Technical Report 480

TARGET INFORMATION PROCESSING: THE EFFECTS ON REACTION TIME OF TERRAIN, DOWNLOOK ANGLE, AND RESPONSE PROCESSING LEVEL

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U. S. Army
Research Institute for the Behavioral and Social Sciences

October 1980

NOTICES

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: Technical Report 480	2. GOVT ACCESSION NO. AD-A107	3. RECIPIENT'S CATALOG NUMBER 395
4. TITLE (and Subtitle) TARGET INFORMATION PROCESSING: THE EFFECTS ON REACTION TIME OF TERRAIN, DOWNLOOK ANGLE, AND RESPONSE PROCESSING LEVEL		5. TYPE OF REPORT & PERIOD COVERED --
		6. PERFORMING ORG. REPORT NUMBER --
7. AUTHOR(s) Richard M. Johnson		8. CONTRACT OR GRANT NUMBER(s) --
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Research Institute for the Behavioral and Social Sciences, 5001 Eisenhower Avenue, Alexandria, VA 22333		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 2Q161101A91B
11. CONTROLLING OFFICE NAME AND ADDRESS Department of Defense, Army Deputy Chief of Staff for Personnel, Washington, DC 20310		12. REPORT DATE October 1980
		13. NUMBER OF PAGES 25
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) -- (14) ARI-TR-480		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE --

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

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18. SUPPLEMENTARY NOTES

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Target identification
Target recognition
Target acquisition
Information processing
Reaction time
Visual performance

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This experiment explored the applicability of a serial exhaustive memory scan as a model of the observer's cognitive behavior in a target acquisition task. Reaction times were examined for identification, recognition (friend-enemy), and set responses to stimulus scenes consisting of armored vehicles varying in background (forest road, or plain) and downlook angle (10°, 20°, or 30°). Positive set size was either one, two, or four vehicles. The results provided support for the serial exhaustive model in the linear set size

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function with a zero intercept of 1.4 seconds (s) and a slope of .2 s. Parallel functions were obtained for the forest condition adding .2 s over the equivalent road and plain conditions. The 10° downlook angle resulted in the slowest response times, and the 20° angle the fastest. The response times were the fastest for the positive set items only, followed in order by recognition and identification responses.

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TARGET INFORMATION PROCESSING: THE EFFECTS ON REACTION TIME OF TERRAIN, DOWNLOOK ANGLE, AND RESPONSE PROCESSING LEVEL

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Department of the Army

October 1980

Army Project Number
2Q161101A91B

Basic Research in Target Identification

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FOREWORD

The U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) conducts research concerned with understanding and improving personnel performance and training This report presents results of an In-House Laboratory Independent Research (ILIR) project on the development of an information processing model of target acquisition funded under Army Project 2Q161101A91B. Previous research has been concerned with application of principles of learning and perception to training programs in target identification (ARI Technical Report 79-A13, Research Report 1216, and Technical Paper 358). This report explores the perceptual and cognitive processes of the observer in target recognition and identification.

JOSEPH ZEIDNER
Technical Director

TARGET INFORMATION PROCESSING: THE EFFECTS ON REACTION TIME OF TERRAIN, DOWNLOOK ANGLE, AND RESPONSE PROCESSING LEVEL

BRIEF

Requirement:

Successful target acquisition on the battlefield requires that detection, recognition, and identification of the target followed by deployment of the appropriate weapon system be accomplished in less than 30 seconds (s). The target acquisition task takes on great importance as complexity increases as a function of the number of different types of armored vehicles, aircraft, and other potential threat targets. In addition, nations may have weapons in their inventories from both friendly and traditionally hostile countries. Thus, distinguishing friend from enemy becomes a complex task.

The objective of the present research was to determine reaction times required to make recognition (friend-enemy) and identification responses to armored vehicles under various viewing conditions. The data from this effort will provide input to the development of a model of the human observer in the target acquisition process.

Procedure:

Scale models (1:87) of armored vehicles were viewed by enlisted personnel as background (forest, road, or plain) and downlook angle (10°, 20°, or 30°) was varied. The observers were asked either to identify, recognize (friend-enemy), or determine only if the vehicle was a member of the positive set, as designated in instructions. The positive set of relevant targets could number either 1, 2, or 4. The observer's task was to make the appropriate response as rapidly as possible after a test scene with target was exposed.

Findings:

The major results indicate that it takes approximately 1.5 s to identify one target, with about .2 s added for each additional target that would be possible in a given situation. When a target was against a background of trees, another .2 s was added to response time as compared to the equivalent plain and open road scenes. For downlook angle, the 10° angle resulted in the slowest response times, while the 20° angle produced the fastest times. As expected, the response time for only positive set items was the fastest at a mean time of 1.53 s, followed by the recognition responses at 1.64 s and identification at 2.06 s.

Utilization of Findings:

In addition to providing information concerning the effects of the specific variables investigated in the present experiment, the results demonstrate that the choice reaction time paradigm is a useful method for study of the target acquisition process. These data and data from subsequent experiments will provide information on the basic processes underlying the human observer's cognitive processes during target acquisition. By understanding the process of target acquisition and the ways various parameters systematically affect it, meaningful input can be made to programs on target identification, camouflage techniques, and vehicle design.

