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A FIELD SURVEY OF AIR-TO-GROUND TARGET-DETECTION PROBLEMS

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HUMAN ENGINEERING LABORATORIES

ABERDEEN PROVING GROUND,
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ABSTRACT

Twenty enlisted men were tested on a target-detection task at Ford Ord, California. Each subject was required to detect ten targets appearing at ranges of 1000 meters to 2100 meters. Forty trials were run. The results indicate that detection and identification depend on more than mere distance between target and observer. Not only did a target's size and form affect its detectability, but it appeared that the main cause of misidentifications was differing targets with similar sizes and forms. These results are related to current literature, and their implications for the course of the program are examined.

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A FIELD SURVEY OF AIR-TO-GROUND TARGET-DETECTION PROBLEMS

INTRODUCTION

The U. S. Army Human Engineering Laboratories Aircraft Weaponization program deals primarily with air-to-ground target detection and identification and its associated visibility problems. The current concept of armed helicopter engagement of enemy ground forces and tactical ground support emphasizes the need for quantitative information about air-to-ground target detection and identification. Perhaps the more important of these categories is identification: it is useless to merely detect, if the observer cannot distinguish targets or identify them as friendly or hostile. Furthermore, choosing optimum weapons or weapon systems, tactical and pilot aids depends on knowing such things as the most probable range for target identification or the probability of identification at a given range.

The problem of target detection/identification is not a simple one and is governed by such variables as are listed in Table 1.

There are difficulties associated with problems in the area of target-detection, as Gordon (4) has discussed: "Detection in a military field situation implies a type of identification, i.e., that the target is not a textural detail of ground or foliage, sea or sky, but something man-made and not usually seen in that position." Field detection and identification distances will vary, depending on backgrounds, observers, atmospheric conditions, and observer information. Thus it can be very complex to apply classical predictive methods to practical detection problems. In addition, many of the relevant variables (Table 1) have not been quantified, and the manner in which other factors interact is not precisely known. It seems obvious from this statement and the variables presented in Table 1 that the problem of air-to-ground target detection cannot be investigated in a single study but must be examined in a systematic manner: first, by assessing the influence of single variables and, second, by determining the effects of the interactions between combinations of variables.

This investigation, conducted at Fort Ord, California, examined the target detection/identification complex in a dynamic situation as a guide for future efforts in this area. Although the data in this report are entirely descriptive in nature, they indicate areas that should be investigated in the future.

TABLE 1

Variables Influencing Air-to-Ground Target-Detection Research[a]

Areas	Variables
Target	Target Size Target Shape Target Luminance
Target/Ground	Target/Ground Contrast Clutter, Number of Objects Target Density
Environmental	Illumination Sun Angle Visibility Sky/Ground Ratio Terrain Vegetation
Aircraft	Attitude Range Speed Approach Angle
Observer	Visual Skills Training, Experience
Task	Search and Scan Techniques Knowledge of Target Location
Secondary	Apparent Target Motion Apparent Target Size Apparent Target/Ground Contrast Exposure Time

[a]Taken from Franklin (3).

METHOD

Subjects

The subjects (Ss) were 20 enlisted men of the 41st Infantry Brigade, Combat Development Command Experimentation Center, Fort Ord, California. All Ss possessed 20/20 vision. None of the Ss had any previous experience as observers.

Apparatus

The apparatus for this investigation consisted of two each of five target types:

a. Two M-60 tanks (Fig. 1)

b. Two M-109 self-propelled 105mm howitzers (Fig. 2)

c. Two 2-1/2-ton trucks (Fig. 3)

d. Two M-151 1/4-ton trucks (Fig. 4)

e. Two sets of two pup tents (Fig. 5)

In addition, a standard photographic light meter and a nautical astro-compass were used to measure ambient illumination and sun angle. Subjects' responses were recorded on prepared answer sheets.

The target-detection range was a relatively flat field approximately 2100 meters long by 300 meters wide. The field ran in an east-west direction; thus the sun travelled almost parallel to the length of the range. This orientation meant that the dominant shadows were always either in front of or behind the target.

