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A Comparison between the Detectability of Human Targets and Standard Visibility Objects in an Evergreen Rainforest

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D. A. Dobbins and C. M. Kindick

February 1966

USATECOM Project 9-6-0069
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(An In-House Laboratory Independent Research Project)

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ABSTRACT

The purposes of this study were (a) to compare the interchangeability of human targets and several standard visibility objects in jungle visibility studies, and (b) to quantitatively evaluate the effectiveness of one US Army camouflage pattern in reducing visual detection in the jungle.

Twenty US infantry soldiers with normal vision were presented 108 targets at distances ranging from 30 feet to 120 feet on two sites in a Canal Zone evergreen rainforest. Observers were presented 18 each of the following targets: olive drab silhouettes, olive drab cylinders, double white discs, single white discs, silhouettes camouflaged by the USAERDL four-color 1948 pattern, and human targets in olive drab fatigue uniforms. Tests were conducted in September and October 1965, toward the latter part of the wet season.

Comparisons between human targets and standard visibility objects were made using four criteria: 50% detection thresholds, total number of detections, visibility gradients, and observer response variability. Quantitative comparisons showed that both the olive drab silhouette and the olive drab cylinder closely approximated the detectability of the olive drab clothed human targets; of the two objects, the silhouette was considered superior. Neither the double white discs nor the single white discs closely approximated the detectability of human targets. The evidence suggested that target size was the more important detection cue at near distances, and color contrast the more important at farther distances.

The USAERDL four-color camouflage cloth effectively and significantly reduced detections by ground observers in jungle vegetation.

FOREWORD

This is the sixth report in the Tropic Test Center series dealing with personnel detection in tropical forests. The research is supported by the US Army In-House Laboratory Independent Research Program (DA Project 1L013001A91A, USATECOM Project 9-6-0069, USATTC Work Unit #001).

The primary purpose of these studies is to make available, for the first time, a baseline of quantitatively sound data concerning the visual capabilities of the solider in the jungle. From the standpoint of the test and evaluation mission of the Center, these data afford quantitative standards for evaluating the effectiveness of various types of personnel detection aids through jungle foliage. Moreover, the new test techniques developed for measuring visual thresholds in the field are applicable both to tests of visual aids and to tests of certain types of personal equipment which may restrict normal visual proficiency. To date, the reports have dealt with visual capabilities in different types of tropical forests, with the effects of seasonal variations, and with evaluations of potential performance aids. The present report is methodological in nature and compares detectability characteristics of human targets with several standard visibility objects.

The Tropic Test Center, because of its geographical location, is ideally situated to collect these basic data and thus help close the gap in present knowledge.

Beyond the test and evaluation mission, these reports may have implications for tactics, training, and operations. For these reasons, the reports are widely distributed.

The authors gratefully acknowledge the assistance rendered by the US Army Natick Laboratories, who made available the camouflage cloth used as one visibility object. Mr. R. Ah Chu of the Tropic Test Center assisted in the inventory of the vegetation and the art work. The field work of the present study was accomplished under contract by the Weather Engineers of Panama Corporation.

All observers were provided by the Commanding Officer, 4th Battaltion, 10th Infantry, through the assistance of the Chief, Combat Developments Office, US Army Forces Southern Command.

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BRIEF OF RESULTS

The major purpose of the present study was to compare the interchangeability of human targets and several standard visibility objects in jungle visibility investigations. A secondary purpose was to quantitatively evaluate the effectiveness of US Army camouflage cloth in denying visual detections to observers in jungle vegetation.

