

DATA DESCRIPTION

Means

The percentages of correct forced-choice identifications are presented in Figure 3. Correct identifications increase gradually between 2 and 6 sec with 10-line image sizes. The percentage of correct identifications increases gradually between 2 and 4 sec with 13-line image sizes, but levels off between 4 and 6 sec. With 7 TV lines across the image, 50% of the responses are correct at both 2- and 4-sec exposure times, but then

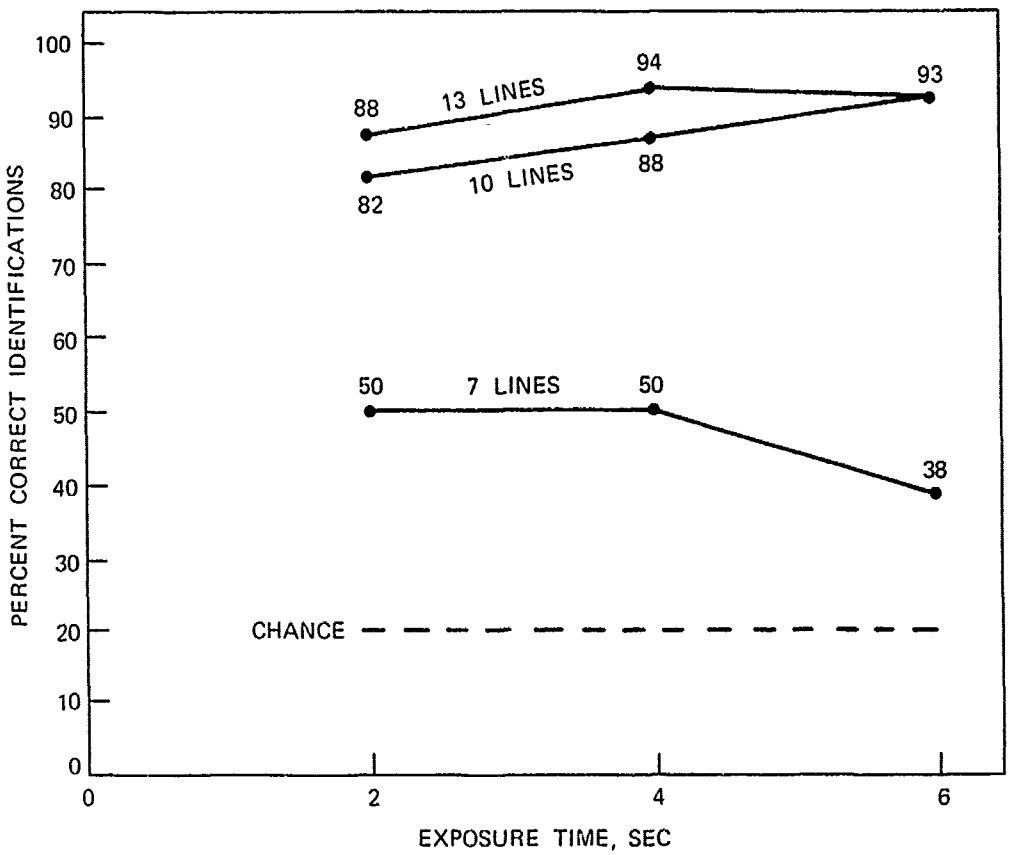

FIGURE 3. Percent Correct Forced-Choice Identifications at Each of the Nine Experimental Conditions. Image size is shown on the curves.

identification performance drops to 38% correct at 6 sec. Observers may have had greater difficulty retaining the barely perceptible target features in their memories for the longer time required. In general, though, exposure time had little effect on forced-choice performance.

The percentages of correct voluntary identifications (omissions excluded) are presented in Figure 4. Voluntary performance, based on correct and incorrect verbal identifications, was about the same as forced-choice performance for each of the conditions, with one exception. Under the 4-sec exposure time and 7-TV line condition, observers performed better when they responded voluntarily at the time the image was on the monitor than they did when they made forced-choice responses after each set of five images had been presented. The difference may have been a result of the small number of voluntary responses at 7 TV lines. Of the 120 possible voluntary responses observers could have made, only about 14 were made at each level of exposure time when the image size was 7 TV lines. The total number of voluntary responses at 10 and 13 TV lines varied from 56 to 104 per exposure time. Percentages based on larger numbers of observations are probably more reliable.

