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## MATERIALS RESEARCH LABORATORIES

MELBOURNE, VICTORIA

**REPORT**

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# COMPARATIVE ASSESSMENT OF THE DETECTABILITY OF PATTERNED M113 VEHICLES IN NATURAL TERRAIN BACKGROUNDS

C.J. Woodruff, R.J. Boyd and P.J. Beckwith





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## ABSTRACT

Photographic simulation was used to produce materials for a psychophysical assessment of the relative detectability of four different paint schemes on M113 vehicles viewed against six different backgrounds, and having their running gear obscured by ground foliage. Vehicles were presented in one of two possible orientations to the direction of viewing. The geometry of the simulation limited target range to approximately 50 metres. Using controlled image degradation, and limited viewing times, differential error rates for target detection were obtained in a four-alternative temporal-forced-choice procedure. Analysis of variance results showed a highly significant effect due to background, and significant effects due to both pattern and orientation. It is concluded that the technique is a useful method for quantifying the detectability of complex targets in natural terrain.

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Comparative assessment of the detectability of patterned M113 vehicles in natural terrain backgrounds


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Photographic simulation was used to produce materials for a psychophysical assessment of the relative detectability of four different paint schemes on M113 vehicles viewed against six different backgrounds, and having their running gear obscured by ground foliage. Vehicles were presented in one of two possible orientations to the direction of viewing. The geometry of the simulation limited target range to approximately 50 metres. Using controlled image degradation, and limited viewing times, differential error rates for target detection were obtained in a four-alternative temporal-forced-choice procedure. Analysis of variance results showed a highly significant effect due to background, and significant effects due to both pattern and orientation. It is concluded that the technique is a useful method for quantifying the detectability of complex targets in natural terrain. Keywords: Armored personnel carriers; Camouflage; Observers; Visual detection. (Australia)


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# COMPARATIVE ASSESSMENT OF THE DETECTABILITY OF PATTERNED M113 VEHICLES IN NATURAL TERRAIN BACKGROUNDS

## 1. INTRODUCTION

The systematic assessment of camouflage schemes prior to their realisation in military materiel ought to be standard practice. However proper field assessment is expensive as well as being disruptive to military activities. Hence alternative methods have been investigated for quantification of the relative detectability of targets embedded in natural terrain backgrounds. A common approach [1] has been to develop a terrain model and locate targets within this, then have a group of observers search this 3-dimensional scene using aided or unaided vision as required. Other approaches have used photographic or videotape records of a terrain model to present static or dynamic search scenes to observers.

Luckeish and Moss [2] introduced an instrumental measure of letter legibility, and various extensions of this approach to assess target detectability have been investigated by Skinner and Beckwith [3] and Rubinfeld and Jenkins [4]. Such measures degrade the image in a controlled manner, for example by superimposing veiling glare or reducing the higher spatial frequency components.

In an extensive comparison of field detection performance with laboratory detection performance Foster [5] found strong evidence for the validity of laboratory performance as a measure of field detectability, using either time to detect or percentage of detections as the criterion. Foster used panoramic displays, utilising pairs of 35 mm slides projected by matched Leitz projectors, to give an 86 degree search field containing three targets, one at each of three ranges. Each subject served as an observer only once - i.e. carried out a single search for an unspecified number of targets in either the field or the laboratory. Foster's results firmly establish the possibility of adequate simulation, and provide justification for treating photographic simulation as a valid approach to assessing likely field detectability. However the practicality of his technique for developmental assessment of designs is doubtful, as there are considerable technical difficulties in producing suitably high resolution in panoramic scenes.

The development of near optimum paint schemes for camouflage of military objects requires comparative assessment of patterns varying in both colour and design. It is not feasible to paint real targets with the range of patterns which are likely to serve the purpose of camouflage. Hence simulation methods based on either computer graphics or photography seem likely ways of producing an appropriate range of target materials. Computer graphics techniques are limited by raster line visibility to search scenes of approximately 10 degrees unless expensive computing and display facilities are available. Photographic techniques, which may be somewhat labour intensive, are technologically simple and are of low capital cost.