Twenty enlisted men from an infantry unit in the Canal Zone, preselected for normal visual acuity, were each presented 108 targets. These targets included an equal number of the following standard visibility objects: olive drab silhouettes, olive drab cylinders, double white discs, single white discs, and camouflaged silhouettes (USAERDL four-color 1948 pattern). In addition, an equal number of human targets dressed in olive drab fatigue (OG-107) uniforms were presented as controls. The faces of human targets were blackened with charcoal. Targets were presented in triads on two sites in a mature evergreen rainforest. Targets appeared at six distances (30 feet to 120 feet) in a random sequence along three radii within a horizontal search area of 180°. Testing took place in September and October, 1965, during the latter part of the wet season. The degree of similarity between standard visibility objects and human targets was based on comparisons of four detectability characteristics: 50% detection thresholds, total number of detections, visibility gradients, and observer response variability. Results were as follow:

1. Two standard visibility objects--the O.D. silhouette and the O.D. cylinder--yielded detectability characteristics similar to the human target. The O.D. silhouette is considered interchangeable with the human target in jungle visibility studies. The O.D. cylinder is considered an adequate substitute for the human target, though not as desirable as the silhouette.

2. Two other standard visibility objects--the double discs and the single disc--yielded detectability characteristics considerably less similar to the human target. The double discs, as compared to human targets, resulted in significantly higher total detections, significantly higher observer variability, and a slightly flatter visibility gradient. The single disc, as compared to the human targets, resulted in significantly fewer total detections, significantly higher observer variability, lower 50% detection thresholds, and a visibility gradient of much lower and flatter slope. Neither of the two objects is considered an adequate substitute for the human target. The evidence suggests that target size was the dominant detection cue at the lesser target distances and target color contrast was more important at the greater target distances.

3. The silhouette covered with the USAERDL four-color camouflage 1948 pattern was the least detectable visibility object. The camouflaged silhouette, as compared to the human targets, resulted in a 16.4 feet reduction in the 50% detection threshold, significantly fewer total detections (12.1% reduction), and a visibility gradient of a much lower level.

The camouflaged silhouette also resulted in a 12.7 feet reduction in the 50% detection threshold and a 14.5% reduction in total detections when compared to the O.D. silhouette; these two objects were identical in all respects except one--the camouflage cloth. Thus, in spite of its larger surface area and human conformation, the camouflage pattern effectively and significantly reduced detections of the silhouette by ground observers through jungle vegetation.

4. There was no significant difference in intrinsic difficulty of detection between the two test sites considering the total detections for all types of targets. However, detections for three of the standard visibility objects, the double discs, single disc, and O.D. cylinder, fluctuated significantly from one site to the other.

5. Average levels of ambient illumination ranged from approximately 18 to 24 foot-candles between the two sites, and did not differ significantly. There was a small but statistically significant increase in illumination on both sites during the course of approximately 3-1/2 hours of testing time. The increase in light levels did not facilitate target detectability.

INTRODUCTION

Little quantitative data are available on visibility in tropical forests. The US Army Tropic Test Center has initiated a series of studies to establish normative visibility data under a variety of experimental conditions to provide this information.

The present report is methodological in nature. It is the sixth of this series and compares the extent to which five types of standard visibility objects approximate the detectability of human targets through jungle foliage.

BACKGROUND

At least two agencies of the US Army have had a long term interest in the effects of environmental factors on visibility. These agencies are the US Army Natick Laboratories (1, 2, 9)* and the Waterways Experiment Station (WES) (10, 13, 14). More recently, other agencies have initiated similar research with a specific emphasis on the obscurative effects of tropical vegetation (3, 4, 5, 6, 7, 8, 12).

A recent report summarized the results of past Natick visibility studies undertaken in several major types of environments and using different types of visibility objects (e.g., white Secchi discs, clipboards, green cylinders) as well as human targets (2). The report recommended the adoption of a 30-cm. diameter Secchi disc mounted on a tripod as a standard visibility object for all work in forested areas. The purpose of this recommendation was to insure uniformity of visibility measures taken in different types of forests by different investigators. The Natick report also urged the continued use of targets other than the Secchi disc for comparison purposes, and made a distinction between "military" and "standard" visibility.

The Waterways Experiment Station also has set forth a series of target configurations for experimental evaluation. Those objects include disc type targets of varying diameters mounted at varying vertical distances on poles (14). Other variations, to include panel boards, color variation, and form perception tasks, are also described.

