TRACKING WITH INTERMITTENT RADAR COVERAGE

II: INTERRUPTIONS AFTER TWO OR MORE CONSECUTIVELY-COLLECTED FRAMES OF IMAGERY*

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Abstract

Simulated moving target indicator (MTI) radar imagery was used in
the two experiments performed in this, one of an on-going series of
studies in which we are investigating conditions of intermittent
radar coverage. In the first of these experiments there were two,
and in the second experiment there were two, three, or four conse-
cutively-collected frames of imagery before each interruption in
coverage. In both experiments there were twelve operators and the
imagery was presented in time compression. The results of the two
experiments showed that the use of more than one frame of imagery
before the occurrence of the interruptions in radar coverage resulted
in improved performance. For the larger, 25- and 50- vehicle units,
two consecutively-collected frames, and for the smaller 10- vehicle
units, four consecutivelycollected frames helped to prevent the
decrement in tracking performance that otherwise occurred with 120-
second interruptions.

Introduction

This is the second study in a series of investigations of the situation in
which a moving target indicator (MTI) radar is switched back-and-forth between two
areas, in order to provide coverage of both of them. In the first study, Bloomfield
and Little (1984) investigated the effects of switching away from one area after
each complete radar scan of that area and varying the length of the interruptions.
They found that there were decrements in the tracking performance of operators
with small, 10- vehicle target units with interruptions of 45 seconds or longer,
and with larger, 25-, or 50- vehicle units with interruptions of 120 seconds.
The two experiments reported here used imagery from the master sequences developed
by Bloomfield and Little, and were performed in order to determine whether
increasing the number of consecutively-collected frames before each interruption
would reduce or eliminate those decrements.

It should be noted that, the fact that there were interruptions in radar
coverage, did not mean that there were corresponding interruptions in the flow of
images being displayed to the operator. He or she did not see any blanks or
gaps. After selected frames were removed from the master sequences, in order to
produce the various experimental conditions, the remaining frames were shown in
time compression. With this mode of presentation, several frames of imagery
are collected then played back in the same order that they were acquired, but
at a faster rate. The result is that returns from a particular moving target
appear on an operator's display as a steadily moving dot. When only single
frames were retained before the interruptions, as was the case in both

experiments in Bloomfield and Little's study, the effect was to lengthen the update rate, reduce the number of images to be viewed and shorten the viewing time. In the two experiments reported here, another effect was possible. The use of or more consecutive frames before an interruption results in a variable update rate, as can be seen in Table 1, which shows the interruption conditions for the first experiment. It was possible that, when presented in time compression, imagery obtained with variable update rate would produce target movement that appeared to be spasmodic rather than smooth, and that target units might be harder to track.

FIRST EXPERIMENT: INTERRUPTIONS AFTER TWO CONSECUTIVELY-COLLECTED FRAMES

Method. The generation of the master sequences of simulated MTI imagery was described by Bloomfield and Little. We obtained our experimental conditions by omitting selected frames from these master sequences. The conditions are shown in Table 1.

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	18	19	20
A	15	0	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
B	15,30	1	X	X		X	X		X	X		X	X		X	X		X	X		X	X
C	15,60	3	X	X				X	X				X	X				X	X			
D	15,120	7	X	X								X	X								X	X

TABLE 1. Interruptions of 0, 1, 3, or 7 Frames Occurring After Each Pair of Consecutively-Collected Frames

The conditions used here were similar to those used in Bloomfield and Little's first experiment: the interruptions were of the same duration, but two frames were retained before each interruption, instead of one.

The imagery was shown in time compression, with a presentation rate of five frames per second. The experimental procedure was essentially the same as that described by Bloomfield and Little.

Twelve operators were used. Eight of them took part in both of Bloomfield and Little's experiments, three took part in their second experiment, and one was new.

Results. For each of the twelve operators, there were nine experimental trials for each combination of four interruption conditions and three target unit sizes. Figure 1 shows a plot of the average number of trials on which targets were successfully tracked, as a function of these combinations.

An analysis of variance performed on this data showed the interaction between the two main effects, interruption duration and target size, was significant at the $p < .0005$ level. The interaction can be seen in Figure 1. For the larger
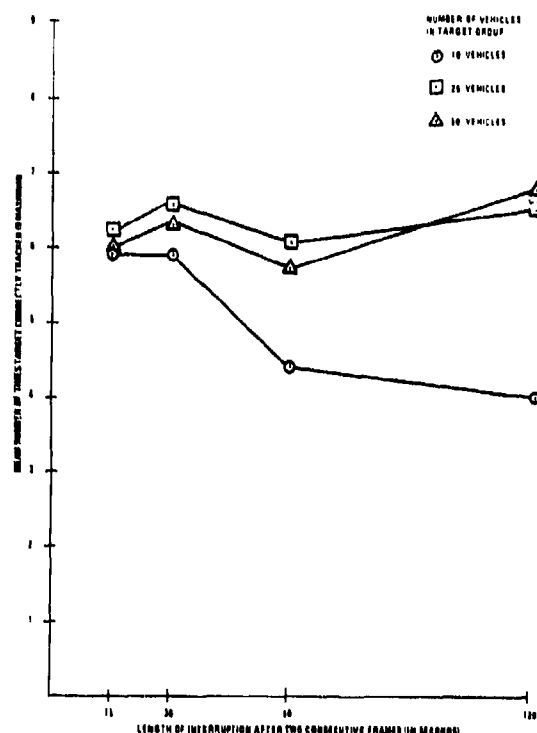
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Figure 1. Tracking Performance as a Function of
Duration of Interruption After Two
Consecutive Frames: Data Averaged
Across Twelve Operators.

units, with 25 or 50 vehicles, changes in the duration of the interruptions up to
120 seconds had no effect. On the other hand, for smaller, 10-vehicle units, a
decrement occurred with 60-and 120-second interruptions.