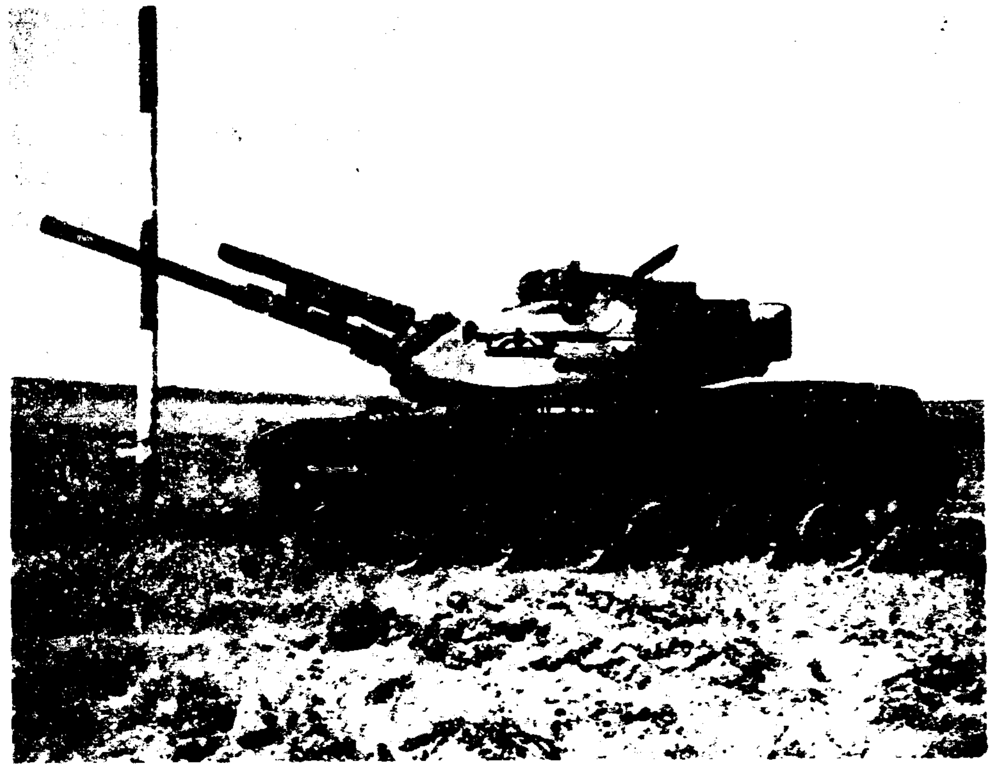

Fig. 1. M-60 TANK

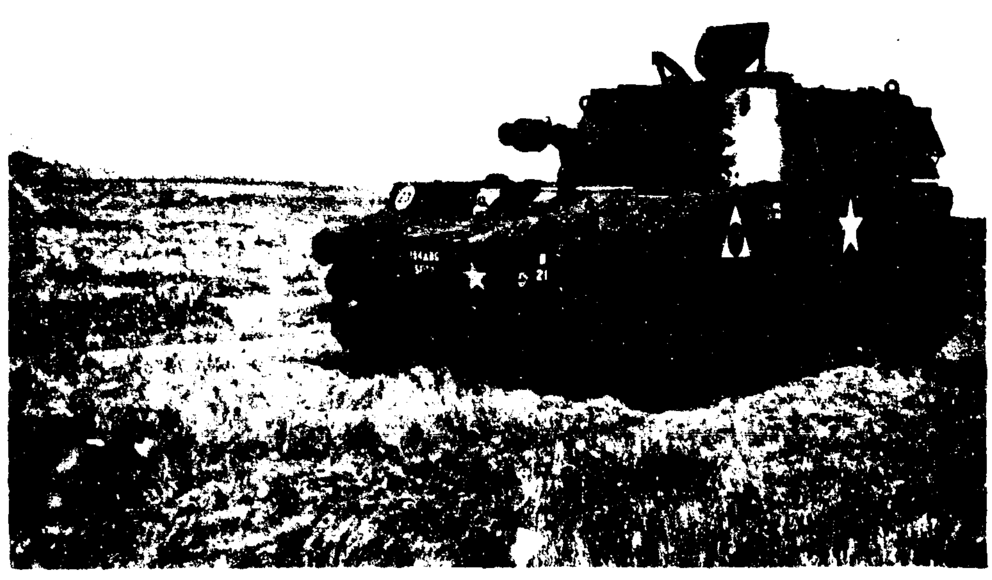

Fig. 2. M-109 SELF-PROPELLED 105mm HOWITZER

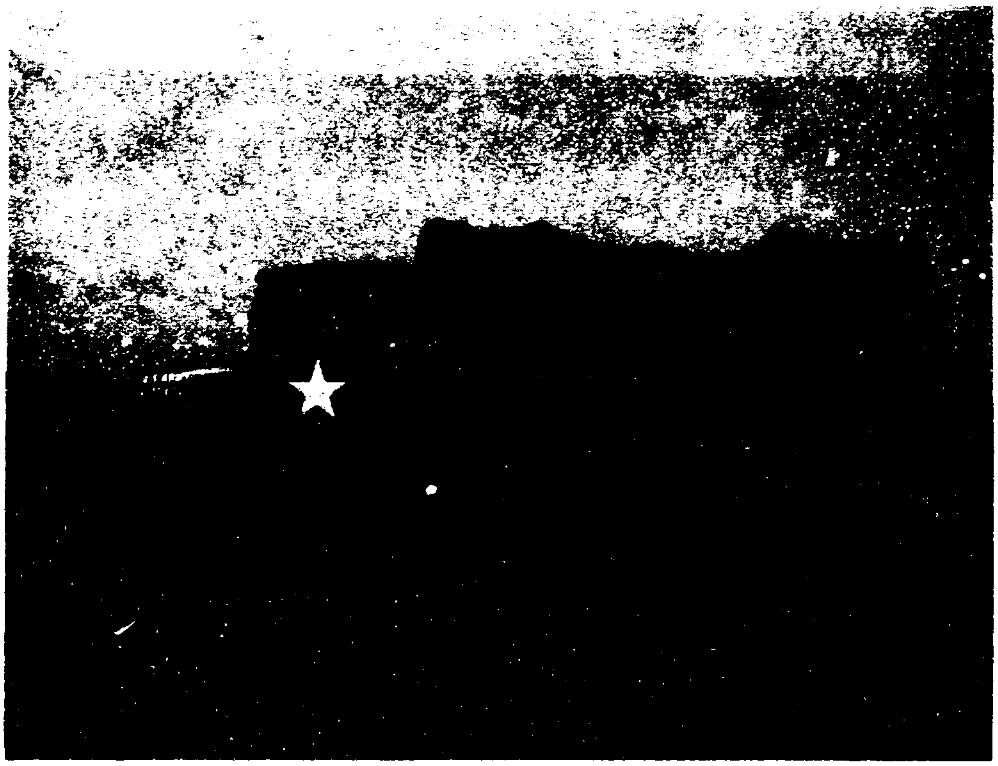

Fig. 3. 2-1/2-TON TRUCK

Fig. 4. M-151 1/4-TON TRUCK

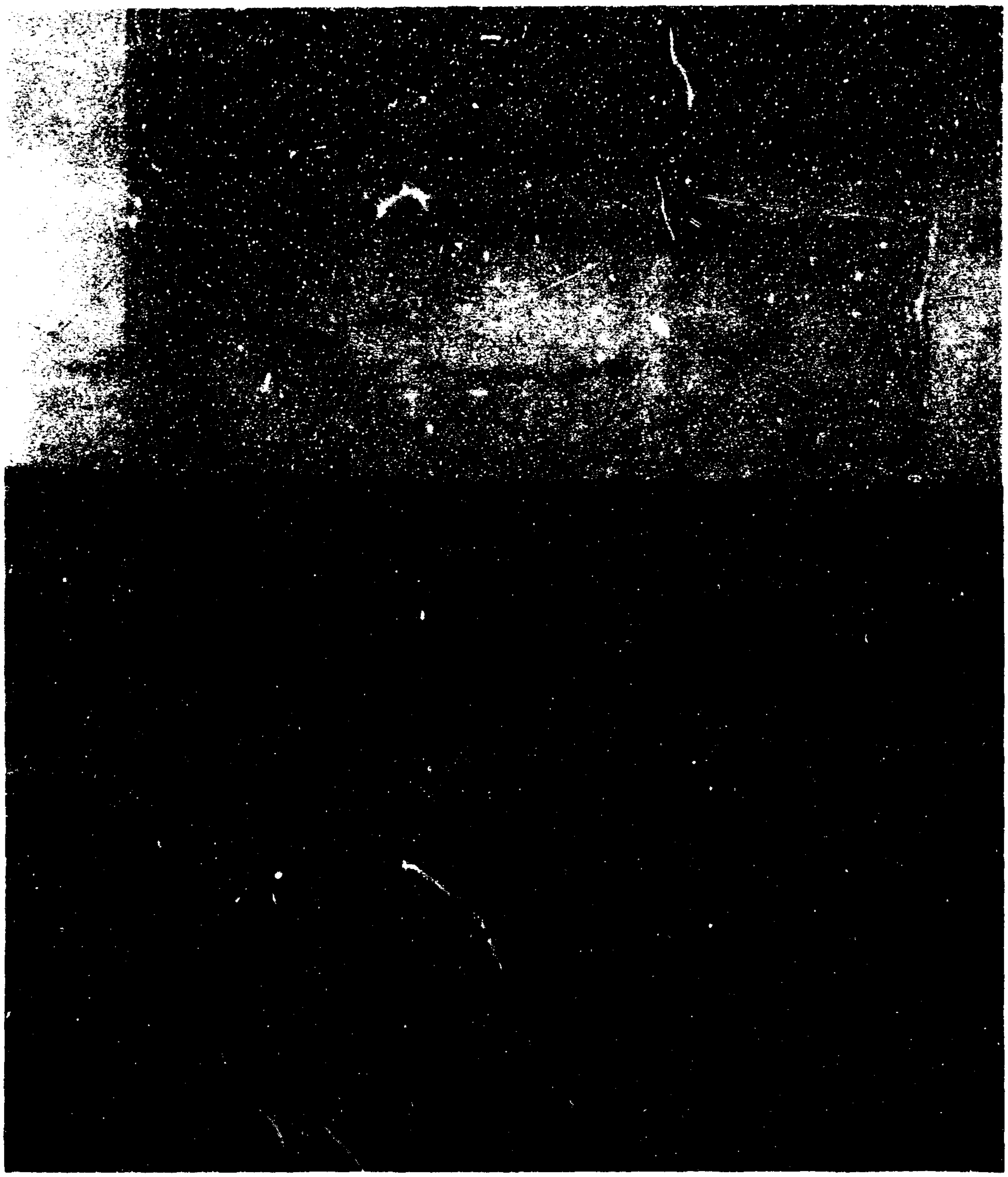

Fig. 5. PUP TENTS

Procedure

Before the study began, the target-detection range was surveyed and divided into a grid of 15 rectangles. Each rectangle was approximately 250 meters long by 100 meters wide. The grids or target-location points were numbered 1 to 15 from left to right and front to rear. The minimum range used was approximately 1000 meters from the observation point. Actual ranges of target locations are shown in Table 2.

The Observation Point was on the crest of a hill 2050 meters from the farthest target and in line with the center of the target area. This location gave an unobstructed view of the complete target-detection range.

Each of the ten targets was placed in one of the 15 target locations during each trial. After each trial, the targets were relocated and another trial was run until 40 trials had been completed. The order of target presentation, while basically random, was balanced so each target appeared at each range an equal number of times.

Before and after each trial, the sun angle was measured with the astro-compass, and ambient illumination was measured with the light meter. These readings were recorded on each S's answer sheet.

After all targets were positioned, the Ss looked into the field to detect and identify them. The Ss then placed X's on their data sheets to identify and locate each target in relation to prominent landmarks and other targets in the field. No range estimate was required. Each S had five minutes to do the task. Subjects were tested in groups of five.

The performance criterion was simply the number of correct identifications. A correct identification meant:

a. Locating the target correctly in relation to terrain features.

b. Locating it correctly in relation to other targets in the field.

c. Giving correct identifying information (i.e., Tank, M-60).

A response without any identifying information was considered incorrect. A response placed in the proper grid (as defined by the target order) but without correct identifying information was considered a misidentification.