There are many good arguments for the use of standard visibility objects (SVOs) instead of the particular military target of interest. Among the advantages of SVOs are uniformity of physical characteristics, economy, convenience for the investigator, and comparability of results from study to study, site to site, and region to region. However, it is the opinion of the authors that it is premature for researchers in military visibility to adopt a single SVO before considerably more research has been done. The reason for this opinion is the lack of convincing

* See "REFERENCES."

published evidence that the detectability characteristics of SVOs bear a predictable relationship with the most common classes of military targets, i.e., men, vehicles, and weapons.

It is felt that the eventual selection of SVO(s) useful in military visibility studies must be done in one of two following ways:

a. Devising SVO(s) which yield empirical detection data of close magnitude to the most common classes of military targets, or

b. Devising statistical scaling methods, through field experimentation, by which detection data based on SVO(s) may be converted to "synthetic" detection data applicable to the common classes of military targets.

The development of some system similar to those described above would relieve the investigator from the arbitrary distinction between "military" and "standard" visibility.

The present study attempts a modest beginning along these lines. This report compares the relative visibility characteristics of several SVOs and human targets in a tropical evergreen rainforest. Thus, the scope of the study is limited to a particular environment. It is hoped that other investigators will extend similar studies to other vegetative environments, other targets, and other observers.

It should be clearly understood that the present study does not attempt an overall assessment of the usefulness of SVOs in visibility research. If an investigator is interested in the detectability of high contrast targets through vegetation, he is justified in using highly reflective and brightly hued surfaces in combination with any shape or type of target he desires. If he is interested in form perception through vegetation, he is limited only by his own creativity in devising geometric shapes. The present study evaluates SVOs from one standpoint only--their interchangeability with olive drab (O.D.) clothed human targets in terms of visual detectability through jungle foliage.

OBJECTIVES

1. The primary objective of the present study was to compare the visibility characteristics of five SVOs with those of human targets through jungle foliage. The characteristics compared included: 50% detection thresholds, number of detections, visibility gradients, and observer response variability.

2. A secondary objective was to compare the detectability of the US Army Engineer Research and Development Laboratory (USAERDL) four-color 1948 pattern camouflage cloth with the detectability of olive drab targets.

METHOD

Targets. Several SVOs were arbitrarily selected. Two were selected from past Natick studies. One was adapted from the several configurations suggested by the Waterways Experiment Station. Two additional objects were devised by the Tropic Test Center. Human targets in O.D. fatigue clothing were used as the control (see Figure 1). Detailed descriptions follow:

a. O.D. Silhouette. The O.D. silhouette, devised by the Tropic Test Center, was selected for its obvious similarity to the targets of comparison, i.e., personnel dressed in standard fatigue clothing. The silhouettes were cut from 1/4" plywood and painted with olive drab, lusterless enamel (Fed. spec. TT-E-522). The silhouette dimensions were those of the 50th percentile U.S. soldier in terms of height (69.0"), shoulder breadth (17.9"), head width (6.0"), and shoulder height (55.9") (11, pp. 509, 517, 519, and 523). Each silhouette was mounted on a wooden pedestal* to hold it upright.

b. O.D. Cylinder. This object was built to the same specifications as those reported by Drummond and Lackey (9). The cylinder was 6.0 feet high and 1.5 feet in diameter. However, Drummond and Lackey's cylinders were constructed from metal pipe, plywood, and O.D. canvas cloth; those used in the present study were made from welded galvanized sheet iron, .015" thick, painted a flat O.D. (Fed. spec. TT-E-522). The change was made to increase the durability required by operations in the jungle. Drummond and Lackey originally chose this target to correspond to the approximate dimensions of a soldier equipped with a field load.

c. Double Discs (White). The Waterways Experiment Station lists a series of disc configurations (14). The configurations vary the diameter and heights of three discs attached to a single pole. In the present study, one of the WES configurations was adapted for use. The adaptation was the decision to use double discs in the present study instead of triple discs used by WES. One upper disc of 12" diameter was centered on the pole at a height of 80.7" from the ground. A lower disc of 19.7" diameter was centered on the pole at a height of 19.7" from the ground. The discs were made of 1/4" masonite and were painted a flat white (Fed. spec. TT-E-527). The pole to which discs were attached was 102" high, constructed of 1" x 1" lumber, and painted O.D. There was no strong reason for selecting this particular configuration over others presented

* It should be noted that a wooden distance marker was rigidly emplaced on each of the 18 target positions. The target pedestals were so constructed that when placed flush against the distance marker, the observer was assured a full view of the complete target. This control was necessary to prevent oblique views of the thin targets. The areas at the distance markers on which the pedestals were emplaced were also leveled to prevent oblique views in the vertical plane of targets.