TARGET INFORMATION PROCESSING: THE EFFECTS ON REACTION TIME OF TERRAIN, DOWNLOOK ANGLE, AND RESPONSE PROCESSING LEVEL

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INTRODUCTION

On the modern battlefield, with its highly accurate lethal and rapidly deployable weaponry, it is critical that the soldier be able to detect, recognize, identify, and acquire targets rapidly. This skill is essential to insure survival of U.S. forces as well as to engage the enemy effectively. First, detection must be made--determination that a potential target exists. Recognition, used here to mean the friend-enemy determination, is complicated by the presence of equipment from traditional threat nations in the arsenals of potential U.S. allies. Thus, the soldier will have to cope with a large variety of equipment, some of which may be either friend or enemy. Second, once the friend-enemy determination is made, identification of the specific vehicle or aircraft type may be important from an intelligence viewpoint and for determination of weapon vulnerability. Finally, the target must be acquired and destroyed with the appropriate weapon system. All of this must be done in less than 30 s and at ranges often exceeding 3,000 m. Detection alone can be extremely difficult at this range.

A voluminous literature on the target acquisition process has been reviewed by Jones, Freitag, and Collyer (1974). Examining this review makes it evident that more attention has been given to physical and geometric properties of scenes, sensing and display systems, and capabilities of the human visual system than has been given to the cognitive processes of the observer. Certainly these noncognitive aspects of the problem are important, but regardless of the clarity of the image that can be presented to the observer, the observer must still extract the relevant information. It is important to determine the effects of physical variables (e.g., camouflage, clutter, contrast) and response variables (e.g., recognition versus identification) on human processing times in the target acquisition process.

If one examines what the observer must do in the target acquisition process once detection has been made, one sees that the problem is one of choice or decisionmaking at the recognition and identification level. The observer has a set of possible choices ranging from friend-enemy in recognition to many potential choices in identification. For example, at least 25 NATO-Warsaw Pact armored combat vehicles could be in the identification set. For a given situation, it is hoped the set would be smaller. Of course, the choice must be made in the shortest possible time. This process lends itself to study as a choice reaction time situation. The choice reaction time paradigm has been used to study information processing, starting at least with Donders' work in 1868-69 (Donders, 1969). Donders felt that the duration of mental processes could be revealed by the appropriate arrangement of experimental tasks. Since Donders, a large volume of research has used the choice reaction time paradigm, especially in the past 20 years with the surge of interest in the study of cognitive processes or human information processing. For recent reviews of this literature see Smith (1968), Pachella (1974), and Teichner and Krebs (1974).

One modern view of choice information processing that appears particularly relevant to the target acquisition problem views the process as a serial exhaustive memory scan (Sternberg, 1969, 1975). In a typical experimental situation, the digits 0 through 9 represent a total memory set. A subset of these digits is given to the observer and is designated as the positive set. The remaining digits constitute the negative set. A digit is presented visually and the observer responds as rapidly as possible as to whether the digit is a member of the positive or negative set. According to the serial exhaustive model, a memory scan of the positive set is made in a serial fashion, with each comparison resulting in either a match or mismatch. Each comparison takes a finite and constant amount of time. Thus, as illustrated by hypothetical data in Figure 1, reaction time increases in a linear fashion as a function of positive set size. The slope of the function gives the time needed for one comparison, which was around 38 milliseconds (msec) in Sternberg's experiments using digits. The positive and negative response functions have equal slopes. This indicates that the process is exhaustive. Otherwise, the positive response function would have half the slope of the negative function in the case of a self-terminating search, which stops when a match is obtained (Sternberg, 1975). The Y intercept in Sternberg's work usually was around 400 msec and represented processing other than memory scanning. One component of this processing can be conceptualized as an image "cleanup" or preprocessing stage. If the stimulus was degraded by superimposition of a checkerboard pattern, the slope of the function remained the same (see Figure 1) but the Y intercept increased in comparison to the nondegraded conditions (Sternberg, 1967). Thus, once the stimulus is cleaned up, the comparison scan occurs as usual.

In the present experiment, armored tanks were used as stimuli in an experimental paradigm similar to Sternberg's to determine if the observer in a target acquisition setting behaves in a manner similar to observers in a choice situation with digits or letters. The variables examined were number of different tanks (positive set size), terrain as a potential degrading variable, viewing angle of the observer with respect to the target, and type of response required (positive versus negative set, recognition, or identification). These data will provide an initial data base and framework for the development of a model of the observer in the target acquisition process.[1]

METHOD

Observers

The observers were 15 enlisted military personnel from the Military District of Washington. Both males and females in a variety of Military Occupational Specialties were represented in the sample.

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[1]I would like to thank Ms. Susan Burbidge and Ms. Lucy Baker for their assistance in collecting and analyzing the data from this experiment.