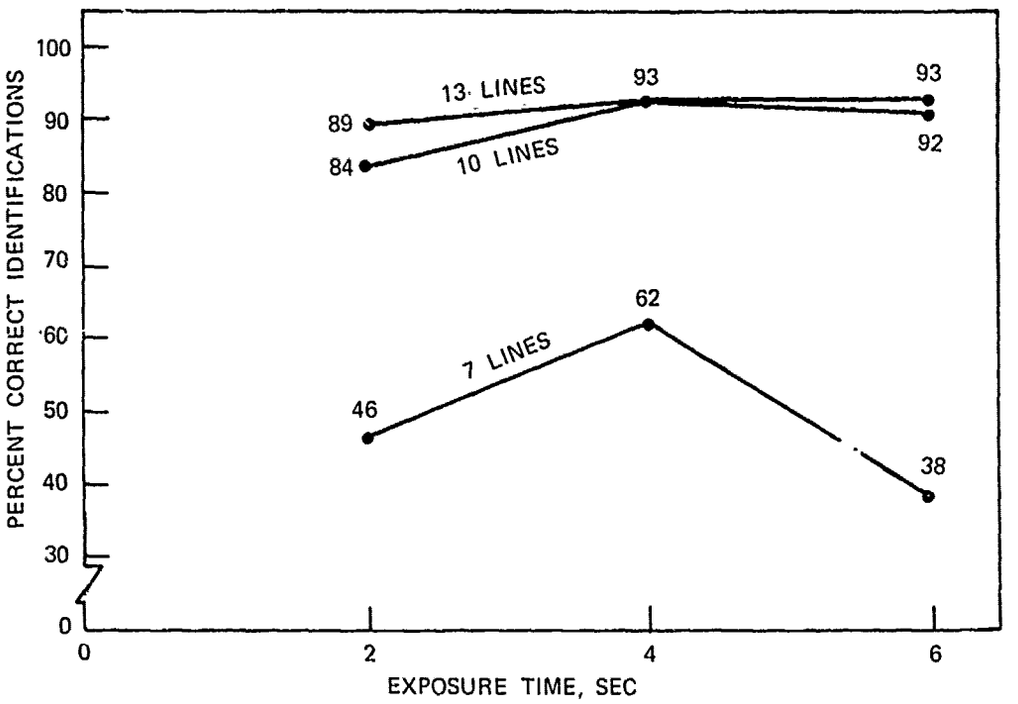

FIGURE 4. Percent Correct Voluntary Identifications at Each of the Nine Experimental Conditions. Omissions were not counted in the total. Image size is shown on the curves.

Figure 5 presents the percentages of correct voluntary responses based on all the data (responses and omissions) from each condition. There were fewer correct voluntary identifications than forced-choice identifications at each condition. Forced-choice responses were not necessarily more effective than voluntary responses because observers also made fewer incorrect voluntary than incorrect forced-choice responses.

Figure 5 shows that voluntary performance improves for exposure times over 2 sec when the image size is 10 or 13 TV lines. However, there is little difference between 4- and 6-sec exposure times. Exposure time had little effect on performance with 7 TV lines across the target.

The available evidence indicates that observers received little benefit from viewing all five images before responding. Percentages for voluntary responses were computed for those instances in which the target was presented first in each set of five images, and for those instances in which it was presented fifth. The observers were correct 48.6% of the time and incorrect 1.7% of the time when they viewed the target first. They were correct on 56.5% of the trials and incorrect on 11% of the trials during which the target was last in the set. Thus, observers were correct more often if the target was last in the set, but they were also incorrect more often when making voluntary responses.

The percentages of correct and incorrect identifications (marginal means) were computed for each level of exposure time across observers and image sizes, and for