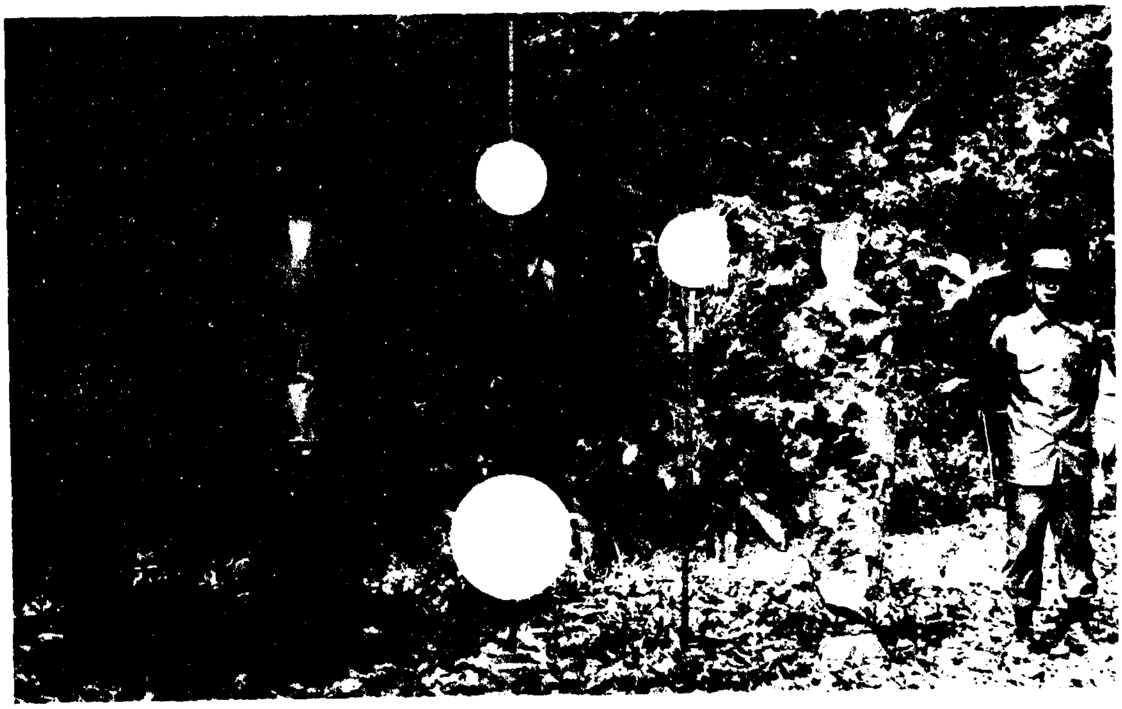

Figure 1. Targets (Left to right: O.D. silhouette, O.D. cylinder, double discs, single disc, camouflaged silhouette, and human target.)

by WES. The selection was based only on the investigators' conjecture that its visibility would approximate that of human targets. The double discs allow the observer an opportunity to detect both from approximately eye level to nearer to the ground. This object contrasted highly in color with the green jungle surroundings and gave the observer a symmetrical search object in the midst of asymmetry. Wooden pedestals were devised to allow the discs to stand upright without human support.