Whichever method of simulation is chosen, it remains necessary to compare the detectability of the generated patterns in such a way that the laboratory measure correlates highly with field measurements of relative detectability. The study reported here was concerned with the laboratory assessment of detectability of targets in projected photographic transparencies. Targets were M113 vehicles painted with one of four different patterns, and set at one of two orientations to the direction of viewing. The targets were, in fact, 1/35 scale models, photographed using a front projection simulation [6].

## 2. METHOD

A four-alternative temporal-forced-choice procedure was used to assess target detectability in a three-way complete factorial experiment with randomised blocking, using subjects as blocks [7]. Targets were displayed briefly, defocussed slightly and viewed peripherally. They were presented against six backgrounds, in four patterns and two orientations, each seen in three positions: slightly left of centre, slightly right of centre and centrally located; thus there were 144 targets. A target appeared exactly once in a detection trial which consisted of four scenes, each presented for 160 ms. Within a detection trial all backgrounds were different*.

Trials were randomly ordered such that the same patterned target did not appear in consecutive trials, and a target did not appear more than twice in succession in the same temporal order. Backgrounds in non-target slides were selected at random, subject to the constraint that all four backgrounds in a single trial were different, and all backgrounds appeared equally often over 144 trials.

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* In a pilot study all backgrounds in a single trial were almost the same, being from the same base background but slightly laterally displaced with respect to each other. Results in agreement with those of this experiment were found in that pilot study. However it was considered that responses under these circumstances could be based on the detection of a change in the whole scene, rather than the detection of a mismatch between the background and the colour or pattern of the target.

Eight subjects each performed four observation sessions. In each session 144 trials were presented in blocks of 36 with a few minutes break between blocks. The order of block presentation was variod within groups of four subjects in a completely balanced Latin square design with two replications [7]. Prior to experimental sessions subjects had at least one practice session, thus reducing learning effects, and providing information needed to adjust viewing conditions to obtain a useful error rate.

All projected images were defocussed to eliminate some sharp edges resulting from the photographic simulation used to hide the target's running gear. The amount of defocussing was fixed throughout the experiment by focussing the image at a point 725mm in front of the screen, which was 3250mm from the projector (see APPARATUS).

A textured grey image with a central fixation marker was projected when the test images were not being shown. Manipulation of the subject's error rate was obtained by varying the eccentricity of the fixation marker from $8.2^{0}$ to $12.0^{0}$ vertically above the centre of the test slide. This method for control of error rate is not entirely satisfactory as it introduces possible systematic effects associated with both retinal variation in resolution and chromatic sensitivity variation with eccentricity.

## 3. APPARATUS

Two Pradovit C2500 projectors with 90 mm focal length lenses were placed side by side and used at f/2.8 numerical aperture. A mechanical shutter was arranged such that only one of the projectors threw an image on the screen at any instant. The shutter mechanism was driven by a stepper motor controlled electronically to produce exposure durations of 160 ms for each image. On completion of every trial sequence of four images a buzzer sounded and the subject verbally responded during the next two seconds. Responses were entered by the experimenter into computer memory as ordinal data and ultimately scored as correct or incorrect.

## 4. MATERIALS

Targets consisted of a single M113 viewed against natural foliage terrain, with the running gear obscured by low foliage near and in front of the vehicle. Plate 1 shows representative examples of the target materials, including the four paint schemes and each background type. Target slides were produced by multiple exposure techniques, Skinner [6], with a model placed in front of a retro-reflective screen and a carefully shaped piece of screen material in front of the model for track obscuration. Slides of the background-only were also obtained by photographing images projected onto the retro-reflective screen. All images were recorded on 64 ASA Ektachrome film.

## 5. RESULTS

Primary data consisted of responses of eight subjects to four sessions of 144 trials, presented as four blocks, with each session providing a complete set of target response data. The presentation order of blocks differed between sessions and was counter-balanced between groups of four subjects. Each combination of pattern, background, orientation and lateral position appeared exactly once in a session.