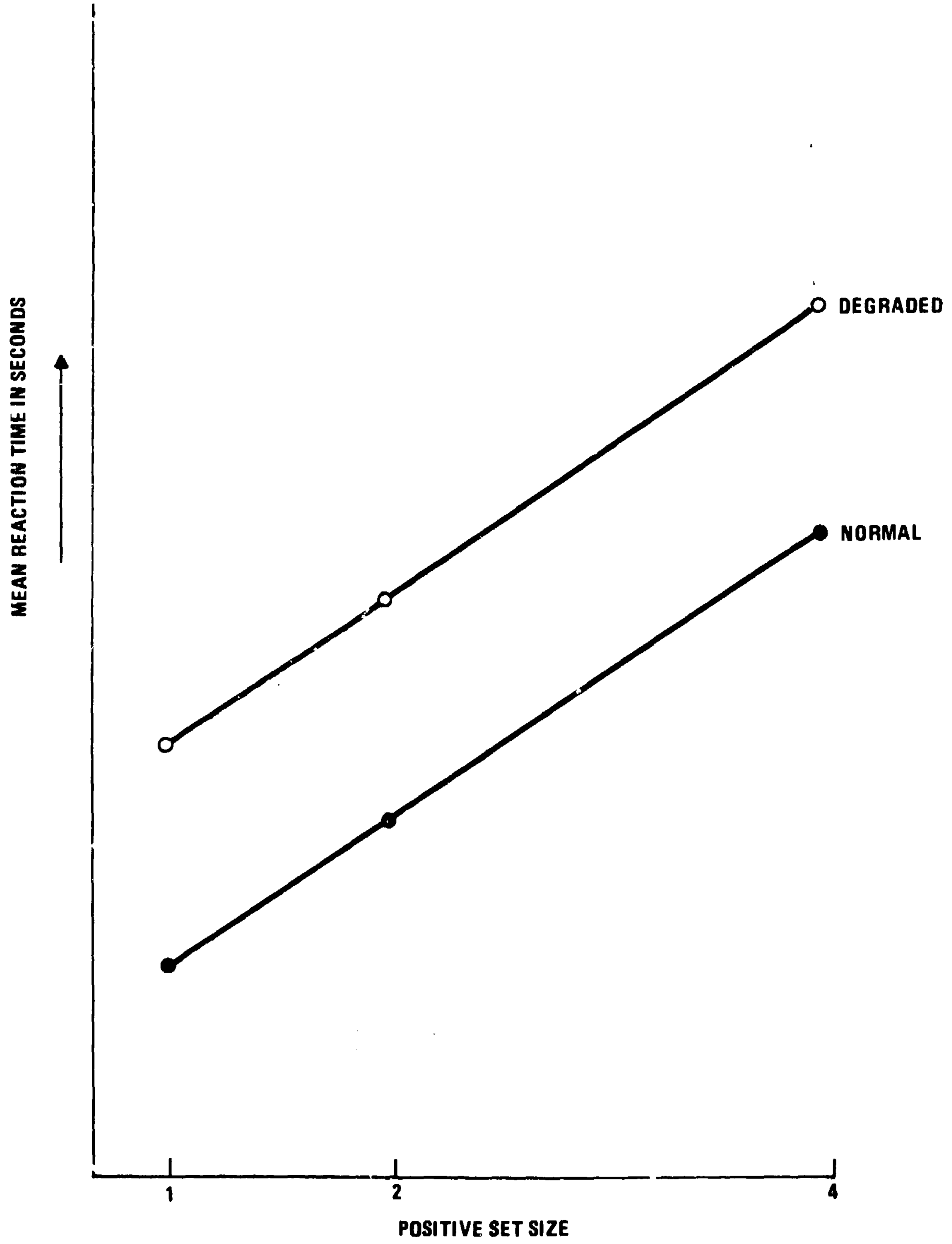

Figure 1. Ideal serial exhaustive model.

Stimuli and Apparatus

Eight armored vehicles were photographed on either a 1:87 scale terrain model or on a white homogeneous background. Four vehicles were of U.S. origin (M60A1, M60, M48, and M103), and four were Soviet vehicles (T62, T55, T10, and PT76). Each vehicle was photographed in side profile against a background of trees, on an open road, or against a homogeneous white background. At each background position, downlook angle was varied to produce stimuli at 10-, 20-, and 30-deg angles. Photographs from a fourth angle of zero deg were taken with the homogeneous background to be used as training stimuli. The 35mm black-and-white photographs were presented in 2-inch x 2-inch slide format. The observer was situated 145 cm from a POLACOAT[2] screen on which the stimulus slides were rear-projected by two Kodak RA960 random access projectors. At this distance the target vehicles subtended approximately 2 deg of visual angle and simulated an actual viewing distance of about 200 m, or about 2,600 m if viewed through the 13x optics of a tube-launched, optically tracked, wire-command linked guided missile system (TOW) sight. The total field of view was 40 x 60 deg. An Automated Data Systems 1800E minicomputer controlled the projectors, each fitted with solenoid-actuated shutters. One projector presented a fixation point that coincided with the target position on each of the stimulus presentations.

Design

Using reaction time as a dependent variable, five independent variables were examined in the present experiment. A summary of the design is presented in Table 1. In a factorial design the target background could be either forest, a road through open terrain, or a plain homogeneous backdrop. These will be referred to as forest, road, and plain conditions, respectively. The second independent variable of interest was downlook angle, which could be 10, 20, or 30 deg. The third variable was the size of the positive memory set designating the targets to be responded to during a given trial block. This variable was designated set size and could take on values of 1, 2, or 4 targets. The fourth variable was response times to positive set versus negative set items. This was a procedurally defined variable rather than one manipulated experimentally. The probability of either a positive or negative set target was always .5. The fifth independent variable, Response Level, was the only between-subjects variable. One group of five observers responded only as to whether the target was in the positive or negative set (set response). A second group of five observers was asked to make a friend-enemy determination (recognition), and the third group was asked to specify the model number of the vehicle (identification).

[2]Product names are used only for precision of description and do not reflect endorsement by the Department of the Army.

Table 1

Experimental Design for Each Independent Variable: Positive Set Size, Downlook Angle, and Background

Response level group	Set size 1								
	10 deg			20 deg			30 deg		
	Forest	Road	Plain	Forest	Road	Plain	Forest	Road	Plain
Set response									
Recognition									
Identification									

Note. Only set size 1 is illustrated. The entire table would be repeated for set sizes 2 and 4 for each variable.