d. Single Disc (White). The single white Secchi disc was fabricated to the dimensions recommended by the Natick Laboratory (2). One 30-cm. diameter disc, cut from 1/4" masonite and painted a flat white (Fed. spec. TT-E-527), was fixed to a single pole cut from 1" x 1" lumber and mounted on a wooden pedestal. The base of the disc was five feet from the ground. The pole and the pedestal were painted flat O.D. This particular object, while having a much smaller surface area than the others, compensated partially by relatively high color contrast, symmetrical shape, and an eye-level fixation point.

e. Camouflaged Silhouette. This object was simply an O.D. silhouette over which was fastened a piece of the US Army camouflage cloth, USAERDL four-color 1948 pattern. The four colors are olive green, light green, medium brown, and black in mottled patterns. The silhouette itself was cut to the same dimensions as those described in paragraph a, preceding. The camouflage cloth was furnished by the US Army Natick Laboratories at the request of the Tropic Test Center.

f. Human Targets. Three persons dressed in the standard fatigue (OG-107) uniform served as the points of comparison, or "controls", for the preceding visibility objects. The targets were contract personnel dressed in fatigues without insignia, including jacket, cap, and bloused trousers. The targets blackened their faces with charcoal prior to testing. The targets ranged in height from 5' 7" to 5' 10", and ranged in weight from 135 to 170 lbs. The same targets were used throughout the experiment. Each target was responsible for emplacing and removing SVOs on the radius to which he was assigned.

Observers. Twenty observers (Os) were tested. Observers were members of the 4th Battalion, 10th Infantry, Fort Davis, Canal Zone. All Os were pretested with an Ortho-Rater vision tester to insure normal far visual acuity and color vision.

Experimenter. The experimenter (E), a contract employee, controlled testing on both sites. The E gave instructions to Os, scored detections, and supervised target deployment.

Independent Variables. Only one independent variable was of interest to the present study: type of target. Testing took place on two sites to increase generality of results. Target distance was varied from 30 to 120 feet in six increments, and horizontal placement (radii) of targets was varied in three ways (45° intervals) in a 180° field of search. This was done to increase vegetative coverage within a site and to make target presentations less predictable. See Figure 2 for layout of test site.

Test Sites. Two sites were selected in the Fort Sherman mature evergreen rainforest (see Figure 3). These sites had never before been used in the present series of studies. Site "V"* was located on road S-1, 6.8 miles west of its junction with road S-10, at approximate map coordinates 17P-PA-084289. Site "W" was also located on road S-1, 8.4 miles west of its junction with road S-10, at approximate map coordinates 17P-PA-098283. The primary differences between sites were the greater density of palm trees at site W, slightly lower top canopy at site W (approximately 80-100 feet) than at site V (approximately 100-125 feet), and relatively flatter terrain at site W. (See Figure 4 at end of report for photographs of sites.) More detailed descriptions of these sites follow:

a. Site V. The ground at this site was relatively flat, sloping very gently at approximately four percent. A two-inch mat of decaying leaves and twigs covered the brownish clay loam surface soil; the subsoil was composed of a reddish-brown clay.

* All sites used in this series of studies are represented by a simple letter designation. Sites X, Y, and Z were used in previous studies.

