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Target Detection in the Field

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16. Abstracts

A factorial experiment was designed to determine (a) whether a negative exponential target detection model was adequate for describing the detection of moving human targets by stationary observers, and (b) whether the observer's detection behavior was affected by target speed, target-to-observer range, or the terrain in which the target appeared. Ninety Army enlisted men detected moving human targets in three different types of terrain. Analysis showed that the negative exponential model did not adequately describe the men's detection behavior, but that target speed, target-to-observer range, and the terrain in which the target appeared significantly affected their detection times.

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Prefatory Note

This paper was presented at the 79th annual meeting of the American Psychological Association in Washington, D.C., in September 1971 by Mr. Maxey. It was part of *Paper Session: Sensory Functions and Information Processing in Task Performance* in Division 19 of the APA. The research was performed as technical advisory service to the Department of the Army, at the Human Resources Research Organization Division No. 4, Fort Benning, Georgia, where Mr. Maxey is a Research Associate and Dr. Caviness is a Senior Scientist.

TARGET DETECTION IN THE FIELD

Jeffery L. Maxey and James A. Caviness

What are the significant variables that affect the detection of enemy targets by infantrymen? How do these variables differentially affect the detection of enemy targets? These questions form the core of an important military problem, that is, what factors determine the adequacy or inadequacy of the infantryman's detection performance in a battlefield situation?

Stollmack (1966) showed that the probability of the detection of moving tanks by stationary human observers may be described by the negative exponential distribution. Stollmack and Brown (1966) demonstrated that the probability model proposed by Stollmack (1966) was adequate for describing the detection of moving tanks in a field situation, and that the observer's detection rate was a function of (a) the rated complexity of the terrain in which the tank appeared, (b) the crossing velocity of the tank, and (c) the target-to-observer range.

The research reported here was designed to determine (a) whether Stollmack's detection model was adequate for describing the detection of moving human targets by human observers, and (b) whether the detection behavior of stationary observers searching for a moving human target was affected by the target's speed, the target-to-observer range, or the type of terrain in which the target appeared.

METHODS USED FOR EXPERIMENT

Experimental Design. The design of the experiment conformed to a 3 x 3 x 3 repeated measurements factorial with three levels of terrain complexity (low, medium, and high) as the between-subjects variable. The two within-subjects variables were the target-to-observer range (100, 200, and 300 meters), and the target's speed (walk, slow run, and fast run).

Army Subjects. The subjects were 90 male, junior enlisted men stationed at Fort Benning, Georgia. The men ranged in age from 17 through 26 years.

Human Targets. The human targets received training in moving at the three speeds required by the experimental design. Each target was dressed in camouflaged fatigues, and camouflage make-up was used to cover exposed skin.

Test Sites and Target Positions. Test Site No. 1, representing low terrain complexity, was lightly vegetated with a dearth of concealment, being covered with tall grasses and a few small pine trees. Test Site No. 2, representing medium terrain complexity, was heavily covered with tall grasses and was grown up with bushes and large pines. Test Site No. 3, representing high terrain complexity, had a plethora of concealment, being heavily overgrown with many large bushes and with pine and deciduous trees.

On each test site, the target search area was designated as a 30-degree sector of a circle with a radius of 300 meters. Within each search area, an observation point was established at the apex of the search area. Three lines of sight were laid out from the observation point as follows:

(1) To the center of the search area
(2) To a point 7.5° to the left of the center of the search area
(3) To a point 7.5° to the right of the center of the search area

Along each line of sight, three target positions were established at 100, 200, and 300 meters. From each target position on a given line of sight, a left and a right path were laid out perpendicular to the line of sight. These procedures resulted in 18 different target movement paths.

Procedure of Experiment. At the observation point, the experimenter indicated to the subject the limits of the search area and gave him a hand switch. The man was instructed to push the hand switch when he detected a target moving in the search area. Next, he was told to turn away from the search area. Concurrently, the experimenter informed the target controller that the subject was ready to detect a target. The target controller contacted the appropriate target and told him to leave his position at a particular speed moving in a particular direction. As the human target left his position, he closed a switch that activated a timer. As soon as the timer began operating, the experimenter told the subject to turn and face the search area and to begin searching for the target.