Procedure

Before beginning the experiment, it was necessary to train the observers to identify the eight armored vehicles. During the training session each observer viewed profile views of each of the eight vehicles photographed on plain backgrounds (i.e., zero degree, plain background). The observer initiated a training trial by pressing a button to expose a slide. When the observer identified the vehicle, the button was again pushed. This removed the slide, leaving a blank screen while the observer made identification by selecting one of eight buttons labeled with the model number of each tank. Once the response was made, a feedback slide provided the correct identification. Each vehicle was presented in random order every eight trials. During the first eight training trials the experimenter identified each vehicle for the observer as the use of the observer's response panel was explained. The experimenter pointed out distinctive features of each vehicle and answered any questions. After the first eight trials, the observer was left to work alone until three consecutive blocks of eight errorless trials were obtained. If this criterion was not achieved in 30 minutes, the experimental trials were nitiated.

Following the training session, each observer viewed nine blocks of 72 experimental trials each in which background, downlook angle, and vehicle model were factorially combined. The observers were assigned to the three response levels on the basis of order of arrival for the experiment. Each observer received three blocks of trials at set size 1, 2, and 4. The order of trial blocks was counterbalanced among observers. Prior to the beginning of each trial block, the appropriate positive response set was given to the observer, and the observer viewed each vehicle once as a refresher. Three blocks of 72 trials were then given with that positive response set. The first block was considered a practice block, and the data analysis was performed on only blocks 2 and 3 for each set size.

Before each trial began, a fixation field was presented with a small dot indicating the position of the target in the next stimulus scene. The observer was instructed to fixate the point and then initiate a trial by pushing a button labeled "signal." This action resulted in the presentation of the stimulus. As soon as the observer made a decision consistent with the response group instruction (e.g., recognition), the signal button was again pushed, causing the stimulus to be replaced by the next fixation field. At this time the observer entered the appropriate response information by depressing another button. The recorded reaction time (RT) was the time between the first and second activations of the signal button. The observer could then initiate another trial at his or her own pace. The observers were asked to respond as rapidly and accurately as possible. At the end of the nine trial blocks, the observer was completely debriefed and any questions answered.

RESULTS

The major analysis consisted of a 3 x 3 x 3 x 3 x 2 analysis of variance (ANOVA) with the first factor (response level) a between-subjects variable and all other within-subjects factors--background, angle, set size, and response type, respectively. Each observer made six responses for each level of the within-subjects variables over two trial blocks. Thus, the RT scores in msec entered into the ANOVA were based on 12 responses for each observer. Only correct responses were included in this analysis.

The main effect of set size, shown in Figure 2, was reliable, $F(2,24) = 3.24$, $p < .05$. The function is essentially linear with a significant linear trend, $F(1, 24) = 11.70$, $p < .01$, and no significant nonlinear components. The slope of this function is approximately .2 sec with a Y intercept of about 1.4 sec. The main effect for response type (i.e., negative versus positive responses) was not significant. Thus, the data on the set size effect are consistent with a serial exhaustive memory search model.

A statistically significant background effect was obtained, $F(2,24) = 5.72$, $p < .01$. The set size function for each background condition is shown in Figure 3. The interaction was not significant. It can be seen that RTs for the road and plain background conditions did not differ. This observation was substantiated by multiple comparison using Duncan's New Multiple Range Test ($p < .05$). Thus, the main effect of background is accounted for by the forest condition.

In Figure 4, the set size by angle interaction is plotted. This interaction was not significant. The main effect of angle was significant, $F(2,24) = 3.69$, $p < .05$. The 10-degree stimuli had the slowest RTs, followed by the 30-degree and 20-degree stimuli in order. In the main effect, these three stimuli were all significantly different from each other (Duncan, $p < .05$). However, in the interaction plotted in Figure 4, this effect was evident only for set size 4. The set of points for set size 1 and 2 did not differ by Duncan's test.

Figure 5 presents response level for each set size. There was no significant main effect of, or interaction with, this variable. This was a between-subjects variable, and there was considerable between-subjects variability

