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TRACKING WITH INTERMITTENT RADAR COVERAGE:

I. INTERRUPTIONS AFTER EACH COLLECTED FRAME OF IMAGERY*

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Abstract

Imagery simulating the output of a moving target indicator (MTI) radar was used in two experiments to determine the effect on the ability of radar operators to track targets moving in one particular area, when the radar was being switched intermittently to provide coverage of a second area as well. In both experiments, we investigated the effects of switching away from the area of interest after each complete scan of that area, varying the length of each interruption that occurred before returning for another scan of the primary area. The frames of simulated MTI radar imagery used for each condition were shown in time compression to twelve operators in both experiments. The results of the two experiments seem to present a coherent picture. Increasing the length of the interruptions in coverage from 15 to 30 seconds had little effect on tracking performance. With interruptions of 45 to 90 seconds, performance was worse with smaller target units, containing ten vehicles, than it was for larger units. However, with interruptions of 120 seconds, there was a decrement for all target units, large and small, compared to the level of tracking performance achieved with shorter interruptions.

Introduction

In a previous study carried out as part of the Stand-Off Target Acquisition System (SOTAS) program, Bloomfield (1981) investigated the effects on detection performance of varyfng various display parameters. The imagery presented to the operators who took part in that study simulated the output of a moving target indicator (MTI) radar. The radar was assumed to be scanning the particular area of interest once every fifteen seconds, so that the data presented to the operators was updated four times a minute.

In a series of studies, the first of which is reported here, we explored the situation in which a similar MTI radar would be used to provide coverage of more than one area of interest. If the radar were to be switched after each individual scan, there would be an update on both areas of interest every thirty seconds, although the two updates would be phased fifteen seconds apart. If the radar were to be switched after two or more scans of either area, the update

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schedule would be more complex. In the two current experiments, we investigated the effects of switching away from the area of interest after each complete scan of that area. We varied the length of the interruptions that occurred before returning for another single scan of the primary area.

In both experiments, the imagery was presented in time compression. With this mode of presentation, first demonstrated by White (1956), several previously-obtained frames of radar imagery are collected and stored. Then, they are played back to the operator in the same order in which they were acquired, but at a faster rate. Returns from a particular moving target appear on the screen as a steadily moving dot.

Method

Imagery: The MTI radar imagery used in this study was devleoped and shown on the ground station simulator designed by Lorence, Kittleson, Ottoson, Baum, and Graffunder (1980). Basically this simulator consists of the hardware and software necessary for simulating a radar ground station, and of a set of computer models capable of simulating radar returns and of converting those returns into imagery.

The imagery used in this series of experiments was taken from a set of 27 specially produced master sequences of simulated MTI radar frames. Each master sequence consisted of 96 frames of imagery assumed to have been collected at fifteen-second intervals throughout a 24-minute period of time.

We wanted our experimental imagery to be representative of the kind of imagery that would be collected by an MTI radar in a realistic operational setting. At the same time, we needed to control the characteristics of the target and some nearby units. These goals were not completely compatible. However, by basing our new imagery on the Stand-Off Target Acquisition System Movement Scenario developed by Stephens, Dolby, Plocher and Little (1980), we were able to satisfy each of them to a large extent. This Scenario was derived from the U.S. Army's depiction of a potential attack on western Europe by Warsaw Pact force (see SCORES, Europe III). It provides a detailed account of expected enemy tactical movement over an eleven-hour period.

Three target areas were chosen from the Movement Scenario battlefield. Within each area, a highly-travelled route was identified. We determined which segments of those routes were masked from the radar, so we could select target paths that varied in the extent to which they were masked on all three routes.

A tracking task was used in the experiments. On each trial the operator was asked to track a designated target as it moved along its particular path. This was not easy, both because of the masking, and because of the presence of other simulated units moving in the vicinity. On each trial, there were four of these other, distractor units. They were of the same size, containing 10, 25, or 50 vehicles, were in the same single-column formations, and moved at the same speed, 10, 20, or 30 kph, as the target unit. In addition, the paths travelled by these units were selected in such a way that they would either intersect, or come close to, the path of the target unit at a point in the trial where it was passing through a masked area. Deliberately, these units were made difficult to distinguish from the target. Fewer cues were provided than might be expected in most operational situations. The operator had to rely on the coherence of motion, and direction of that motion, in deciding which of the units emerging from a masked area were the distracting units and which the designated target.

Design: The basic experimental design was a four-way analysis of variance factorial design. For both experiments, four interruption conditions were combined with the three target areas, three target unit sizes, and three target unit velocities to give 108 unique trials. All 108 trials were presented to each operator taking part in each experiment. The trials were presented in a different, random order to each operator.

The interruption conditions investigated in both experiments were obtained by omitting various frames from the 27 master sequences of imagery. These conditions are shown in Tables 1 and 2.