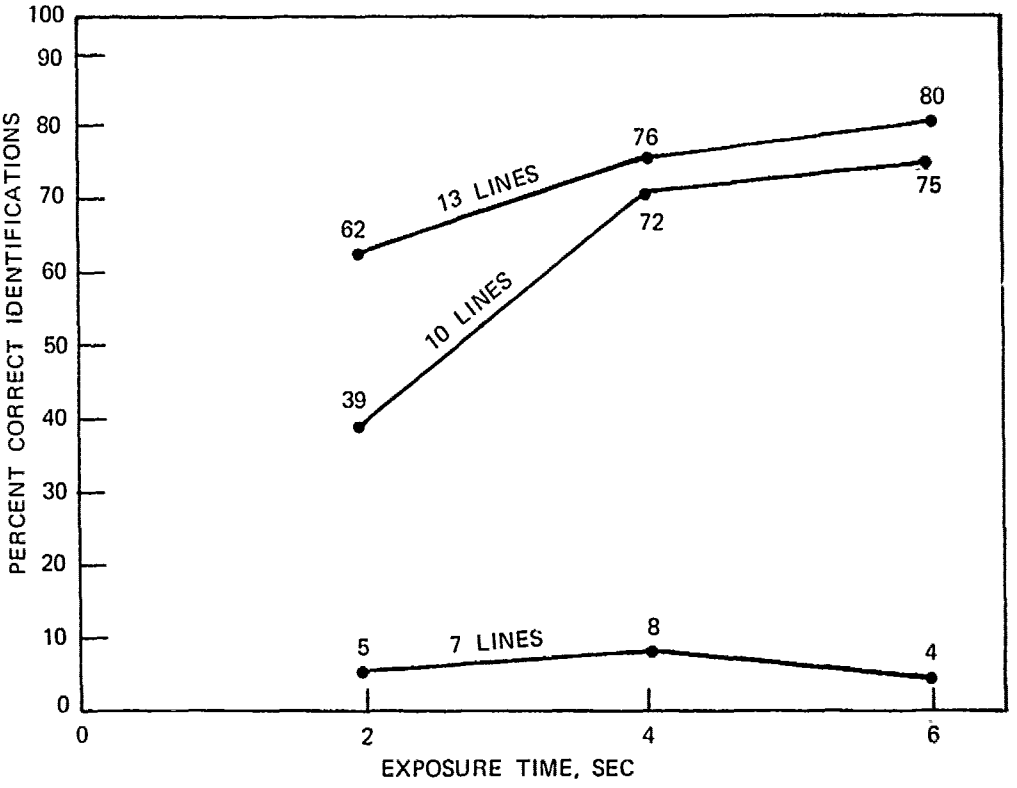

FIGURE 5. Percent Correct Voluntary Identifications at Each of the Nine Experimental Conditions. Percents based on total trials, including omissions. Image size is shown on the curves.

each level of image size across exposure times and observers. The percentages for forced-choice responses and for voluntary responses (both including and excluding omissions) are presented in Appendix C, along with an interpretation of the means.

Cumulative Curves

Cumulative curves for forced-choice and voluntary responses (with omissions included in the total) are presented in Figures 6 and 7, respectively. The curves can be used to estimate the percentage of trials a given number of observers can identify a designated ship target under each condition given.

Confusion Matrices

Confusion matrices, which give the number of times each ship was identified as the target, were produced for forced-choice responses (Table 3) and for voluntary responses (Table 4).