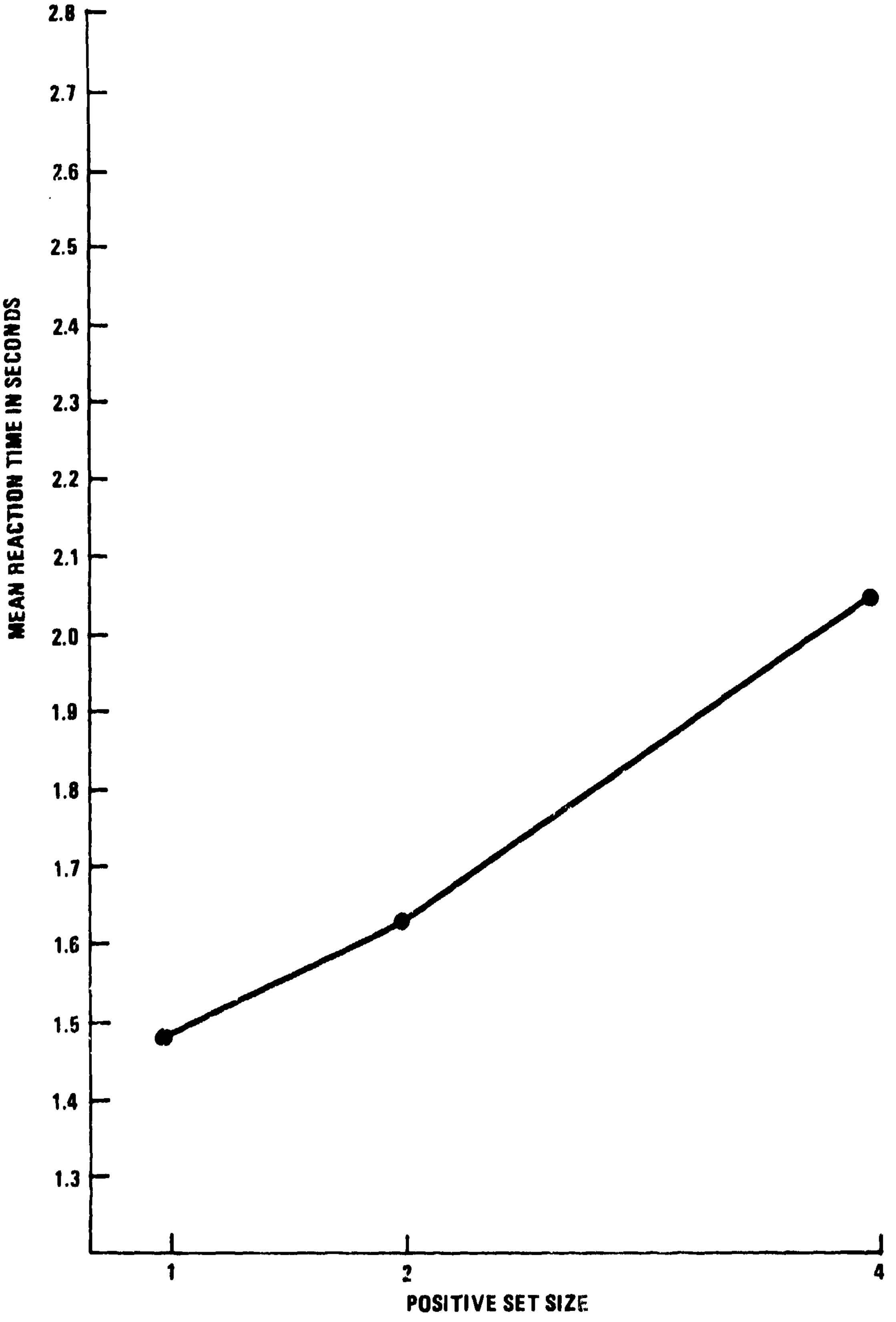

Figure 2. Mean reaction time as a function of positive set size.

