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The Effect of Muzzle Flashes on Air-to-Ground Target Acquisition

by

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FOREWORD

This technical report documents work conducted from July to September 1974 at Wright-Patterson Air Force Base, Ohio and Naval Weapons Center, China Lake, California. The work is part of a joint services program on air-to-ground target acquisition funded under authorization ARAB RA 05 75. The effort was initiated at the Aerospace Medical Research Laboratory in response to Operations Evaluation Group Assistant Chief of Staff, Studies and Analysis (AF/SAV) Project Order SAV-74-002. MAJ R. Jensen served as the ordering component program monitor.

The Joint Technical Coordinating Group for Munitions Effectiveness has established a Target Acquisition Working Group (TAWG) under the Joint Munitions Effectiveness Manual/Air-to-Surface Division. TAWG tasks that have been completed include the definition of problem areas in both fast and slow airborne forward air controller operations, research on target acquisition by flarelight, summary of existing target acquisition field test data, and the evaluation of mathematical models of the visual target acquisition process. Work is continuing on the camouflage of targets, terrain and foliage masking, and math model evaluation and development. This study reports a laboratory experiment conducted to assess the effects of muzzle flashes on air-to-ground target acquisition.

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(U) Two laboratory experiments were conducted on a terrain model to evaluate the effect of muzzle flashes on visual, air-to-ground target acquisition. Observers were "flown" over the model at simulated altitudes of 1,000 and 3,000 ft and a velocity of 300 knots. They were required to search for single tanks or mobile air defense units. The guns on some of these vehicles were firing on half of the runs (simulated by flashing fiber optic extensions on the barrels—but no smoke).

(U) There was no significant difference between the number of targets detected from 1,000 ft altitude when they were flashing or when they were not flashing, the flash per se did not greatly improve target acquisition. Significantly more targets (flashing and non-flashing combined) were detected on the runs when some of the targets were flashing, however. Opposite results were obtained from the 3,000 ft altitude condition, significantly more targets were detected when they were flashing than when they were not flashing. There was no difference between total target detections (flashing and non-flashing) on runs when some targets were flashing versus when none flashed.

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INTRODUCTION

A joint-services Target Acquisition Working Group (TAWG) was established in March 1972 and tasked with pursuing a number of studies of visual, air-to-ground target acquisition. The work has included mathematical modeling, laboratory simulations, analysis, data summary, and field testing.

A question arising in many of these areas has to do with the target signatures and associated cues that help or hinder visual acquisition. Questions have been asked concerning the effects of smoke, target motion, dust, and muzzle flashes. Almost none of the field tests that have been conducted included these factors in a controlled way, if at all. The appropriateness of using simulator as well as field test data in predicting acquisition performance in a mid-intensity scenario can be questioned because these factors have not been included.

This report describes two laboratory experiments that were conducted to provide data on one of these factors: muzzle flash. One of the questions that has been posed by operations analysts is, does the firing of the guns affect the detection and recognition of the firing vehicle? The experiments described here are intended to provide a preliminary answer to this question.

METHOD

Small vehicle targets were located on a model of terrain similar to that found in central Europe. The terrain was predominantly green in color and contained trees, hedgerows, buildings, a road and bridge, and a small airstrip.

The targets were tanks and mobile air defense units (ADU's) equipped with fiber optic extensions on the guns so that muzzle flashes could be simulated. The main independent variable was the presence or absence of simulated gunfire; it was hypothesized that the simulated muzzle flash would provide additional visual cues and thereby enhance target acquisition performance.

Observers were "flown" over the terrain model in a transport mechanism and required to search for the targets. They reported sightings by calling out the type of vehicle. The reports were used to calculate percent targets detected and recognized, and the time of the report was used to calculate the range to the target.

DESIGN

The two experiments were identical except for one factor: observer altitude was a simulated 1,000 feet in the first, and a simulated 3,000 feet in the second. The design, apparatus, procedure, and scoring were the same in both experiments.

Each experiment used two groups of ten subjects. None of the targets was flashing during the "flight" for one group of subjects. Four of the eight targets (2 tanks and 2 ADU's) were flashing (simulating firing) during the flight of the second group. This design resulted in two independent groups of subjects whose performance data were suitable for testing for statistical significance with the Student's *t* distribution.