Because of the experimenters' inability to control the appearance of the Ss in the field* and the short time period available after initial preparation of the test site, the experimental conditions could not be controlled as closely as planned. Therefore, the data have not been analyzed statistically. The results are given in tabular and graphic form, primarily to clarify the role of some variables that may affect target detection and to relate these results to findings in the current target-detection literature. The results are discussed further and related to points which will be emphasized in future experiments under this program.

TABLE 2

Distance and Elevation to Points from Observation Point

Point	Distance (meters)	Elevation	Difference in Elevation
1	1025.00	283.3	-16.7
2	1020.00	282.9	-17.1
3	1024.17	285.3	-14.7
4	1230.38	285.4	-14.6
5	1282.62	283.6	-16.4
6	1271.19	284.5	-15.5
7	1467.49	281.8	-18.2
8	1541.58	280.7	-19.3
9	1495.16	281.8	-18.2
10	1709.26	283.5	-16.5
11	1647.40	284.4	-15.6
12	1648.21	280.7	-19.3
13	1919.18	284.6	-15.4
14	2052.69	280.8	-19.2
15	2080.64	280.5	-19.5
Observation Point		300.0	

* Many of the Ss used in this study were on shipment orders and were subject to recall for processing at any time during the course of the experiment.

RESULTS

Table 3 summarizes the four-day investigation in terms of responses, detections, and identifications. Identifications are further subdivided into correct identifications and misidentifications. Responses refers to the actual number of targets each S reported, regardless of whether or not he was correct. Detections are the number of responses correctly located in the target grid, whether or not they were identified. Identifications mean detections that were labeled with any identifying names. Correct identifications are those detections labeled correctly, while misidentifications are those labeled incorrectly.

TABLE 3

Summary Table

	Responses	Detections	Identification	Correct Identification	Misidentification
	3877	3799	3471	2900	571
$\bar{x}^a$	96.92	94.97	86.77	72.50	14.55
N^b	40	40	40	40	40

[a]Mean number per trial.

[b]Total number of trials.

Table 4 summarizes inter-target confusion (the number of times a target was called by a name other than its own). Table 4 shows that the most readily confused targets were the M-60 tank and the M-109 self-propelled howitzer. The tank was identified as an M-109 149 times, while the M-109 was identified as a tank 105 times. To measure the extent of misidentification more precisely, these data were used to compute a "confusion factor." These factors, which are simply the percentages of misidentifications between any combination of two target types, are presented in Table 4.