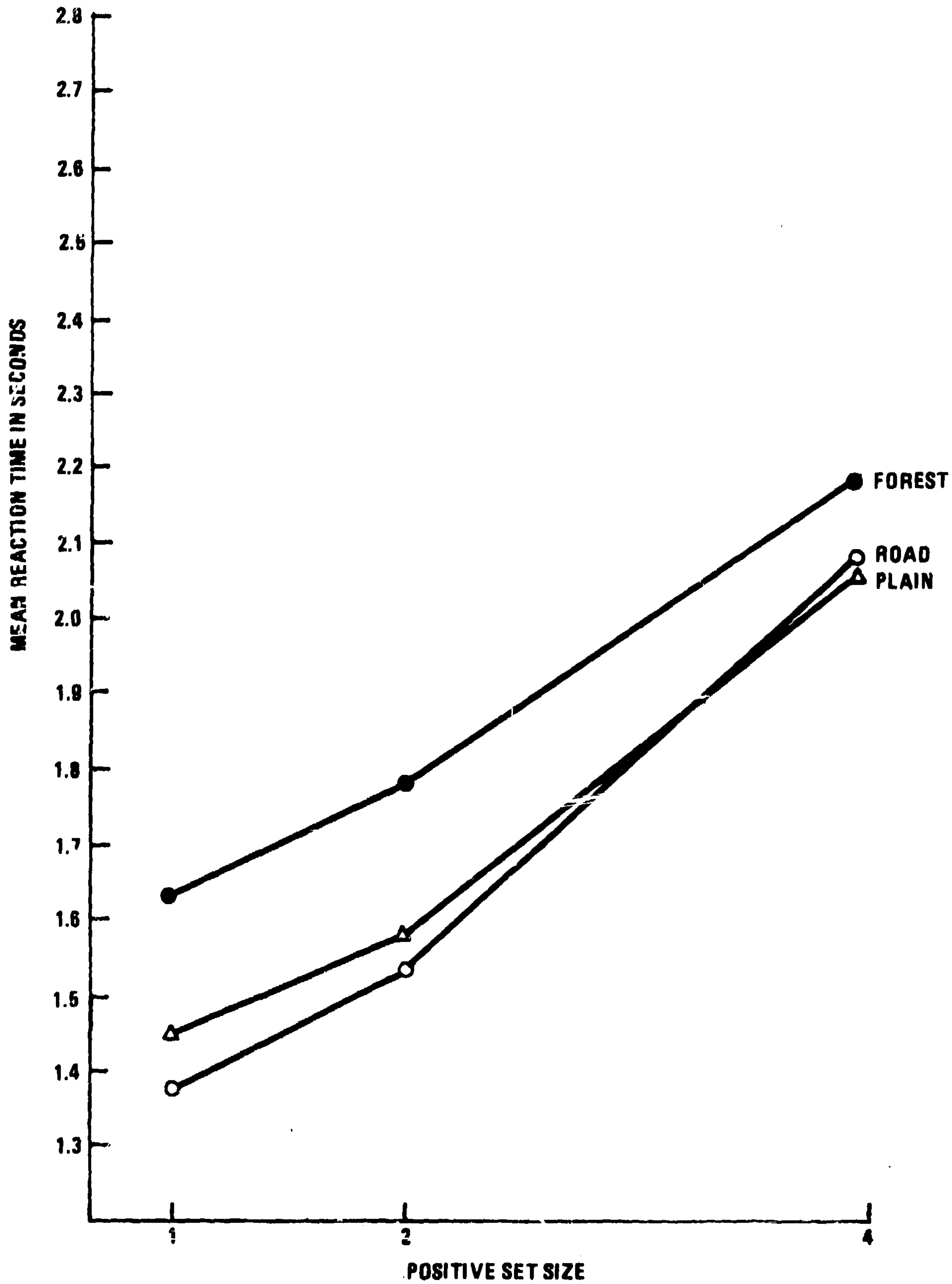

Figure 3. Mean reaction time for positive set size by background.

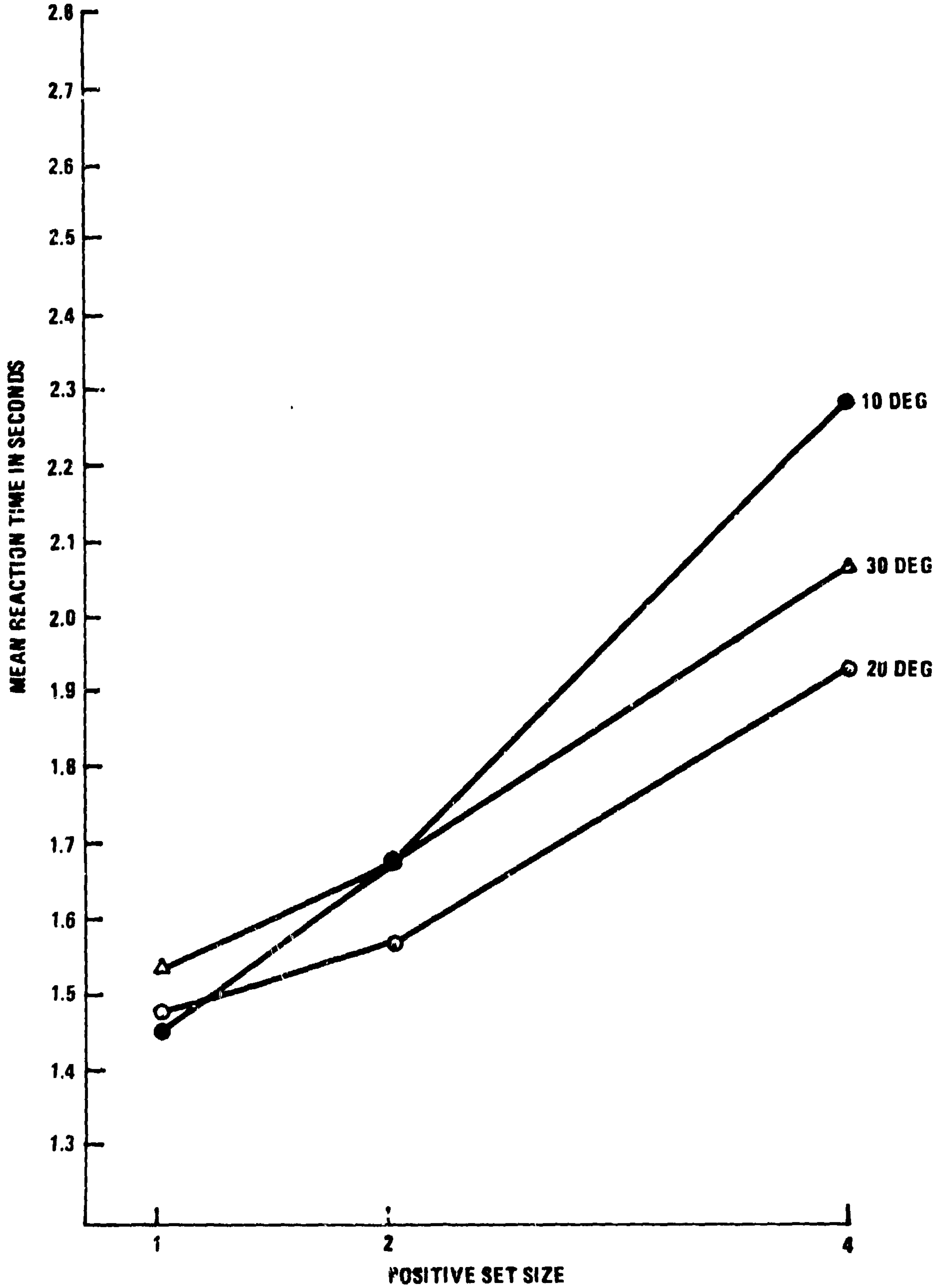

Figure 4. Mean reaction time for positive set size by downlook angle.