The four targets which had a capability to simulate firing by flashing were also used in a non-flashing mode (with the first group of subjects). Hence, there was both a flashing and non-flashing mode, and flashing and non-flashing targets.

The dependent variables were number of target detections, number of correct target recognitions, and response time for each response. Slant ranges were calculated from the latter measure.

SUBJECTS

Four groups of ten subjects each participated in the study (two groups for each experiment). All subjects were male and were college students, active military, or contractor personnel. All had corrected or uncorrected far, binocular visual acuity of 20/20 or better.

APPARATUS

Terrain Model

The 1:200 scale terrain model used as the background over which the subjects searched for the targets was 28 x 8 feet and simulated a mile long strip of land about a quarter of a mile wide (Figure 1). The model contains various topographical and cultural features typical of Central Europe.

Targets

The targets were 1:200 scale model tanks and ADU's, representing real-world military targets measuring approximately 21 feet in length. Two of the tanks and the two ADU's were modified to enable their gun barrels to simulate a muzzle flash. This was accomplished by threading fiber optics into the gun barrel and down to the body of the vehicle where a 15-volt miniature lamp was installed. To simulate the appropriate gun firing rate, the lamps were pulsed by two Hunter timers (Series D, Model III-C), wired to cycle continuously. Two timers were used for each firing target. The fidelity of simulation of the firing rate is considered high while the simulated intensity of the muzzle flashes could be somewhat questionable due to the lack of complete real-world data to use as a guide in constructing the models.

For this experiment, the luminance contrast for a single target element was defined as:

$$C = (L_t - L_b) / L_b$$

where: C = luminance contrast between a single target and background

L_t = average luminance over a single target area

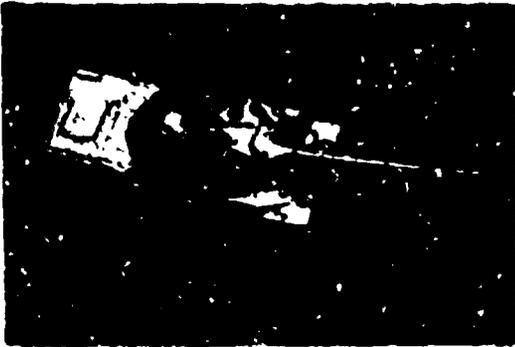
L_b = average luminance over a single target background area taken to be 10 times the target area. The target shadow was excluded.

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Figure 1. Terrain Model With Target Locations Shown

A Pritchard Model 1980 photometer was employed for the luminance measurements. Five measurements were taken of each target and its respective background in the non-flashing modes. Examples of the targets are shown in Figure 2 and a description is given in Table 1; notation corresponds to that shown in Figure 1.



TANK



ADU

Figure 2. The Two Model Targets Used in the Target Acquisition Tests.

Subject Transport Mechanism

The subject was seated on a motorized, remotely-controlled bridge and carriage system suspended over the terrain model. The bridge and carriage was capable of movement along the longitudinal axis of the terrain model. The subject's seat was positioned on the assembly so the eye level of the average subject was maintained at about either five or fifteen feet above the mean level of the terrain model. This corresponded to simulated altitudes of 1,000 and 3,000 feet. The simulated velocity was 300 knots.

PROCEDURE

Initially, the subject was taken to a room with a small terrain model for orientation and training. He was shown the actual sizes of the tanks and ADU's for which he would be searching during the experimental session. The firing modes for the guns of the tanks and ADU's were also demonstrated. The subject was then given instructions on how to respond if he detected a target. Each subject was told to search only for tanks and ADU's and that none, some, or all of the targets might be in their firing modes.

Table 1. Target Description.