It was found that subjects were more likely to select some temporal orders than others. This response bias was reasonably constant for each subject but varied between subjects, as shown in figure 1. A correction factor for this nonuniform guessing was obtained as follows:

Let P be the number of presentations at a particular temporal location of the set of N trials,

Let D be the number of genuine detections at that location,

Let G be the number of guesses that the target is at that location,

Let C be the number of responses which correctly specify that location as the target location,

Let E be the number of incorrect specifications that the target is at that location.

Letting barred quantities denote the corresponding expected values, we have

$$\bar{D} = \bar{C} - \rho\bar{G} \qquad (1)$$

where $\rho = P/N$,

and

$$\bar{E} = (1 - \rho)\bar{G} \qquad (2)$$

Hence, eliminating G, equation (1) becomes

$$\bar{D} = \bar{C} - \alpha E \qquad (3)$$

where $\alpha = \rho/(1 - \rho)$.

If $\bar{C}$ and $\bar{E}$ are replaced by their observed values

$$\bar{D} \simeq C - \alpha E$$

From the experimental set-up P is known, and scoring of responses allows E and C to be determined. Hence the correction factor for guessing, k, can be determined for each subject for each temporal location

$$k = 1 - \alpha E/C \qquad (4)$$

An observers raw score C can be multiplied by this (order-dependent) adjustment factor to provide an improved estimate of the detectabilty of each target.

Since scores on the three lateral positions did not significantly differ - although the central position had more correct responses than either of the flanking positions - data from the lateral positions were combined. Table 1 gives the percentage correct responses of each subject in each experimental session, together with the vertical eccentricity of the fixation marker in that session.

Response data, corrected for guessing, were analysed using a three-way analysis of variance for a complete 3-way factorial design with randomised blocks, subjects being the blocks. In Table z the adjusted number of correct responses in each cell are presented, and Table 3 gives the results of the analysis of variance on this data. For this tabulation the error term was obtained using the mean square of all interactions involving subjects. This is appropriate if error terms are homogeneous, and provides a conservative estimate of orientation effects if error terms are not homogeneous (q.v. [7] op. cit.).

**TABLE 1**

Percentage of responses correct in each session for each subject, together with vertical eccentricity (degrees) of the fixation marker from the centre of the target slide

| Session | 1 | | 2 | | 3 | | 4 | |
|---|---|---|---|---|---|---|---|---|
| | C (%) | Vert. offset | C (%) | Vert. offset | C (%) | Vert. offset | C (%) | Vert. offset |
| Subject | | | | | | | | |
| 1 | 79.2 | 8.7 | 79.2 | 9.5 | 75.0 | 10.4 | 64.6 | 11.2 |
| 2 | 87.5 | 8.7 | 87.5 | 10.4 | 81.3 | 11.6 | 75.7 | 12.0 |
| 3 | 87.5 | 8.2 | 79.2 | 9.4 | 82.6 | 10.4 | 75.0 | 11.2 |
| 4 | 77.1 | 9.1 | 68.8 | 9.1 | 56.9 | 9.9 | 63.9 | 9.5 |
| 5 | 75.7 | 9.4 | 70.1 | 9.7 | 63.9 | 10.4 | 68.8 | 10.4 |
| 6 | 61.8 | 9.5 | 72.2 | 9.0 | 72.2 | 9.1 | 79.0 | 9.1 |
| 7 | 84.7 | 8.7 | 82.6 | 10.4 | 84.0 | 11.6 | 83.3 | 12.0 |
| 8 | 88.2 | 10.4 | 85.4 | 11.6 | 83.3 | 12.0 | 84.0 | 12.0 |

## TABLE 2

Corrected response data, showing percentage correct, for eight subjects and three locations over four sessions

Orientation: 30 degrees (smaller target area)

| Background | Pattern 1 | 2 | 3 | 4 | Total |
|---|---|---|---|---|---|
| 1 | 51.8 | 36.9 | 36.0 | 40.8 | 165.5 |
| 2 | 64.3 | 51.3 | 60.4 | 64.3 | 240.3 |
| 3 | 54.4 | 64.4 | 69.7 | 64.6 | 253.0 |
| 4 | 63.2 | 55.0 | 63.8 | 56.1 | 238.1 |
| 5 | 50.0 | 48.3 | 43.1 | 43.0 | 184.3 |
| 6 | 38.2 | 44.5 | 34.7 | 23.8 | 141.2 |
| Total | 321.9 | 300.4 | 307.7 | 292.5 | 1222.5 |