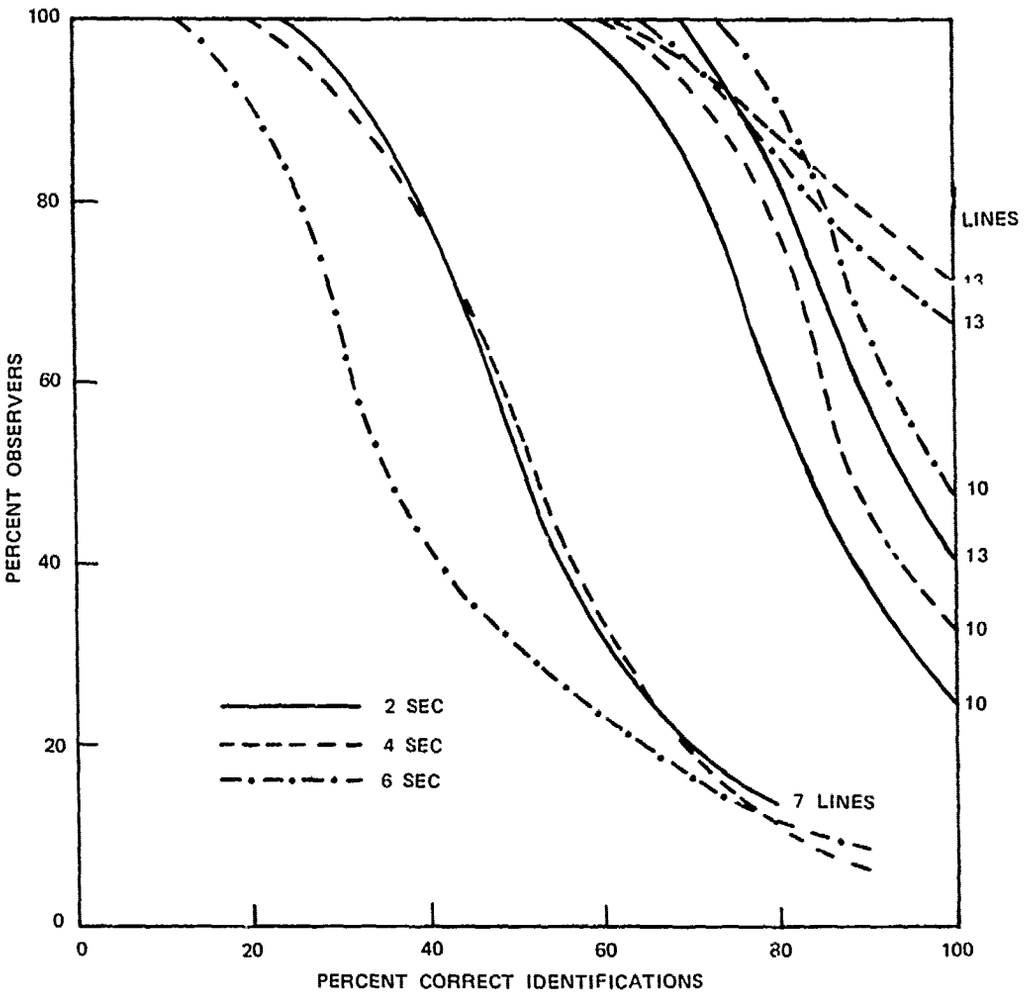

FIGURE 6. Cumulative Percent of Observers Who Had at Least the Number of Correct Forced-Choice Identifications Given at Each Condition.

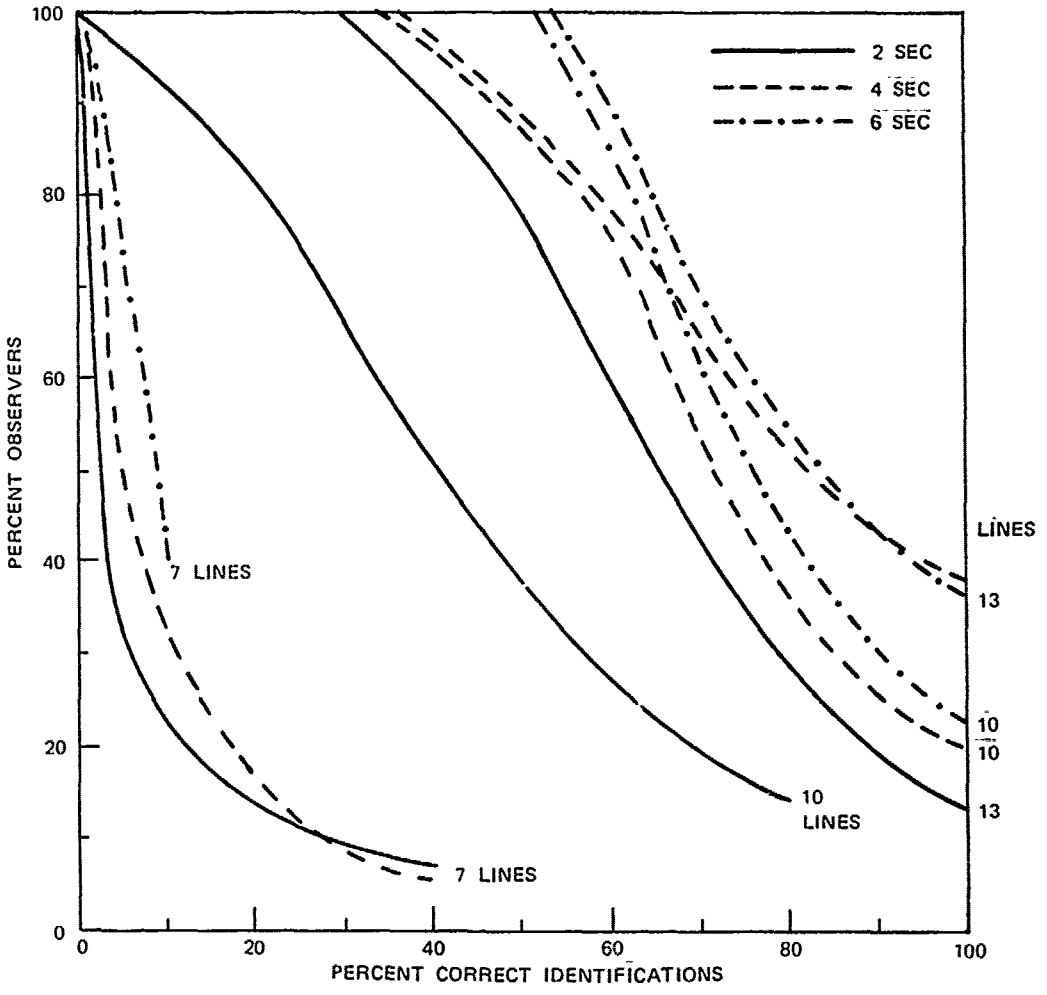

FIGURE 7. Cumulative Percent of Observers Who Had at Least the Number of Correct Voluntary Identifications at Each Condition.