Target*	Mode**	Ground Range (Feet)	Luminance Contrast	Remarks
T ₀	non-flashing	1,000	-0.20	At intersection of two tree-lined roads
T ₁	non-flashing	2,000	0.34	On a tree-lined road
T ₂	non-flashing	2,000	0.39	On a tree-lined road
T ₃	non-flashing	3,000	-0.10	In a clearing next to a primitive runway
T ₄	flashing	3,900	-0.34	In a clearing circled by trees
T ₅	flashing	4,000	-0.04	On the top of a hill
Q ₁	flashing	4,000	-0.10	On top of a small knoll near terrain model edge
Q ₂	flashing	4,500	-0.01	On top of a hill with sparse vegetation

*T indicates tanks; Q indicates ADU's (or Quads).

**Flashing (simulated firing) targets were also used in a non-flashing mode.

Each subject was given only one pass over the terrain model. The time for each pass was just under 11 seconds, the time required to simulate the 300-knot airspeed. Upon completion of the pass, the subject was debriefed and target detections and recognitions were verified.

SCORING

A detection was defined as a subject's response to a target (by calling out the name "tank" or "ADU") regardless of what the target was. A recognition was defined as a correct call-out, so that detection and recognition occurred at the same time.

RESULTS

EXPERIMENT I (1,000 FT ALTITUDE)

Percent Detections and Recognitions

The percent of the time that the targets were detected and recognized is shown in Table 2 for each target. It can be seen that there is a large variability between targets: T_0 , T_2 , and T_4 were never seen, whereas Q_2 was always seen. The simulated muzzle flashes on 3 of the 4 targets did not make the targets more detectable. Although a "firing" Q_1 was seen more often than when it was not firing, the difference is not statistically significant.

Table 2. Percent Targets Detected and Recognized, 1,000 Feet Altitude

Target Number	Total Number of Possibilities	Percent Detected		Percent Recognized	
		Non-Flashing	Flashing	Non-Flashing	Flashing
T_0	20	0		0	
T_1	20	10		10	
T_2	20	0		0	
T_3	20	70		70	
T_4	10	0	0	0	0
T_5	10	40	40	40	40
Q_1	10	20	60	20	60
Q_2	10	100	100	60	80

A number of comparisons can be made at a lower level of detail among the targets using the Student's t test on the two groups of subjects. The target classification and number of detections made by all subjects are shown in Table 3.

Table 3. Classification of Targets and Number of Detections Made

Mode	Target Type	
	Non-flashing (T_0, T_1, T_2, T_3)	Flashing Capability (T_4, T_5, Q_1, Q_2)
No Targets Flashing	7	16
$T_4, T_5, Q_1,$ and Q_2 Flashing	9	20

It is seen that over twice as many of the targets which could flash were detected than non-flashing targets when none of the targets was flashing (16 vs 7). This difference is statistically significant ($t = 4.02, p < .01$); it suggests the possibility that the location of the flashing targets toward the end of the run (Figure 1) resulted in better performance.

About twice as many flashing targets were detected as non-flashing targets under the flashing condition also (20 vs 9). The fact that this ratio is the same as (and not greater than) that for the non-flashing condition indicates that the flashes per se did not aid in detection. Target characteristics or placement may have been more important factors.

Other t-tests showed that:

1. Non-flashing targets were not seen any more often under the flashing than the non-flashing condition.
2. Flashing targets were not seen any more often under the flashing than the non-flashing condition.
3. Performance across all targets was better under the flashing condition (29 vs 23 detections) as indicated by a one-tailed $t = 1.89, p < .05$. The latter result comes from summing the non-significant trends shown in Table 3 (9 higher than 7, 20 higher than 16).

Contrast

The absolute value of the luminance contrast of the targets (Table 1) is shown plotted against percent detection (Table 2) in Figure 3 for the non-flashing targets.

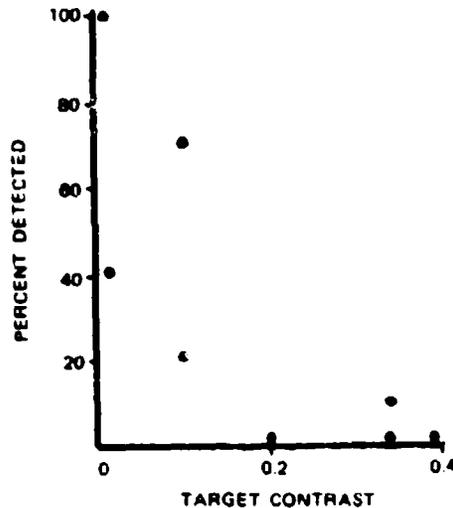


Figure 3. Target Contrast vs Percent Detections

It can be seen that there is an inverse relationship between the variables; the higher the contrast, the fewer targets detected. This unexpected relationship is statistically significant ($r = -0.78$; $p < .05$), and is contrary to all expectations. However, it supports the possibility that location and placement of the target were more important than luminance contrast in this search-for-targets-of-opportunity type of task.