Orientation: 65 degrees

| Background | Pattern 1 | 2 | 3 | 4 | Total |
|---|---|---|---|---|---|
| 1 | 41.8 | 52.1 | 51.3 | 42.8 | 188.0 |
| 2 | 65.5 | 38.5 | 57.1 | 61.6 | 222.7 |
| 3 | 60.8 | 63.1 | 61.5 | 61.4 | 246.9 |
| 4 | 58.4 | 68.2 | 62.0 | 63.5 | 252.0 |
| 5 | 52.8 | 56.1 | 56.6 | 44.8 | 210.3 |
| 6 | 39.1 | 19.4 | 54.2 | 40.7 | 153.5 |
| Total | 318.4 | 297.4 | 342.6 | 314.8 | 1273.2 |

## TABLE 3

Analysis of variance on corrected response data from all experimental sessions of each subject

| | Sum of Squares | Degrees of Freedom | Mean Square | F-test Ratio |
|---|---|---|---|---|
| Orientation | 6.7 | 1 | 6.7 | 4.5 * |
| Background | 528.4 | 5 | 105.7 | 70.5 ** |
| Pattern | 20.0 | 3 | 6.7 | 4.5 * |
| Subjects | 723.3 | 7 | 103.3 | 68.9 ** |
| Orient. x Bkd. | 22.4 | 5 | 4.5 | 3.0 * |
| Orient. x Ptn. | 11.4 | 3 | 3.8 | 2.9 |
| Orient. x Subj. | 2.9 | 7 | 0.4 | 0.2 |
| Bkd. x Ptn. | 91.5 | 15 | 6.1 | 4.1 ** |
| Bkd. x Subj. | 182.5 | 35 | 5.2 | 3.5 ** |
| Ptn. x Subj. | 42.0 | 21 | 2.0 | 1.3 |
| O x B x P | 126.5 | 15 | 8.44 | 5.6 ** |
| O x B x S | 38.9 | 35 | 1.11 | 0.7 |
| O x P x S | 30.0 | 21 | 1.43 | 0.9 |
| B x P x S | 101.9 | 105 | 0.97 | 0.6 |
| O x B x P x S | 94.8 | 105 | 0.90 | |

* indicates significance at the 0.05 level,
** indicates significance at the 0.01 level.

The analysis of variance shows that all main effects are significant, as were differences between subjects. All two-way interactions involving background are significant, and the three-way interaction between orientation, background, and pattern is significant. An appropriate test of the sensitivity of the experiment is provided by whether differences in target detectability due to orientation can be detected. The more side-on view resulted in a greater number of correct responses, as would be expected, and the analysis of variance shows that this difference is significant at the 0.05 level. The pattern effect is seen to be of the same magnitude as the orientation effect.

## 6. DISCUSSION

We have described a novel technique for the quantitative assessment of the detectability of targets in complex backgrounds. We have also provided experimental data validating the technique. This new procedure provides a sensitive,low technology procedure for comparing camouflage effectiveness against human observers. The difference in area of the retinal image for the two orientations is only about 12%, yet the difference in target detectability due to this difference in area was detected. The technique, then, is sufficiently sensitive to detect relative differences in detectability which are likely to be of interest to the military camoufleur. The front-projection apparatus for producing embedded targets is of straightforward construction using readily available materials. The shutter and its timing system are of simple design and construction, and data recording relied only on an RS-232 link to a microcomputer.

The study presented here did not deal with a wholly realistic camouflage situation, in that the M113 vehicles were closer to the observer than would be expected under normal operational conditions. This was due to a constraint imposed by the apparatus that produced the experimental materials. However simulations have been made of more distant targets, such as aircraft at several kilometres. Such simulations are, in fact, easier to produce, and a smaller target size would obviate the need for use of such large eccentricities as were required here. It is therefore considered that the technique described in this report is potentially capable of making useful comparisons between candidate examples of camouflage materiel.