TABLE 4

Inter-Target "Confusion Factors"

Target	Identification	Frequency	N[a]	Confusion Factor
M-60	M-109	149	1424	10.5
	M-151	18	1424	1.3
	2-1/2 ton	17	1424	1.2
	Pup Tent	0	1424	0.0
M-109	M-60	105	1424	7.4
	M-151	17	1424	1.2
	Truck	33	1424	2.3
	Pup Tent	0	1424	0.0
M-151	M-60	2	1424	0.1
	M-109	23	1424	1.6
	2-1/2 ton	16	1424	1.1
	Pup Tent	24	1424	1.7
2-1/2 ton	M-60	25	1424	1.8
	M-109	90	1424	6.3
	M-151	39	1424	2.7
	Pup Tent	0	1424	0.0

[a]Total number of presentations for target vehicle and response vehicle.

A second, and perhaps more valid, index of confusion is simply the percentage of times a single target was misidentified. This information, presented in Table 5, reveals that the greatest confusion centered around the three largest targets.

TABLE 5

Single-Target "Confusion Factors"

Target Type	N[a]	Misidentification	Confusion Factor (%)
M-60	1424	184	12.9
M-109	1424	155	10.8
2-1/2-ton Truck	1424	154	10.8
M-151	1424	65	4.6
Pup Tent	1424	5	0.3

[a]No. of observations.

For the purposes of this program, the most important information is how detection/identification probability depends on the target's distance from the observer. Classically, it might be expected that detection probability would be inversely related to range (i.e., at greater ranges, detection/identification probabilities would be lower). Thus a typical detection-by-range curve would be a negative, negatively accelerating curve, closely approximating a straight-line function. However, detection-by-range curves from this experiment's data (Figs. 6 - 11) deviate from this classical pattern. They are indeed negative and negatively accelerating to about the middle of the total range of the target-search area, but then the detection probabilities increase abruptly and resume a negative trend at points representing the outer ranges. The shape of these curves, then, suggests that factors other than just the distance between observer and target play an important part in air-to-ground target detection. Some factors which may contribute to these unexpected trends will be discussed later in this report.

Target orientation and time of day apparently had no effect on target detection as defined by this experiment.