In addition, another consideration often overlooked is the relationship between the color of a target and the color of its background discounting luminance contrast. An experiment concerned with examining the effects

of variations in color and brightness on acquisition performance indicated that the effects of color may have more impact than was traditionally thought.¹

An analysis of target Q₂ provides a good illustration that location and color contrast may be factors important in target acquisition. Q₂ was more consistently detected and recognized than any other target, regardless of its simulated firing mode. However, its luminance contrast with its background is the lowest of all the targets. On the other hand, it was located at the top of a hill towards the center plane of the terrain model with few clutter elements around it. Finally, it subjectively appeared to have good "color contrast" with its background: olive drab against light brown.

Detection Range

The range data calculated in this study is only approximate. The range was determined by recording the subject's response time when he stated that he detected or recognized a target. The slant range for this response time was then calculated by determining the position of the subject's head relative to the target. There was a subject response time lag and an experimenter's response lag plus the rounding off of the response times to the nearest second. This resulted in considerably less than precise data, and discrete steps in the data.

When the non-flashing ADU's (Q₁ and Q₂) were detected and/or recognized, it always occurred at the same approximate range (1,025 feet). This obviated the possibility of developing detection/recognition probabilities as a function of range for these targets in this mode. Figure 4 shows the cumulative percent detections as a function of range for the flashing ADU's and the non-flashing tanks. The cumulative percent of recognitions for these targets are effectively the same curves.

EXPERIMENT II (3,000 FT ALTITUDE)

Percent Detections and Recognitions

There was the same large variation among targets as seen in Experiment I: T₀, T₁, T₂, and T₄ were never seen, and a flashing Q₂ was seen by all subjects (Table 4).

¹Aerospace Medical Research Laboratory. *SEEKVAL Project IA1: Effects of Color and Brightness Contrast on Target Acquisition*, by Robert L. Hilgendorf and John Malenski, Wright-Patterson A. F. Base, Dayton, Ohio, AMRL, July 1974 (Report No. AMRL-TR-74-55, publication UNCLASSIFIED).

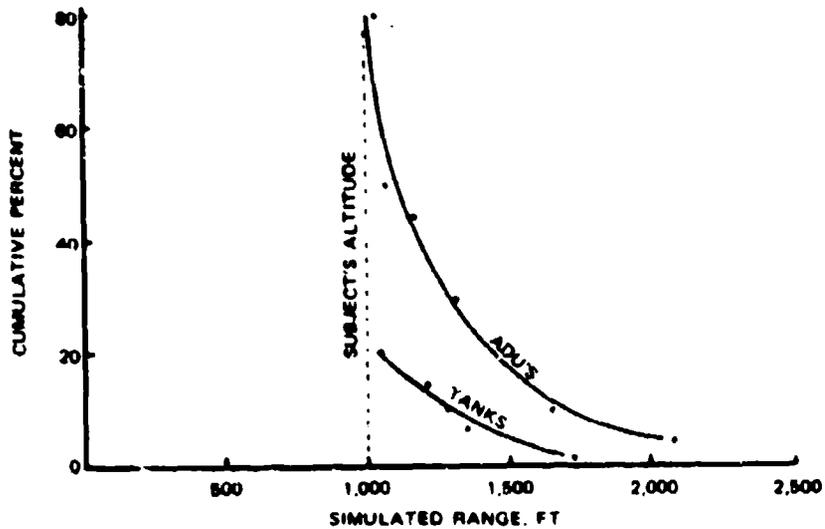


Figure 4. Cumulative Percent Detections and Recognitions for Flashing ADU's and Non-Flashing Tanks