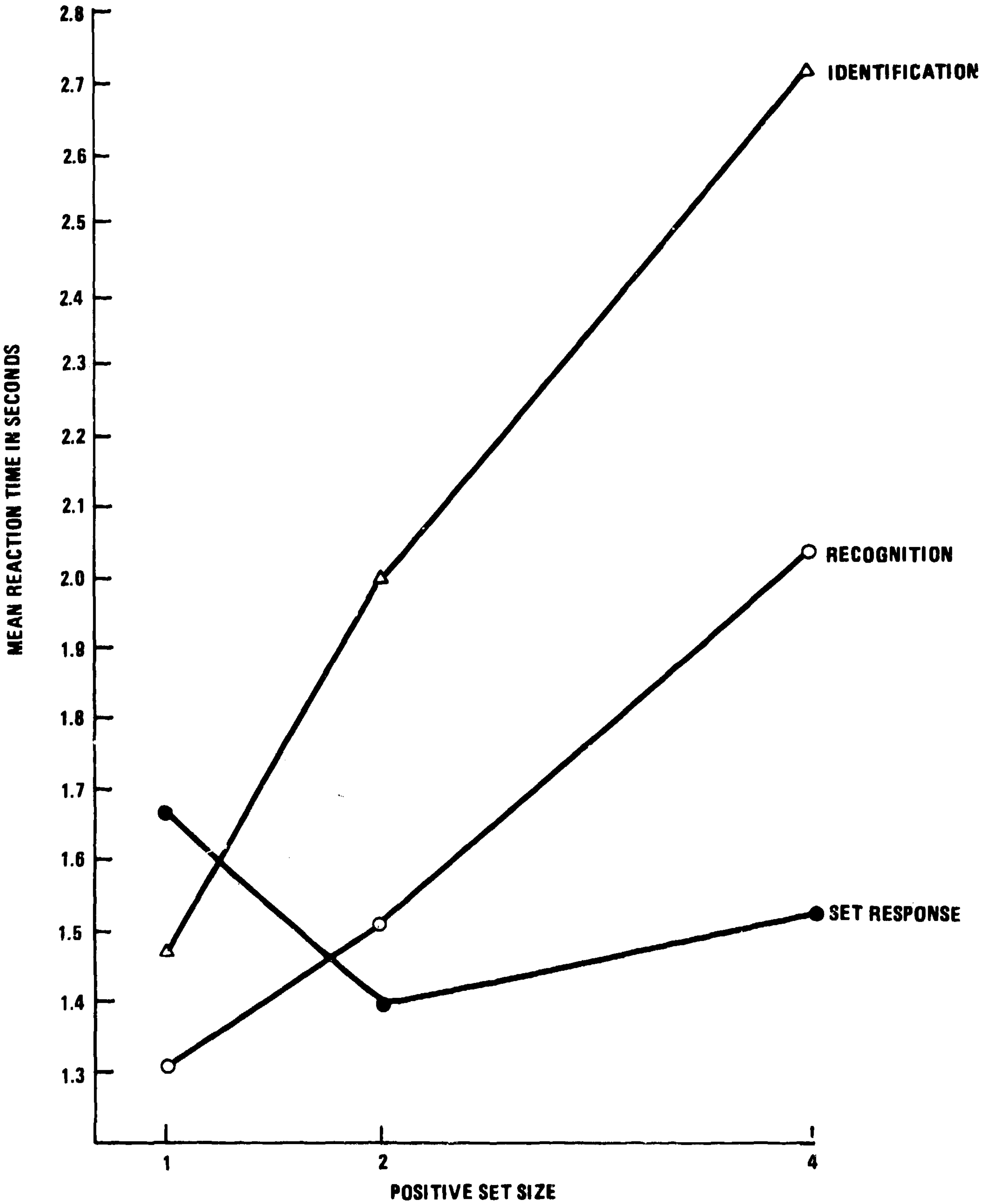

Figure 5. Mean reaction time for positive set size by response level.

in the present study. The mean RT was 1.53 sec for the set response, 1.61 sec for recognition, and 2.06 sec for identification.

The error rate was much higher than is usually obtained or desired in choice reaction time study. During training, it was clear that discrimination of eight armored vehicles is not an easy task. Only 6 of the 15 observers reached the cr erion of three consecutive errorless trial blocks. Two observers had three errorless trial blocks, but not consecutively. Four observers had no errorless trial blocks. This factor could certainly increase error variance in the present analysis. However, an ANOVA of percent errors during the experimental trials showed no differences between the three response level groups. There was a significant main effect of set size, with error rates of 15%, 20%, and 30%, respectively, for the 1, 2, and 4 set size conditions, $\underline{F}(2, 24) = 4.42$, $\underline{p} < .01$.

Table 2 shows a confusion matrix containing conditional probabilities for each possible response to the presentation of a particular vehicle. This table contains data from only the group of observers in the identification condition. The breakdown was not possible for the set response or recognition groups. It is clear that the vehicles were not equally discriminable. A chi-square test on the frequency of correct responses supported this observation, $\underline{X}^2$ (17) = 24.32, $\underline{p} < .001$. The Soviet PT76 was by far the easiest vehicle to identify, while the M103 was the most difficult; it was identified as the M60A1 15% of the time. The T55 was identified as the M60 on 27% of the trials. In terms of confusion between friendly and enemy vehicles, enemy vehicles were identified as friendly on 11% of the trials, and friendly vehicles were identified as enemy on slightly less than 7% of the trials. Thus, there tends to be a bias toward making a friendly identification.

Table 2 shows the mean reaction time for the correct responses in parenthesis. In general, these RTs are correlated with proportion of correct responses (Rho = .60). Two notable exceptions are the T10 and T55. The T10 was ranked second in proportion correct, but it had a long RT. On the other hand, the T55 was ranked seventh in proportion correct, but it had a short RT.