The fear that variable update rates might lead to displayed targets appearing
to move in a spasmodic fashion and, as a result, being harder to track, proved
to be unfounded, with the particular update rates used in this experiment.

When this experiment is compared with Bloomfield and Little's first experi-
ment, some interesting differences and similarities emerge. First, the differ-
ences: in the earlier experiment, there were decrements in performance for the
two larger target units for 120-second interruptions, while here, with two conse-
cutive frames retained before each interruption in coverage, those decrements
have disappeared. Next, the similarities: with the smaller, 10-vehicle target
units, tracking performance was significantly poorer with 60- and 120-second
interruptions, both when there was one, and when there were two frames of imagery
before each interruption. The addition of the second frame did not help. However,
it seemed possible that the addition of further frames, so there would be three or
four of them before each interruption, might be beneficial. The next experiment
explored this possibility.

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Method: Several changes in experimental design were made for this experiment. Two target unit sizes, the larger, with 50 vehicles, and the smaller, with 10, were used instead of three: the 25-vehicle units, which had produced tracking performance very like that obtained with the 50-vehicle units, were omitted. In addition, only two interruption durations were used: 30 and 120 seconds. There were, however, six interruption conditions. They are shown in Table 2

INTERRUPTION CONDITION	RATE OF UPDATE (SECONDS)	RATIO OF COLLECTED TO OMITTED FRAMES	FRAME NUMBER																								
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
A	30	1/1	X		X		X		X		X		X		X		X		X		X		X		X		X	
B	15,30	2/1	X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X
C	120	1/7	X								X								X								X	
D	15,120	2/7	X	X								X	X								X	X						
E	15,15,120	3/7	X	X	X								X	X	X								X	X	X			
F	15,15,15,120	4/7	X	X	X	X								X	X	X	X								X	X	X	X

Table 2: Interruptions of 1 or 7 Frames After 1, 2, 3, or 4 Consecutively - Collected Frames

It should be noted that conditions A and C were similar to two conditions (B and D) in Bloomfield and Little's first experiment. And conditions B and D were similar to conditions B and D in the first experiment reported here. Conditions E and F, with three and four consecutively-collected frames, had not been tested before.

The imagery was presented in time compression to twelve operators, ten of whom had taken part in earlier experiments in this series, and two of whom were new.

Results. While the duration of the interruptions and the number of consecutive frames were both varied, a full factorial experiment was not conducted. Hence, an overall analysis of the data was not justified. Instead the results were examined by means of several detailed, partial comaprisons. A series of t-tests were performed using Dunn's procedure to control error rate (Kirk, 1968).

Two comparisons of the effect of changing the duration of interruption were made. These involved comparing performance with 30- and 120- second interruptions and one and two consecutive frames. With one frame, the reductions in tracking performance from 30 (condition A) to 120 seconds (condition C) were not large enough to be statistically significant, as they were in Bloomfield and Little's first experiment.   It is possible that the higher-than-expected scores obtained here for these two 120-second interruption conditions may, in part, have been the result of practice. Ten of the twelve operators had taken part in one, or more, previous experiments in this series. Also, since the same basic imagery was used throughout the series, and, in addition, the particular characteristics of conditions A and C had been utilized before, it is possible that some learning

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could have occurred. Some support for this possibility is suggested by the fact that the two operators who had not taken part in any of the earlier experiments in the series did perform at a level comparable to Bloomfield and Little's operators.

With two consecutive frames, with the larger units there was no decrement in performance, while with the smaller, significantly fewer (at the $p < .01$ level) target units were tracked successfully with the 120-second interruption, confirming the results of the first experiment reported here.

Two comparisons of the effect of increasing the number of consecutively-collected frames of imagery were made: one with 30-second, the other with 120-second interruptions. As might be expected from a comparison of the first experiments in this report and in Bloomfield and Little's study, tracking performance is similar, whether there there are one or two consecutive frames, for both large and small target units, when there are 30-second interruptions in radar coverage.

With 120-second interruptions, the main point of interest was, whether the use of three or four consecutive frames of imagery before the interruptions, would lead to improvements with the smaller target units. When there were two or three consecutive frames, the mean number of 10- vehicle units successfully tracked was significantly smaller than the number of 50- vehicle units (at the $p < .05$ level). However, with four consecutive frames, the difference between the number of small and large target units successfully tracked was not significant. The use of four consecutive frames did result in improvements.

CONCLUSION

The presentation of two or more consecutive frames of imagery, instead of only one, before the occurrence of the interruptions in MTI radar coverage, resulted in improved tracking performance. With larger target units, containing 25 or 50 vehicles, there was no decrement in performance, when two consecutive frames of imagery were used with interruptions as long as 120 seconds (first experiment). For the smaller units, with 10 vehicles, the use of four consecutive frames of imagery reduced the decrement in performance, that otherwise occurred with a 120-second interruption (second experiment).

So far, this series of experiments has shown that, as far as tracking performance is concerned, there is no particular advantage in updating the MTI imagery more frequently than every 30 seconds. Further, if four consecutive frames can be acquired before the radar is switched to cover another area, interruptions of up to 120-seconds can be sustained without a statistically significant decrement in performance.

REFERENCES

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