Table 4. Percent Targets Detected and Recognized, 3,000 Feet Altitude

Target Number	Total Number of Possibilities	Percent Detected		Percent Recognized	
		Non Flashing	Flashing	Non-Flashing	Flashing
T ₀	20	0		0	
T ₁	20	0		0	
T ₂	20	0		0	
T ₃	20	25		25	
T ₄	10	0	0	0	0
T ₅	10	30	0	30	0
Q ₁	10	0	40	0	40
Q ₂	10	40	100	10	100

There was no statistically significant difference between the total number of targets detected or recognized under the flashing versus non-flashing modes. For only the targets that could flash, however, significantly more were detected and recognized when they were flashing than when they were not flashing (Table 5).

Table 5. Flashing versus Non-Flashing Targets

	All Targets		Flashing Targets Only	
	Mode		Mode	
	Flashing	Non-Flashing	Flashing	Non-Flashing
Total Number Detected	14	12	14	7
Mean across Subjects	1.4	1.2	1.4	0.7
Standard Deviation	0.5	0.4	0.5	0.7
Student's t (n = 18)	0.94		2.60*	
Total Number Recognitions	14	9	14	4
Mean across Subjects	1.4	0.9	1.4	0.4
Standard Deviation	0.5	0.6	0.5	0.5
Student's t (n = 18)	2.06		4.33*	

*Significant at $p < 0.01$

The data are also shown in a format similar to that of Table 3 (Table 6).

Table 6. Classification of Targets and Number of Detections Made

Mode	Target Type	
	Non-flashing (T_0, T_1, T_2, T_3)	Flashing Capability (T_4, T_5, Q_1, Q_2)
No Targets Flashing	5	7
$T_4, T_5, Q_1,$ and Q_2 Flashing	0	14

About the same number of non-flashing and flashing targets were detected in the non-flashing mode (5 versus 7). In the flashing mode, however, none of the non-flashing targets was seen, but flashing targets were reported 14 times by the 10 subjects. This result is more in line with what was expected before the experiment began.

Contrast

The higher contrast targets (T_0, T_1, T_2 and T_4) were never detected from the simulated 3,000 foot altitude. This result, similar to that from Experiment I, can be interpreted as an indication that luminance contrast was not a factor in the target acquisition process in these experiments. Perhaps contrast was confounded with target location and clutter, so that it was not a driving factor in the search.

Detection Range

The most distant target was a simulated 4,500 feet ground range from the subject's starting point, and he was at a simulated 3,000 feet above the terrain, a condition resulting in steep look-down angles in most cases. When the targets were reported, the subject was looking almost straight down upon them; detection range is therefore not a meaningful measure of performance in the high altitude part of these tests.

LIMITATIONS

This study was conducted on a terrain model with subjects who made only one pass over the model. The view of the model was relatively unrestricted, as compared to cockpit limitations in most fixed-wing aircraft. In the higher altitude tests, the subjects were looking almost straight down when they reported the targets.

There were no atmospheric effects, and no stress of task loading (e.g., piloting) on the subjects. It is not appropriate to use the data to estimate the absolute performance of an observer in the field. It is felt that the data are useful, however, to estimate the relative performance when searching for flashing and non-flashing targets.

SUMMARY

In summary, the condition with targets exhibiting muzzle flashes resulted in more target detections and recognitions than the no-flash condition. When searching from a simulated 1,000 foot altitude, subjects reported more targets (both flashing and non-flashing) when some of the targets were flashing. The targets that had the flash capability were not seen more often when they were flashing than when they were not flashing, however.

The flash effect was more important when seen from 3,000 feet altitude: twice as many of the targets that could flash were seen and recognized when they were flashing than when they were not flashing.

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- 1 The Boeing Company, Seattle, Wash. (James D. Gilmour)
- 1 The Martin-Marietta Corporation, Orlando, Fla. (Dr. Daniel Jones)
- 1 University of California, Scripps Visibility Laboratory, San Diego, Calif.
- 1 Virginia Polytechnic Institute, Blacksburg, Va. (Dr. Harry Snyder)