TABLE 3. Number of Times Each Ship Was Identified as the Target When the Response Was Forced Choice.

Ship	Image size, TV lines								
	7			10			13		
	Exposure time, sec								
	2	4	6	2	4	6	2	4	6
Target A	60	60	46	98	106	112	105	113	112
Combatants:									
B	16	17	20	0	0	2	2	1	0
C	9	6	9	8	5	1	1	1	1
D	9	12	15	3	1	0	4	2	3
E	19	20	22	8	7	4	5	3	3
F	2	1	7	2	0	1	2	0	0
Merchants:									
G	1	0	0	1	0	0	0	0	0
H	0	2	1	0	0	0	0	0	0
I	1	0	0	0	1	0	1	0	0
J	0	0	0	0	0	0	0	0	0
K	3	2	0	0	0	0	0	0	1

TABLE 4. Number of Times Each Ship Was Identified as the Target When the Response Was Voluntary.

Ship	Image size, TV lines								
	7			10			13		
	Exposure time, sec								
	2	4	6	2	4	6	2	4	6
Target A	6	10	5	47	86	90	75	91	96
Combatants:									
B	2	1	1	0	0	2	1	0	0
C	1	0	1	3	3	0	1	1	1
D	0	1	1	0	1	0	2	2	3
E	4	4	2	5	2	4	3	4	3
F	0	0	2	0	0	1	2	0	0
Merchants:									
G	0	0	0	1	0	0	0	0	0
H	0	0	1	0	0	0	0	0	0
I	0	0	0	0	0	0	0	0	0
J	0	0	0	0	0	0	0	0	0
K	0	0	0	0	0	0	0	0	1
No response	107	104	107	64	28	23	36	22	16

These tables show that, for both forced-choice and voluntary responses, the same ships were consistently confused with the target, regardless of the exposure time and image size. It can also be noted that the ships most often confused with the target were combatants. Merchant ships were rarely confused with the target.

DATA ANALYSIS

The forced-choice and voluntary data (omissions included) were both submitted to an analysis of variance. Summaries of the analyses are presented in Tables 5 and 6, respectively.

TABLE 5. Summary of Analysis of Variance on Forced-Choice Data.

Source of variance	SS	df	MS	F	P<	η^2
Observers (O)	8587.96	11	780.72			11.53
Exposure time (E)	312.96	2	156.48	0.88	*	0.42
E X O	3931.48	22	178.70			5.28
Image size (I)	45668.52	2	22834.26	71.33	.001	61.30
I X O	7042.59	22	320.12			9.45
E X I	1909.26	4	477.31	2.98	.10	2.56
E X I X O	7046.30	44	160.14			9.46

*P > .25

TABLE 6. Summary of Analysis of Variance on Voluntary Data.

Source of variance	SS	df	MS	F	P<	η^2
Observers (O)	15736.11	11	1430.56			10.85
Exposure time (E)	6688.89	2	3344.44	9.27	.01	4.61
E X O	7933.33	22	360.61			5.47
Image size (I)	93272.22	2	46636.11	110.52	.001	64.29
I X O	9283.33	22	421.97			6.40
E X I	4388.89	4	1097.22	6.20	.001	3.02
E X I X O	7788.89	44	177.02			5.37

The results of the two analyses are similar. In each analysis, the probability is less than one in one thousand that the effect of image size was due to chance. Also, image size accounts for over 60% of the variation in the data in each analysis. Exposure time is statistically significant in the analysis of the voluntary data. (The probability is less than one in one hundred that the effect occurred by chance.) No such exposure time effect was obtained in the analysis of the forced-choice data. Also, exposure time accounts for a much smaller percentage of the data variation than image size.

The effect of the exposure time × image size (E × I) interaction is statistically significant in the voluntary data analysis, but differences in the forced-choice data are more likely to be just chance occurrences. The E × I interaction effect in the voluntary data can be attributed to the relatively large number of omissions in the data at 2-sec exposure times. The interaction means that the effect of image size on voluntary performance was greater at 4 and 6 sec than it was at 2 sec (see Figure 5). Although the probability is higher that the E × I interaction in the forced-choice data might have been due to chance, it accounted for almost as much of the total variation as in the voluntary data (2.56% and 3.02%, respectively).

Overall, image size had by far the strongest effect on performance. Exposure time had a stronger effect on voluntary than forced-choice performance, but the effect was small compared to image size.