INTERRUPTION CONDITION	RATE OF UPDATE (SECONDS)	NUMBER OF FRAMES OMITTED	FRAME NUMBER																
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
A	15	0	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
B	30	1	X		X		X		X		X		X		X		X		X
C	60	3	X				X				X				X				X
D	120	7	X								X								X

Table 1. First Experiment: Interruptions of 0, 1, 3 or 7 Frames

INTERRUPTION CONDITION	RATE OF UPDATE (SECONDS)	NUMBER OF FRAMES OMITTED	FRAME NUMBER																
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
E	45	2	X			X			X			X			X			X	
F*	60	3	X				X				X				X				X
G	75	4	X					X					X					X	
H	90	5	X						X						X				

*Note: Condition F in this experiment is identical to Condition C in the first experiment

Table 2. Second Experiment: Interruptions of 2, 3, 4, or 5 Frames

The tables show the update rate for each condition, the number of consecutive frames omitted, and then the particular frames retained of the first 17 in the 96-frame master sequences.

Operators: The operators used in these experiments were selected from a pool of 21 veterans (10 ex-Army, 6 ex-Air Force, 3 ex-Navy, and 2 ex-Marine). They were selected because they closely match the population of Army radar operators. Twelve operators took part in the first experiment. For the second experiment, nine of the same twelve operators were used again, with three new people.

Procedure: At the start of each experimental session, the operator was seated in front of a video display terminal, while the experimenter read the instructions for the experiment and answered any questions the operator might have. At the beginning of each trial the initial frame of imagery was displayed and a cursor was centered on the lead vehicle of the target. The imagery was presented in time compression, at a rate of five frames per second. At the end of the trial, the last frame in the trial sequence remained on the screen, and the operator indicated where he or she thought the target unit had stopped by moving the cursor. Trials could not be repeated. The operator was not told whether the responses were correct or incorrect.

Results and Discussion

In both experiments, for each operator, there were nine trials with each combination of interruption condition and target unit size. These trials were the product of using three target areas with three target unit velocities. The results were averaged across the twelve operators taking part in each experiment.

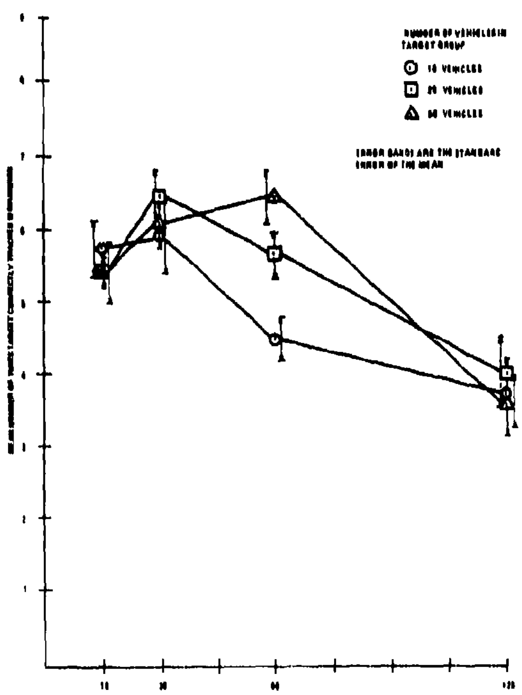

Figure 1. Tracking Performance as a Function of Duration of Interruption: Data Averaged Across Twelve Operators.

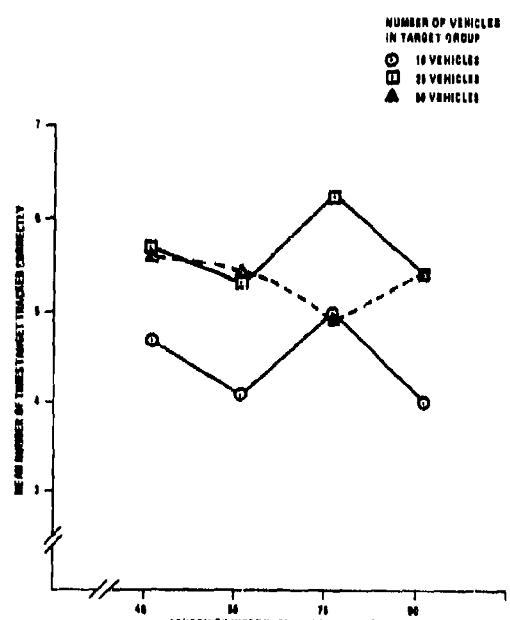

Figure 2. Tracking Performance as a Function of Interruption: Data Averaged Across Twelve Observers.

Figure 1 shows a plot of the mean number of successfully tracked targets as a function of the duration of the interruptions in the first experiment. When the duration changed from 15 to 30 seconds, there was little effect on tracking performance. With a 60-second interruption, performance deteriorated for the smaller, 10-vehicle target units, but not for the larger units, producing a statistically significant interaction between unit size and interruption duration at the $p < .05$ level. When the interruptions were as long as 120 seconds, there was a decrement for all target units, irrespective of size: the effect of interruption duration was significant at the $p < .0005$ level.

Figure 2 shows a similar plot for the second experiment. The interruption conditions investigated in this case did not significantly effect tracking performance, although the effect of target unit size was significant at the $p < .0005$ level.

The results of the two experiments seem to present a coherent picture. The first experiment showed there was little effect on tracking performance when the duration of the interruptions changed from 15 to 30 seconds. Then, for interruptions of 45 to 90 seconds, performance was worse with smaller target units, with 10 vehicles, than it was for the larger units (second experiment, confirmed in first experiment for the 60-second interruption condition). Finally, with an interruption of 120 seconds, there was no difference in tracking performance that was attributable to unit size, but, there was a decrement for all targets when compared with the performance level achieved with the shorter interruptions (first experiment).

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