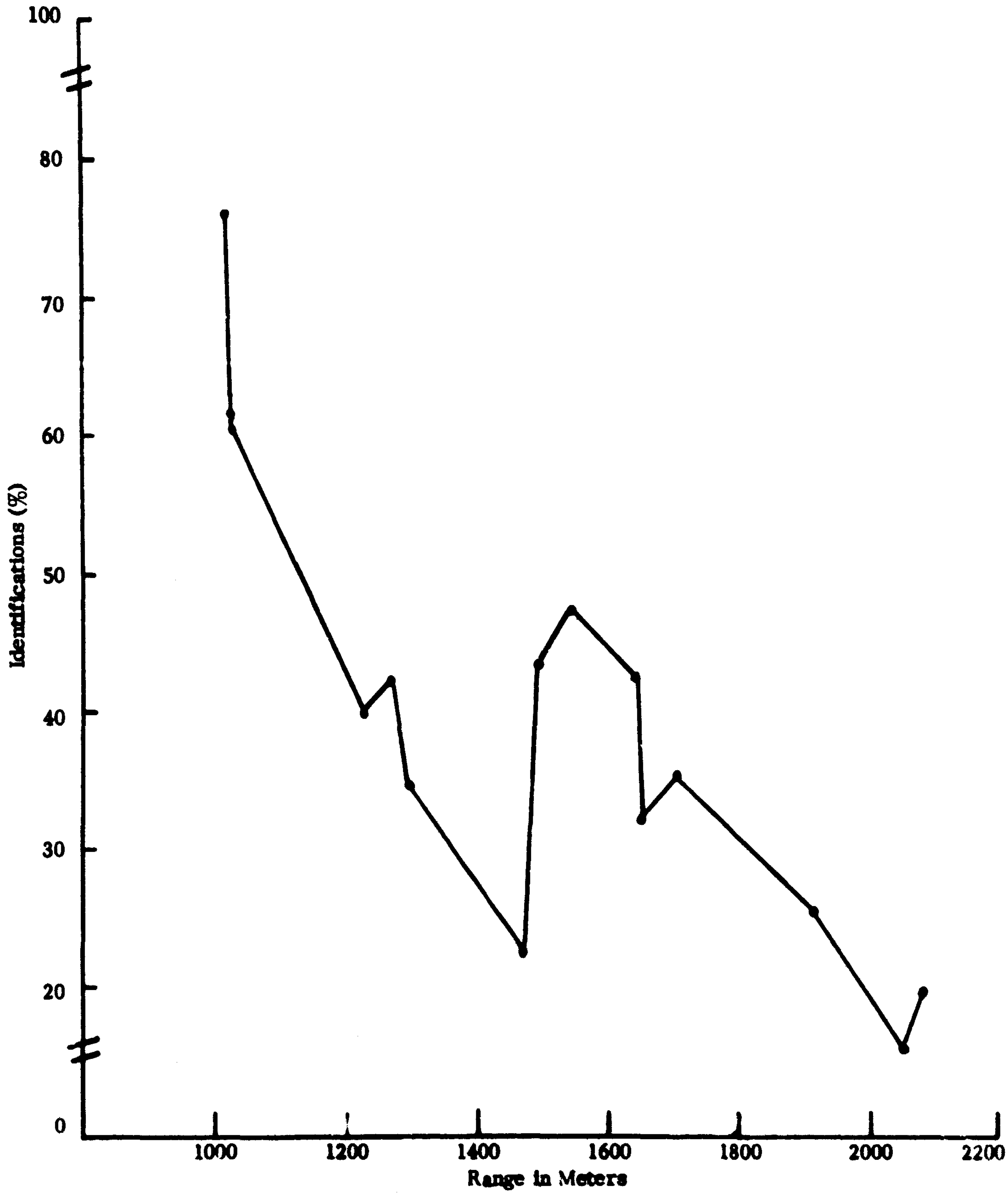

Fig. 6. PERCENT IDENTIFICATIONS (ALL TARGETS) x RANGE

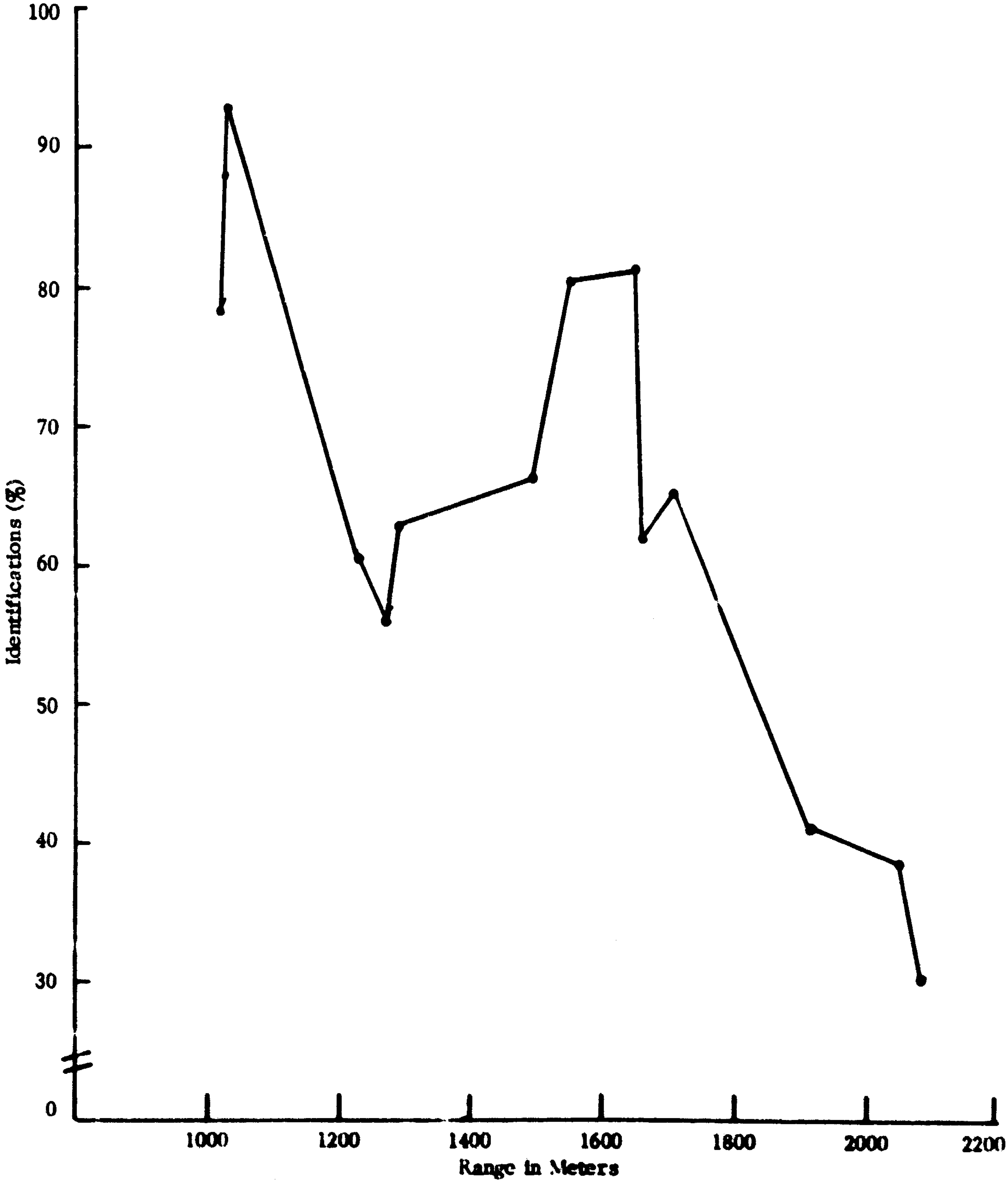

Fig. 7. TANK IDENTIFICATIONS x RANGE

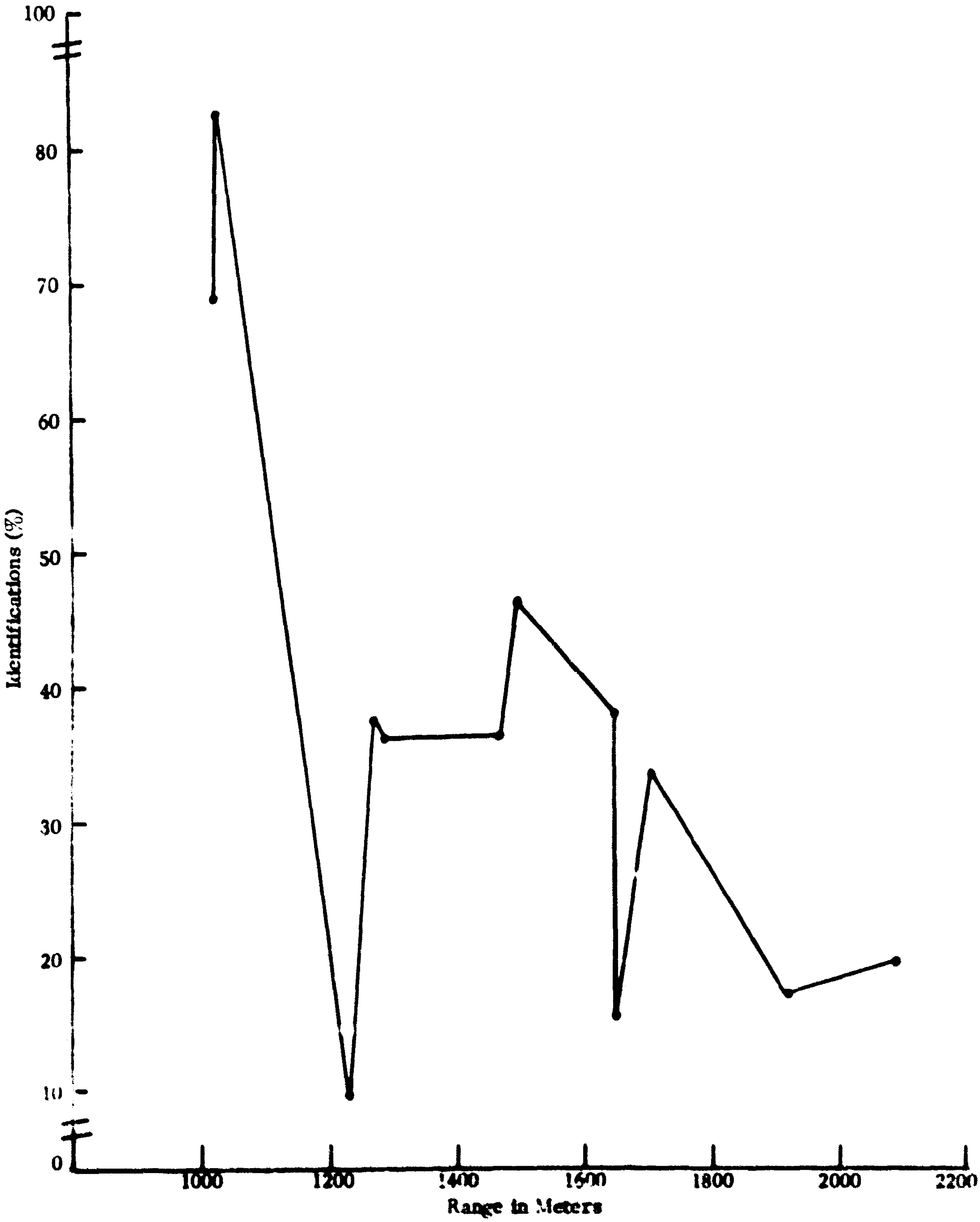

Fig. 8. M-109 IDENTIFICATIONS x RANGE

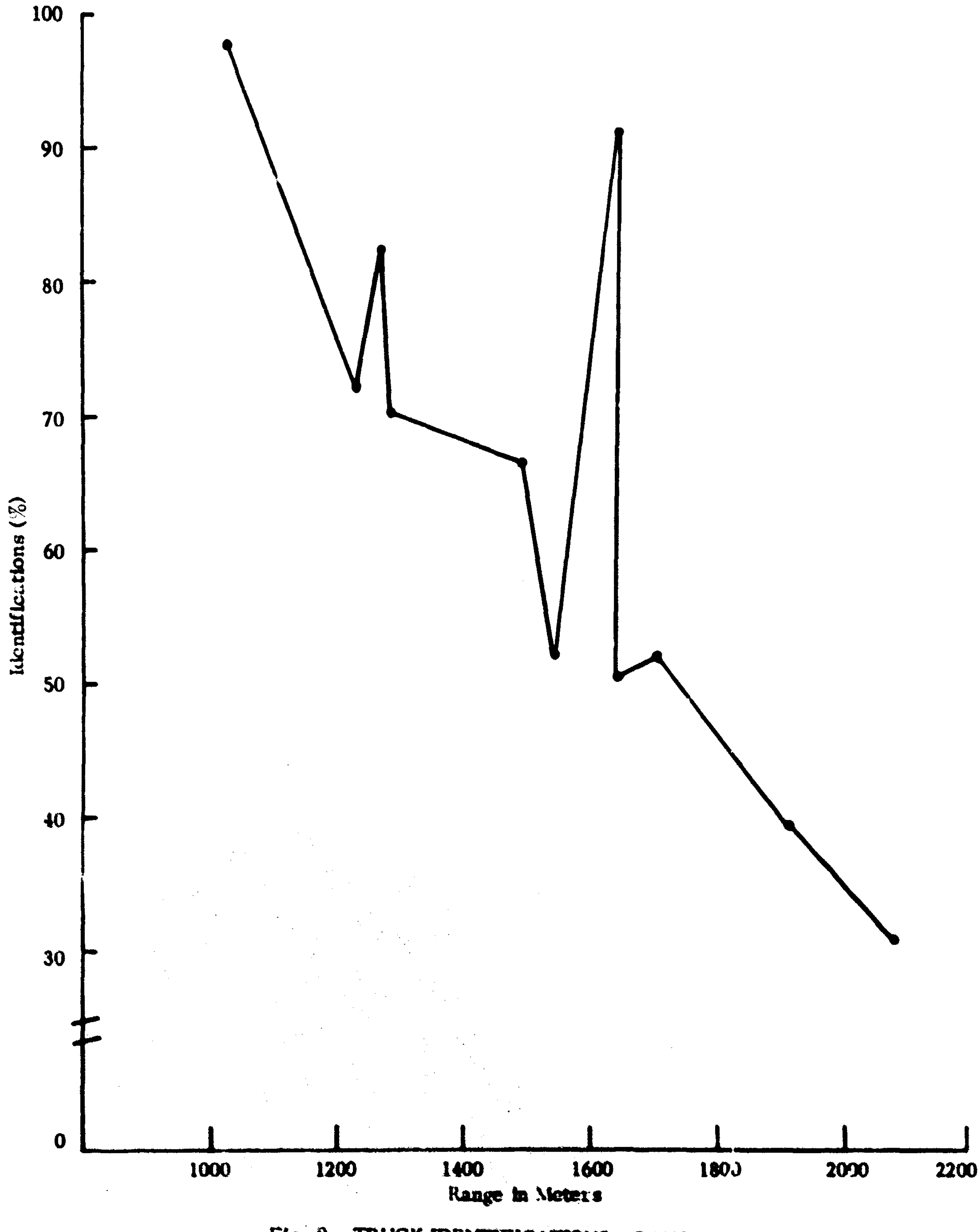