DISCUSSION

The results of the present experiment are consistent with findings reported by Sternberg (1975) in which item recognition using letters and digits was described by a serial exhaustive model of memory search. As in Sternberg's work, when RT is plotted as a function of the positive set size, a linear function results. The slope of the function is about .2 sec, indicating that this amount of time is required to compare the target stimulus (armored vehicle) to memory representations of the designated positive set targets. It was also found that the rate of increase is the same for both positive and negative responses. That is, when a target stimulus is presented from the negative set, the comparison process takes place at the same rate as for positive responses resulting in parallel functions. This supports an exhaustive search model. If the search were self-terminating, i.e., stopping if a match is found, one would expect the positive response slope to be half that of the negative response function. It is interesting to compare the slopes found in the present study to those found by Sternberg. In the typical study using letter digits, the slopes ranged from 35 to 40 msec,

Table 2

Confusion Matrix for Vehicle Identification

	Response							
Stimulus	M60A1	M60	M48	M103	PT76	T62	T55	T10
M60A1	.63 (2.06)	.09	.10	.15		.03		
M60	.03	.81 (2.12)	.10	.01	.01	.01	.03	
M48	.01	.22	.69 (2.99)	.03			.06	
M103	.12	.20	.01	.53 (3.68)	.01		.13	
PT76	.01	.01			.98 (1.17)			
T62	.01	.01		.01		.86 (1.87)	.09	.02
T55	.10	.27	.01				.61 (1.46)	
T10	.02	.01	.01	.03	.01		.03	.90 (2.92)

Note. Reaction times are noted in parenthesis for the correct response diagonal.

whereas in the present study the slope was about 200 msec. Thus the comparison process is much slower per item with complex stimuli such as armored vehicles.

It is also interesting to note that the Y intercept was about 1.4 sec in the present study and averaged around 400 msec in Sternberg's work. This time represents processing other than the serial comparison during memory scanning. Part of this time is surely represented simply in the motor components of making the RT response. More important is the fact that the Y intercept reflects differences in stimulus variables that degrade the stimulus. In Figure 3, the effect of the forest background is reflected in the Y intercept but not in the scan rate, since the functions are parallel. This situation is comparable to Sternberg's (1967) degraded stimulus condition, in which it was hypothesized that a stimulus encoding or cleanup phase precedes the scanning stage. During this phase a clear image of the stimulus is formed, and then the serial exhaustive scan proceeds. In the present experiment, approximately 200 msec were needed to clean up the forest. The cleanup completed, the scan took place at the same rate as if a plain background were present. The results of the target on a clear road were comparable to those on a plain background.

Comparable analysis can be made for the downlook angle results shown in Figure 4, although the results are not as clear-cut. It was expected that the 10-deg downlook angle would result in the fastest RTs since the original training stimuli were 0 deg. Thus, from results on mental rotation of visual objects (e.g., Cooper & Shepard, 1973), one would expect that prior to the memory scan the target would be rotated to match the most familiar angle, 0-deg side as in the training stimuli, and then the scan would proceed. The results for the 20- and 30-deg targets are consistent with this interpretation. These two functions are parallel and suggest that about .1 sec is needed for this mental rotation. However, the 10-deg targets required the largest RTs. Since the interaction was not significant, it could also be that the higher lookdown angles provide a better target for identification regardless of the orientation of the training stimuli. Some observers indicated that the higher angles were easier to work with. These lookdown angles do provide more of the target total area to work with.

The response level data were plagued by large between-subjects variability and did not yield statistically reliable results; however, certain interesting trends are evident. It takes about .5 sec longer to make an identification as opposed to a recognition response, with the recognition response only .1 sec slower than the positive-negative set response. From a practical aspect, it is important to have this information on how long it takes to identify as opposed to making only a friend-enemy decision. The information is also important from a theoretical viewpoint because it suggests that the processing proceeds from general to specific. It was certainly an alternative that identification of the vehicle was necessary before the friend-enemy determination could be made. Another important aspect of this data is that the slopes of the functions shown in Figure 5 are different for each response level as a function of positive set size. Thus, the response level directly affects the scanning rate and is not an additive factor affecting only the Y intercept.

The error rate was much higher than desired. Ideally, the serial exhaustive model assumes error-free performance, and empirical tests normally do not show error rates greater than 5%. It is hoped this error rate will be corrected in future work by increasing the amount of training to insure better performance prior to beginning experimental trials. It would also be of interest to manipulate accuracy by instruction, emphasizing either speed or accuracy. This would approximate the target acquisition tasks under more stressful conditions.

The pattern of results for each target stimulus also provides useful information as to the discriminability of the vehicles. Inferences can be drawn concerning the relevant cues. For example, the results suggest that the turret shape may be the confusion point between the T55 and M60. This is borne out by the pattern of results in that T55 was often identified as the M60, but infrequently as the M60A1. Since the chassis on the M60 and M60A1 are nearly identical, the turret is the likely cue. In future work, the M48, M103, and M60 will be replaced with more current NATO vehicles.

CONCLUSIONS

The present study demonstrates that the CRT paradigm is a useful tool for the study of the target acquisition process. It provides information on the effects of various target acquisition parameters that can provide input to several related programs. For example, training in target identification is an important activity. Many of the studies on training effectiveness are mainly concerned with pre-post measures of training effectiveness (e.g., Cockrell, 1979; Warnick & Kubala, 1979). Reaction time data can provide information pertaining to emphasis to be given in training programs and to effects of different variables on the speed and accuracy of identification responses. The area of camouflage and vehicle conspicuity is another important topic of study (Warnick, Chastain, & Ton, 1979) which is directly addressable by methods used in the present research. Finally, the present approach provides information on the basic processes underlying the human observer's cognitive processes during target acquisition. Understanding the observer's cognitive processes will lead to the most fruitful applications of the target acquisition data base.

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