If the man detected the target and closed his switch (which turned off the timer), his detection time was recorded from the timer, and he was told to turn away from the search area. If the target reached the limits of the search area without being detected, the experimenter stopped the timer, informed the subject that the detection trial was completed, recorded a "no detection" for the man on that trial, and told him to turn away from the search area. After the man turned away from the search area, the target controller contacted the target and told him to move to his next target position for the next trial.

This procedure was repeated until each subject received nine detection opportunities. The first 30 men detected targets on Test Site No. 1; the next 30 detected targets on Test Site No. 2; and the remaining 30 detected targets on Test Site No. 3.

Each sequence of nine detection trials was set up so that each combination of target-to-observer range and target speed occurred once within the sequence. The order in which these combinations occurred within a sequence was varied randomly from subject to subject. For a given target-to-observer range, the particular position (center, 7.5° left of center, and 7.5° right of center) and the direction of movement the target took (either left or right) was varied systematically from trial to trial and from subject to subject.

RESULTS AND DISCUSSION

From the 27 experimental conditions, 24 detection time distributions were obtained. For the experimental conditions representing high terrain complexity and 300-meter target-to-observer range, none of the subjects was able to detect a target, so no detection time distributions were obtained for these three experimental conditions.

A chi-square goodness-of-fit test (Hays, 1963) was applied to each of the 24 detection time distributions to test the hypothesis that each set of detection time data represented a sample from a negative exponential distribution with parameter λ. The use of a powerful criterion of rejection, $\alpha = 0.10$ (i.e., $p < .10$), led to the rejection of the hypothesis of negative exponentiality in 22 of the 24 cases or 91.6% of the time. The use of a less powerful criterion of rejection, $\alpha = 0.01$ (i.e., $p < .01$), led to the rejection of the hypothesis of negative exponentiality in 13 of the 24 cases or 54.2% of the time. These results indicated that the probability of the detection of moving human targets by stationary human observers is not described by Stollmack's (1966) negative exponential model.

In order to determine whether terrain complexity, target-to-observer range, and target speed affected the time it took a man to detect a target, a repeated measurements analysis of variance that assumed a fixed effects model (Winer, 1962, pp. 319-337) was performed on the set of detection time data. For the cases where a subject did not make a detection, the total time the target was available for detection was entered into the set of detection times. Preliminary tests on the analysis of variance model showed that the complete repeated measurements model was appropriate and that the conservative *F* tests suggested by Greenhouse and Geisser (1959) should be used to determine the significance of each main effect and interaction. Application of the conservative *F* tests showed that all main effects and interactions were significant at the $p < 0.1$ level.

Terrain complexity and target-to-observer range were positively related to the time to detection, while target speed was negatively related to the time to detection, as shown in Table 1. The speed by complexity interaction indicated that target speed had its greatest effect on the detection of targets appearing in the highly vegetated terrain, and hardly any effect on the detection of targets appearing in the sparsely vegetated terrain.

Table 1

Detection Time Distributions for Each Major Experimental Condition

Experimental Condition	Detection Time Means	Standard Deviations
Terrain Complexity		
Low	2.82	5.18
Medium	7.52	10.81
High	13.80	18.74
Target-to-Observer Range		
100 meters	2.62	2.61
200 meters	3.93	4.65
300 meters	17.59	19.73
Target Speed		
Walk	12.97	19.44
Slow Run	7.51	10.65
Fast Run	3.66	4.96

The range by complexity interaction indicated that target-to-observer range had its greatest effect on the detection of the more distant targets appearing in the highly vegetated terrain, and less of an effect on the detection of the more distant targets in the sparsely vegetated terrain.

The range by speed interaction indicated that target speed had its greatest effect on the detection of the more distant targets and less of an effect on the detection of the near targets. However, the form the range by speed interaction took depended upon the terrain in which the target appeared.

These results indicate that whether a moving human target will be detected by a stationary observer depends upon the target's speed, its distance from the observer, and the complexity of the terrain in which the target appears. These results agree with common-sense observation that near, fast-moving targets are more likely to be noticed than distant, slow-moving targets. Future experimentation in this area should be oriented toward the study of the effects of visibility, contrast, and the more subtle parameters of human target detection in field situations.

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