Fig. 9. TRUCK IDENTIFICATIONS x RANGE

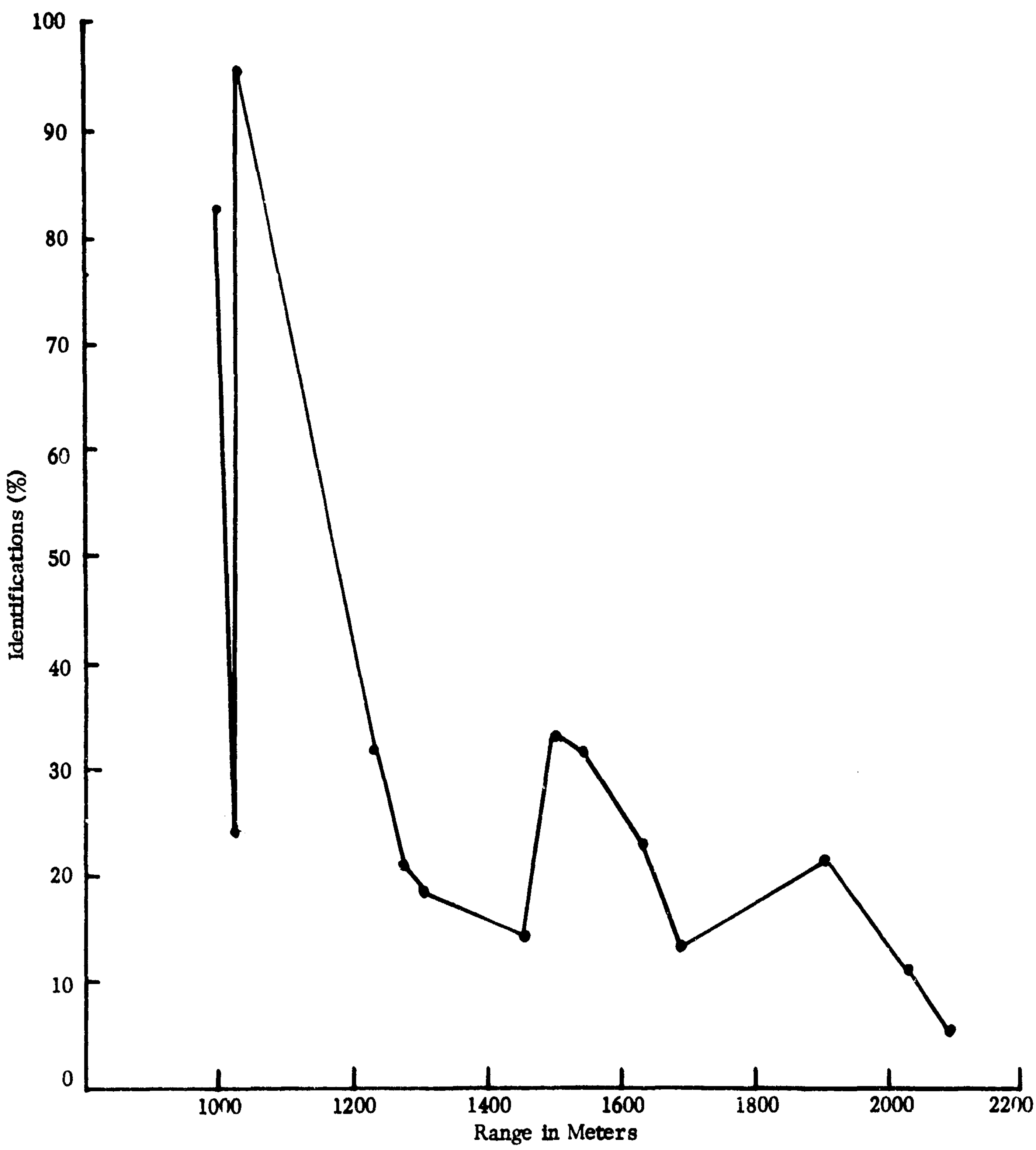

Fig. 10. JEEP IDENTIFICATIONS x RANGE

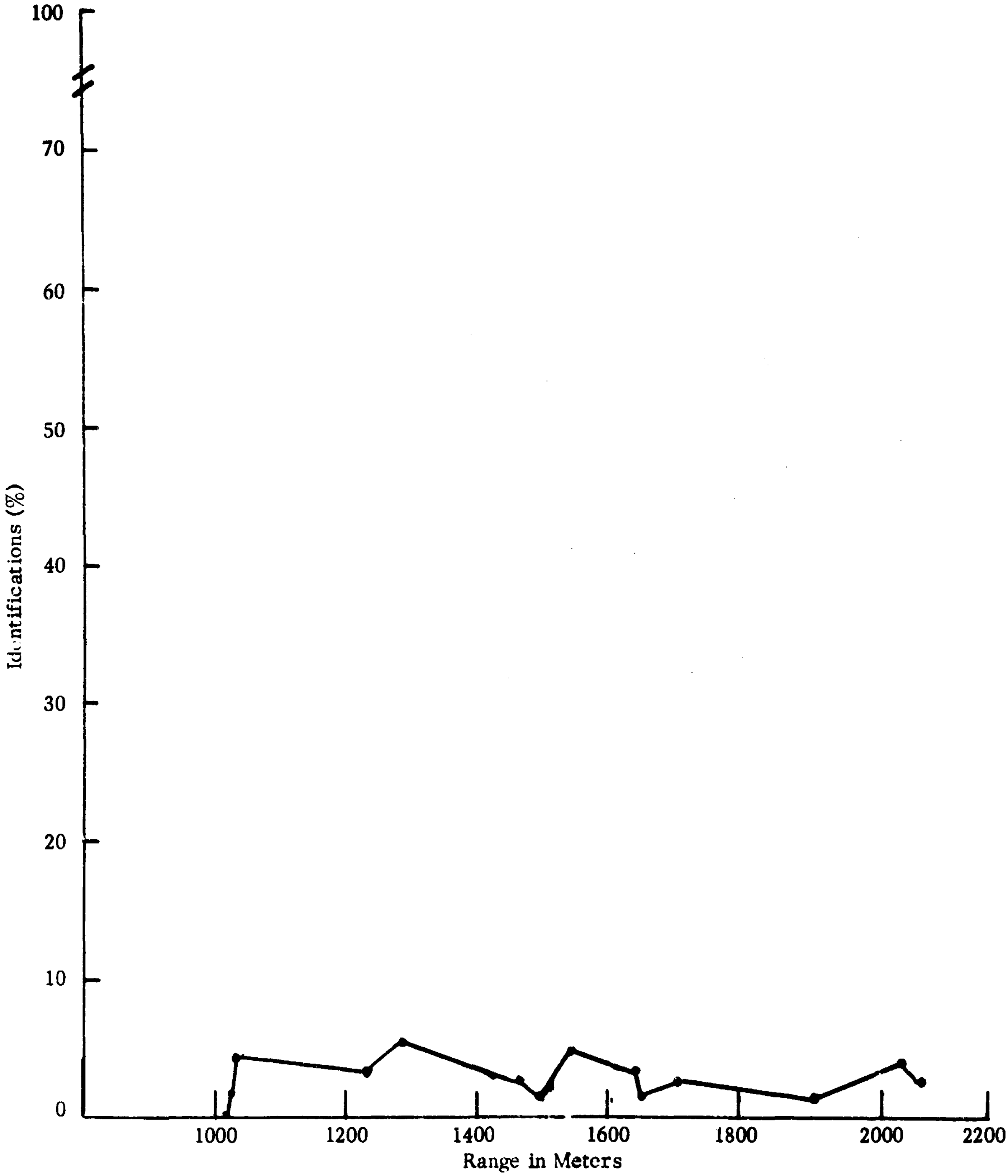

Fig. 11. PERSONNEL CONCENTRATION IDENTIFICATIONS x RANGE

DISCUSSION

Perhaps the most revealing bit of information to emerge from this investigation is the detection-by-range data. It is difficult to explain the increase in detection at the midranges. Obviously, some factors other than mere distance from the observer must influence target detection. While it appears that several variables might be involved, it will take further experimentation to discover which of them are critical.