DATA COMPARISONS

Some of the forced-choice and voluntary data (omissions included) obtained in this experiment were graphed on a common scale with data collected in three other NWC ship acquisition experiments (Figure 8).

For all data plotted:

- Observers had 6 sec or longer to respond.
- Ship images oriented 30 deg or more off the bow were presented on television.
- Only one ship image was visible to the observer at any time.
- Displays were relatively noise free.
- T/B contrast was +20% or higher.
- All TV displays were 9-inch diagonal.

The data also differ in some important ways. For example, in the experiment reported here observers tried to identify one ship profile. One ship was pre-selected as the target and it remained the target throughout the experiment. Observers made more correct identifications at the same target image sizes in this experiment than they did when they were to recognize ships as merchants or combatants. (In two of three experiments reported by Whitehurst.[2] the targets were two combatants and two merchants.) Observers made a higher percentage of correct identifications in the third experiment than they made in the second experiment at the same image size. Part of the difference was probably due to the fact that observers saw the images against a simulated horizon (profile) in the third experiment, and against a simulated ocean from

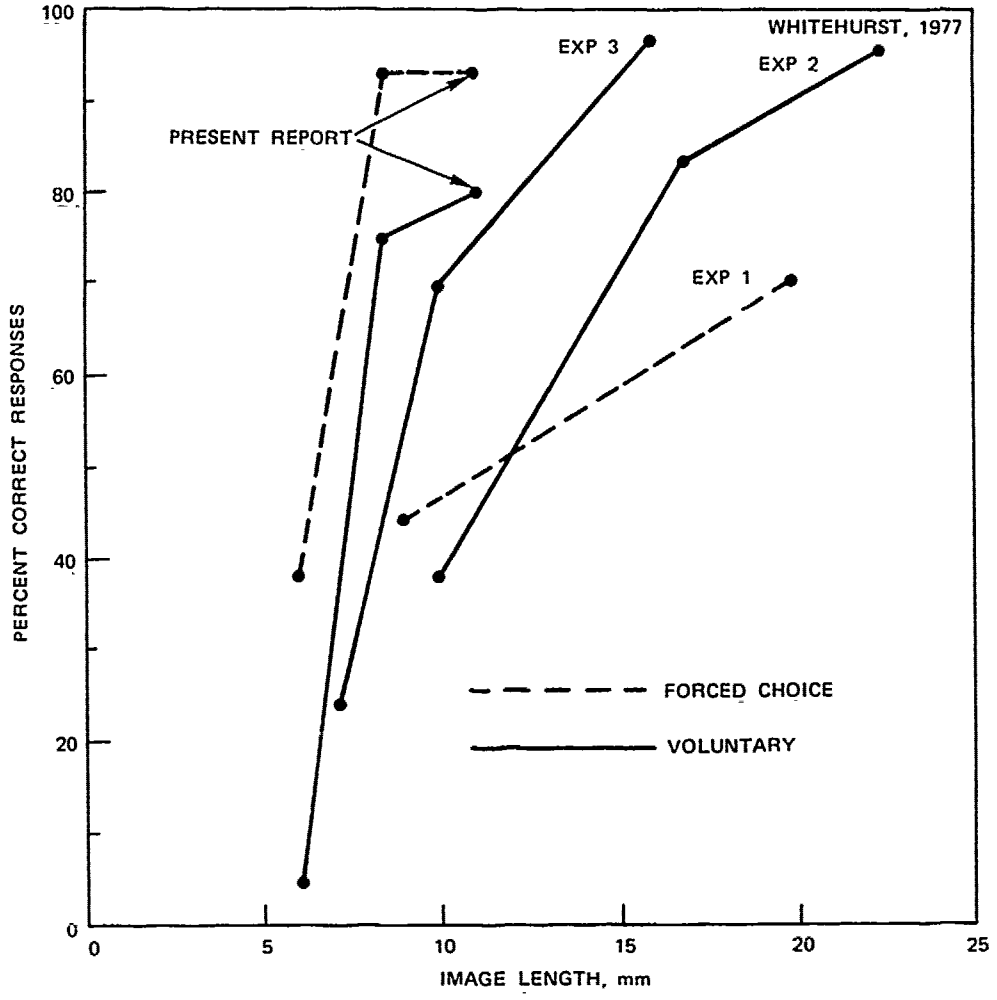

FIGURE 8. Comparison of Data From Three Previous NWC Ship-Acquisition Experiments With Some of the Data Collected in the Present Experiment.

a higher simulated altitude in the second experiment. In the first of the three experiments by Whitehurst, observers tried to identify four combatants presented singly. Generally, fewer correct responses were made for this type of absolute discrimination task than were made for the recognition task (merchant or combatant) or for the single-target-identification task presently reported.