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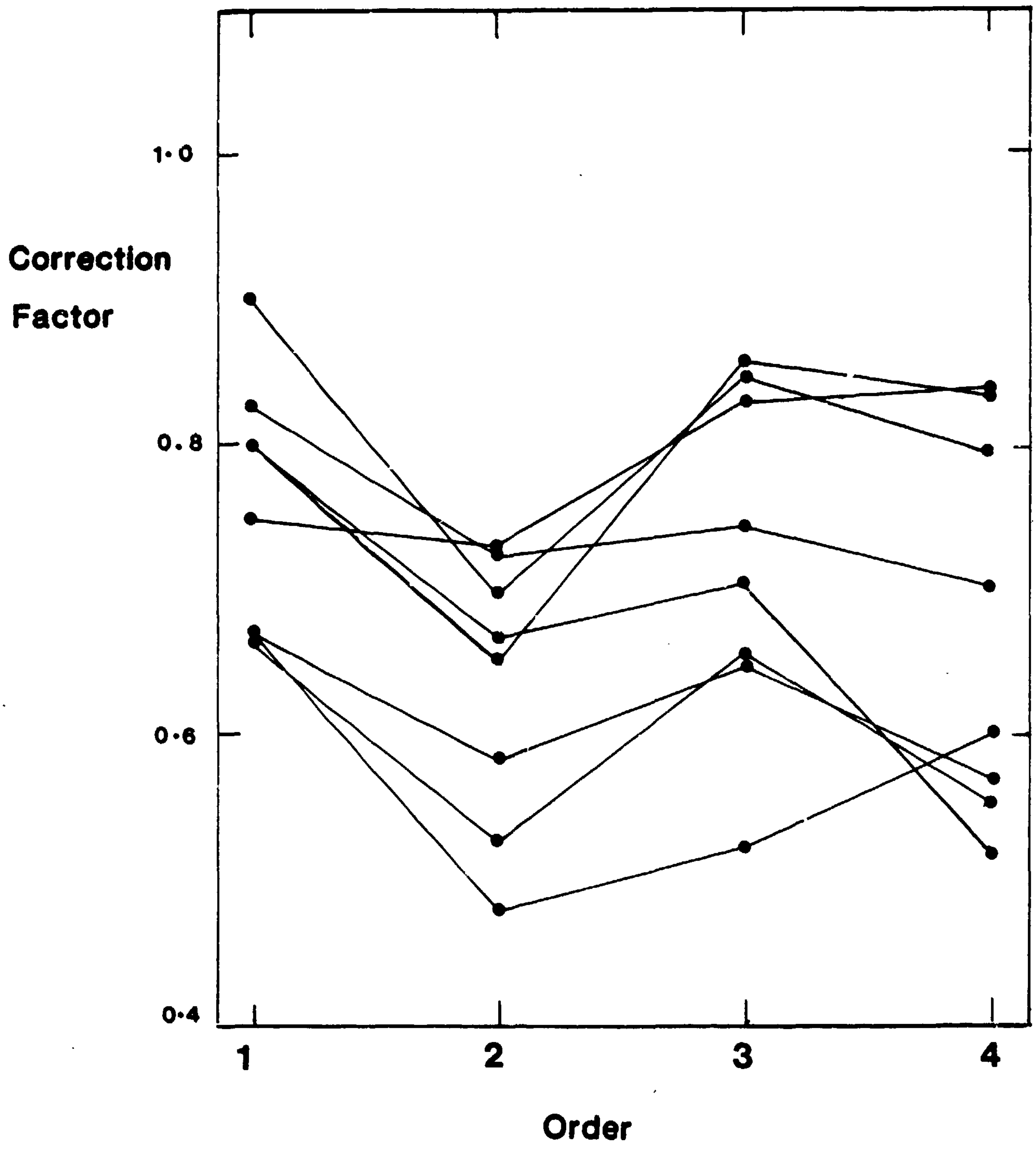


Figure 1 Values of the correction factors applied to response data of each subject at each temporal order. A correct response was scored as 1 then multiplied by the appropriate correction factor.