It should be pointed out here that although the detection curves in the preceding section showed higher detection probabilities at the midranges than at the ranges just below them, the curves otherwise followed what might be considered a typical pattern. Excluding the midrange, detection/identification fell off as range (distance from the observer) increased for each target type used in this investigation.

One factor which might account for these differences between the curves presented here and the classic detection-by-range curve is point-to-point variations in target-background contrast ratios. We cannot state positively that there was a difference large enough to increase detections at certain ranges. Still, if there was a difference at these points, or at any other points in the visual field, the detection or identification probabilities for targets at these points might differ drastically from what they would be with lower target-background contrast ratios.

Second, the method of target presentation rigidly defined the search area and restricted the observer's scan pattern to an area bounded by prominent geographical features. Restricting the search area may have restricted the observers in some way so their scan patterns covered the target area's center more often than any other part of the area. Thus there might be a greater probability of detecting a target which is farther away, simply because the S scans that target area more often. This factor has been discussed in a recent report by Benfari and Ross (1), who stated that, for periods of limited exposure, "A general principle of scan behavior. . .confirms a conclusion that targets in the center of the field of vision are more easily identified than those on the periphery of the visual field." Further, Enoch (3), in a study of photointerpretation, has stated that observers do not devote an equal amount of time to all sections of a display; rather, their natural tendency is to spend most of the time on the center of the display, thus increasing the probability of detecting targets there. While this statement relates to an entirely different type of task than that reported here, the functional portions of both tasks are enough alike that Enoch's findings may well apply to these results and to the findings of Benfari and Ross. However, it is more important practically that similar results may indicate a high correlation between laboratory and field investigations in this one aspect of target detection. If so, laboratory investigations, which would allow control of the extraneous variables that undoubtedly influenced our results, should have a prominent position in the overall program.

It is interesting to note that, of the "confusion factors" reported, the three largest target types had two things in common: they were most likely to be confused and most likely to be detected. The second half of this statement is consistent with Whittenburg's statement in a recent report (3): that although size has not been systematically investigated in field studies, the results generally indicate that detection probability is highest for larger vehicles, such as tanks, and lowest for small targets, such as single infantry personnel. However, it does appear that target size and target shape may interact under some circumstances so that the largest target in an array may not always have the highest detection probability. This seems particularly likely since it is known that target shape may influence a target's detection probability (5). Studies of target shape indicate that the probability of detection decreases as the ratio of length to width increases (i.e., long, thin targets are less likely to be detected). Thus the largest target used in this investigation (tank) had a lower detection probability than the third largest target (truck) (Table 6). In addition, the tank was more readily identified as a different target type than the two other "large" targets (truck and M-109). Consistent with Whittenburg's statement, the tank also has the higher length-to-width ratio, which probably accounts for its lower detection probability and higher "confusion factor."

TABLE 6

Target-Type Identification Probabilities

	Target Type				
	Truck	Tank	M-109	Jeep	Pup Tent
Identification	931	921	567	432	49
% Identification	65.4	64.7	39.8	30.4	3.4
N[a]	1424	1424	1424	1424	1424
Rank	1	2	3	4	5

[a]No. of observations.

Finally, the observers' low altitude above ground level may have affected the results adversely; observers were never more than about 20 feet above ground level (Table 2). According to Whittenburg, other studies have found that observers at higher altitudes not only detect more targets but detect targets at greater ranges -- up to some optimal altitude, above which detection probabilities fall off rapidly. One explanation for this relationship is that altitude affects both the amount of ground the observer can see and the target's apparent size. At higher altitudes, the effects of terrain type and vegetative masking are less, so detection probability increases. At the same time, the target's apparent size gets smaller and, eventually reduces detection probability above a hypothetical optimum altitude. The altitudes used in this experiment were virtually at ground level, so any increase in altitude would almost certainly increase the detection probabilities.

The results of this study and the wide range of variables presented in Table 1 emphasize the need for a rigorous research program in air-to-ground target detection. This problem is further complicated by the fact that interactions between variables, as portrayed in the detection-by-range curves (Figs. 6 - 11), are generally more important than the individual variables themselves. Specifically, it is impossible to specify how any single variable will affect performance without knowing characteristics of several other variables.

Ideally, the effort could be accomplished by simply manipulating each variable in turn, in combination with all other relevant variables in a field setting. However, there are several problems which prohibit an approach of this nature. In general, these problems are: (a) high cost of field experimentation, (b) difficulty in procuring equipment and support personnel, (c) difficulty of controlling important variables such as sun angle, illumination, contrast ratios, etc., and (d) impossibility of controlling important variables like weather and lighting conditions. For these reasons, it appears that the most productive approach would be a balance between laboratory and field investigations. While many questions can be answered best in the field, just as many factors can be investigated more readily in the laboratory.

In short, laboratory experiments are recommended whenever feasible, so data can be collected more rapidly than field studies allow. This type of investigation permits the investigator to control the values of variables and measure their exact relationship to detection probability. Since the interactions between variables undoubtedly influence the task more than single variables, the control possible in the laboratory enables investigators to determine the influence of any combination of variables while controlling extraneous variables. The laboratory phase of the program, then, will lead to the formulation of lawful relationships between the variables influencing target detection and the task itself.

Field studies will serve two purposes. Primarily, they will be used to examine variables which cannot be manipulated efficiently in the laboratory. They will also be used to verify laboratory results, rather than to actually establish laws and relationships between variables.

SUMMARY

Twenty enlisted men stationed at Fort Ord, California, were tested on a target-detection/identification task. All Ss were naive and had 20/20 vision. Five target types were placed at random in a 300-meter by 2100-meter target area. Subjects were required to detect and identify each target by showing where it was in relation to prominent landmarks and other targets in the area. All targets were presented in each trial.

While the results of this study are suggestive, rather than conclusive, many of the findings parallel those of previous related investigations. These results are:

a. Both the target's size and its length-to-width ratio affect detection probability.

b. Detection probability depends on more than mere distance between the target and the observer.

Targets with similar sizes and forms invite misidentification. Confusion factors were computed for each target type, and the size of the confusion factors was directly related to the target's size.

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13. ABSTRACT

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