The image length on the display, and image height in TV lines required for 90% correct responses as a function of the particular task and response type are presented in Table 7. Some of the between-task differences can be attributed to the different ships used in each experiment and slight differences in ship aspect angle.

TABLE 7. Image Length and Height Required for 90 Percent Probability of Correct Response.

Response	Task	Image length on display, mm	Image height, TV lines
Forced choice	Identify pre-selected target ship[a]	8	9
	Identify combatant presented[b]	28*	25*
Voluntary	Identify pre-selected target ship[a]	16*	18*
	Recognize merchant or combatant[c]	15-20	16-21

* Based on extrapolation beyond conditions tested.

[a] Discrimination of single, pre-selected target (present report).

[b] Discrimination of four combatants presented singly.

[c] Discrimination of merchants from combatants in single presentations of four ships (two combatants and two merchants).

DISCUSSION OF RESULTS

The central question addressed by this investigation was how long must a ship image be present on a display for the observer to be able to identify a pre-selected target. At long range, simulated by a 7 TV line image identification, performance was poor. Providing longer exposure times did not improve performance. The following discussion deals with shorter range (more TV lines) performance.

The effect of exposure time on performance was greater for voluntary responses (omissions included) than for either forced-choice or voluntary responses with omissions excluded. However, in all three instances, the graphed data revealed an increase in the percent of correct identifications from 2- to 4-sec exposure times. By comparison, the improvements in performance from 4- to 6-sec exposure times were small. Thus, little gain is realized by allowing the operator more than 4 sec to view the image. The improvement from 2- to 4-sec exposure times was substantial if the response was voluntary and omissions were included in the total count. The operational importance of the performance improvement is not so clear-cut if the responses were forced-choice or voluntary (omissions excluded). However, outside the laboratory, the operator's response is not likely to be forced-choice, and the large

number of voluntary omissions at 2-sec exposure times would probably be unacceptable. Other factors that might govern the minimum exposure time are (1) the direction the ship will be oriented when it appears on the display, (2) the stress and vibration to which the operator will be subjected, and (3) the image quality of the imaging system. It is not known how these factors might affect the minimum acceptable exposure time.

The argument has already been made in the results section of this report that allowing the observer to view all five images in the set before designating the pre-assigned target probably contributed little to performance. Thus, with a 4-sec exposure time, the observer can make a near-optimum identification response at the time the target is present on the display, provided conditions are similar to those tested in this experiment.

CONCLUSIONS

Any conclusions derived from the data in this report are applicable only to conditions similar to those tested.

Under the conditions tested, a four second viewing time provides a near-optimum chance of making a correct voluntary identification.

The observer can usually correctly identify the target when it is presented without waiting to inspect all of the choices before making a decision.

Appendix A
INSTRUCTIONS TO OBSERVERS

This experiment is being conducted to get an estimate of the time it takes an observer to identify a ship that has been designated the target.

Note that there are 11 ship images on the board in front of you. The ship in the center is the target, the one you want to identify.

During this experiment you are to watch the monitor and try to identify the target ship when it appears by saying the word "target." You should not respond at the time the ship is presented if you feel uncertain. After a set of five ship images has been presented you are to press the button which corresponds to the sequence number of the ship you believe to be the target, even if you have to guess.

I'll go through that again. You are to sit here with headphones and microphone on and watch the monitor. Buttons numbered 1 through 5 are directly in front of you. Sets of five ships will be presented one at a time. You can identify the target in each set of five by saying "target" before the next ship is presented, but you need not make a verbal response to any one of the five if you feel uncertain. When you say "target" you are making a commitment to attack that ship. Your second opportunity to make a response is after all five ships in a set have been presented. At that time you are to press the button that corresponds to the sequence number of the ship you believe to be the target. Press one of the buttons even if it is just a guess, and even if you did not say "target."

During this session of the experiment you will be given an opportunity to practice. For the first few trials you will not have to respond in any way. The target will be identified as it is presented. During the second phase of practice, you should say "target" if you believe a ship to be the target and then, after all five ships in the set have been presented, press the button corresponding to the sequence number of the ship believed to be the target. You will be given the actual target sequence number before the first ship in the next set of five is presented. The third phase of the practice session will be exactly like the experimental trials. No feedback will be given during these trials.

Do you have any questions?