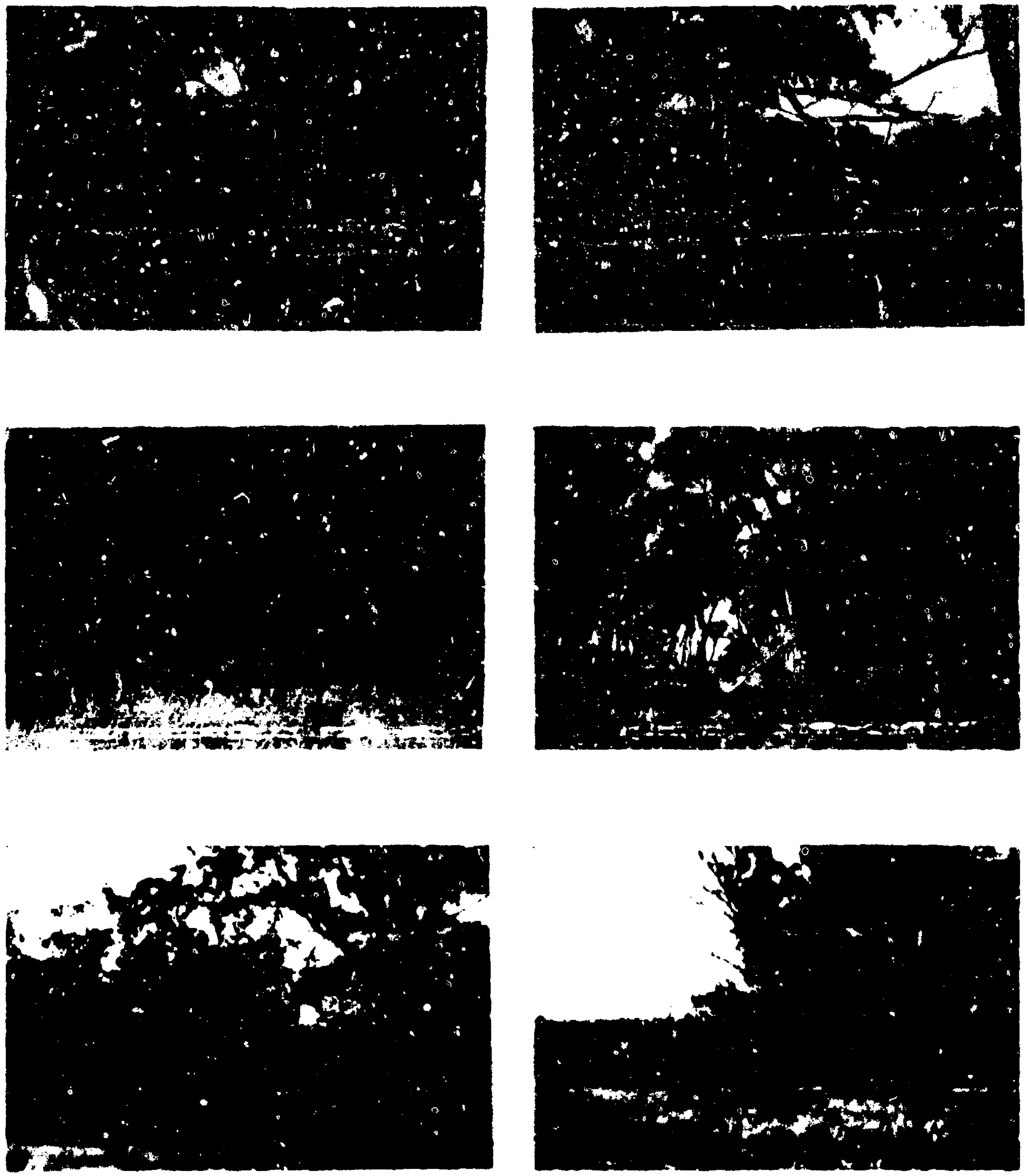

**Plate 1.** Sample target presentations, showing the six backgrounds, four vehicle patterns, and two orientations used.