Appendix B

PERCENT CORRECT IDENTIFICATIONS FOR EACH OBSERVER AND CONDITION

Forced-Choice Data

Ship no.	Image size, TV lines								
	7			10			13		
	Exposure time, sec								
	2	4	6	2	4	6	2	4	6
1	20	20	20	60	90	100	100	100	100
2	60	100	90	80	100	100	70	100	100
2	70	40	20	70	90	80	90	100	90
4	20	30	40	60	70	70	70	60	60
5	60	30	10	100	90	90	90	100	100
6	50	50	80	90	100	100	100	100	100
7	50	50	10	70	90	100	70	100	100
8	40	60	30	100	100	100	90	100	100
9	60	60	40	90	60	100	70	80	90
10	30	40	50	100	90	90	100	90	100
11	80	60	40	80	100	90	100	100	100
12	60	60	30	80	70	100	100	100	80

Voluntary Data, Omissions Included

Ship no.	Image size, TV lines								
	7			10			13		
	Exposure time, sec								
	2	4	6	2	4	6	2	4	6
1	0	0	0	10	50	70	70	90	100
2	0	40	10	20	100	100	40	100	100
3	20	10	0	20	70	70	50	60	70
4	0	10	10	60	90	50	70	50	60
5	0	0	0	30	70	60	50	50	50
6	0	0	0	80	80	100	100	100	100
7	40	30	10	70	90	100	50	100	100
8	0	0	10	30	90	80	60	100	90
9	0	0	0	20	10	50	20	20	80
10	0	10	0	70	70	90	90	80	90
11	0	0	0	50	90	70	80	100	70
12	0	0	10	20	50	60	90	60	50

Voluntary Data, Omissions Excluded

Ship. no.	Image size, TV lines								
	7			10			13		
	Exposure time, sec								
	2	4	6	2	4	6	2	4	6
1	0	0	0	100	100	100	100	100	100
2	0	100	100	67	100	100	67	100	100
3	67	50	0	50	88	78	100	100	88
4	0	20	25	67	90	62	70	71	60
5	0	0	0	100	100	100	75	100	100
6	0	0	0	100	100	100	100	100	100
7	50	75	25	88	90	100	71	100	100
8	0	0	100	100	100	100	100	100	100
9	0	0	0	100	50	100	67	67	89
10	0	100	0	100	88	90	90	89	100
11	0	0	0	100	100	100	100	100	78
12	0	0	100	50	53	100	100	100	83

Appendix C
MARGINAL MEANS

Table C-1 reveals the following:

1. Observers made more correct and more incorrect forced-choice identifications than correct and incorrect voluntary identifications when omissions were included in the total.

2. Observers made very few voluntary responses at 7 TV lines, and a relatively high percentage of those responses were incorrect. Also, observers made a high percentage of incorrect forced-choice identifications at 7 TV lines.

3. At each level of exposure time, observers made a higher percentage of correct, and a lower percentage of incorrect, voluntary identifications with omissions excluded, than they made when the response was forced-choice.

4. At each level of image size, observers made about the same percentage of correct and incorrect forced-choice and voluntary identifications when omissions were included in the total.

If both correct and incorrect identifications are taken into account, voluntary responses were better than forced-choice responses for all exposure times, but there was little difference between voluntary and forced-choice performance as a function of image size. The explanation lies in the low number of voluntary responses, coupled with the relatively high percentage of incorrect forced-choice identifications, at 7 TV lines. Percent correct and incorrect voluntary identifications at each level of exposure time were weighted by the larger number of responses at 10 and 13 TV lines. Percent correct and incorrect forced-choice identifications at each level of exposure time were not weighted by an unequal number of responses at each level of image size. Thus, the relatively poorer performance at 7-TV line image size had a greater effect on forced-choice percentages than it had on voluntary percentages at each level of exposure time.

Voluntary and forced-choice performance was equally effective at each level of image size because the percent correct and incorrect forced-choice identifications were about the same at each exposure time. Also, voluntary identifications at each image size weren't weighted toward superior performance by a large number of omissions at a level of exposure time where a few low-percentage responses were made.

TABLE C-1. Percent Correct and Incorrect Identifications for Each Level of Exposure Time and Each Level of Image Size

Independent Variable/ Level	Dependent Variable	Omissions included		Omissions excluded	
		% correct	% incorrect	% correct	% incorrect
Exposure time, sec					
2	Voluntary	36	7	84	16
	Forced-choice	73	27		
4	Voluntary	52	5	91	9
	Forced-choice	77	23		
6	Voluntary	53	6	90	10
	Forced-choice	75	25		
Image size, TV lines					
7	Voluntary	6	6	50	50
	Forced-choice	46	54		
10	Voluntary	62	6	91	9
	Forced-choice	88	12		
13	Voluntary	73	7	91	9
	Forced-choice	92	8		

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