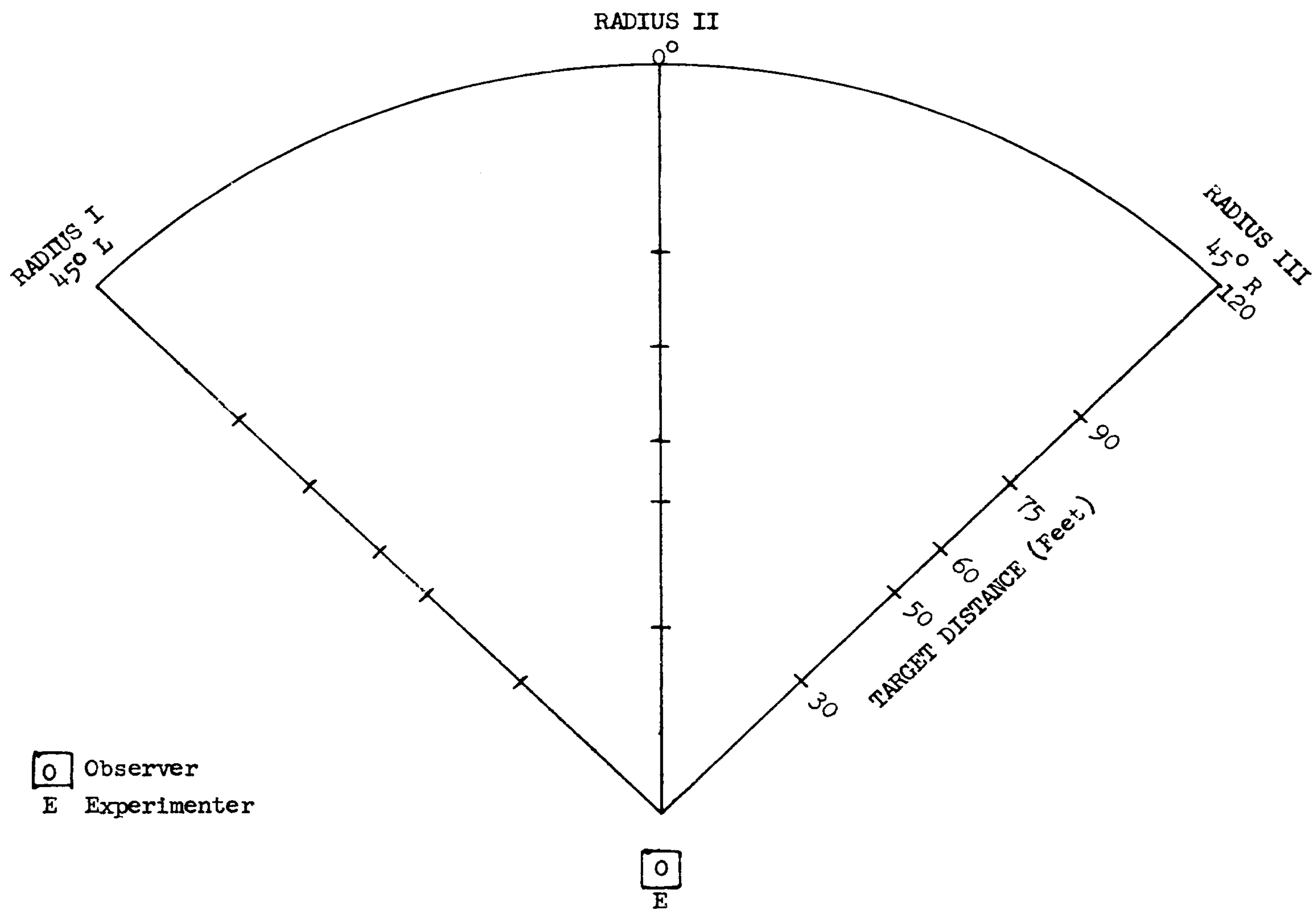

FIGURE 2. SKETCH AT TEST SITE SHOWING TARGET DISTANCES AND PLACEMENT

The upper canopy reached as high as 100-125 feet and was composed mostly of wild fig (Ficus glabrata), balata (Mimusops bidentata), and nisperso (Manilkara chicle). A second canopy, between 40 and 60 feet, was composed primarily of large stilt palms (Socratea durissima), Anonaceae, and various types of woody trees. Trunk diameters generally ranged from three to four inches. The third layer, at heights of 15 to 20 feet, was made up mostly of several varieties of wide-frond palms. The most important palms were the maquengue (Oenocarpus panamanus), the slender stemmed black palm (Bactris balanoidea), and young representatives of stilt palms (Socratea durissima). These palms were sparingly mixed with woody varieties of Desmopsis panamensis and Xylopia macrantha. The lower undergrowth was composed of many small forest palms (Geonoma, Synechanthus, and Chamaedora), as well as Rubiaceae shrubs.

b. Site W. The ground at this site was relatively flat. The brownish, clay loam surface soil was covered by a thin layer of dried leaves and decayed organic matter.

A broken upper canopy, 80 to 100 feet high, was composed mostly of several varieties of buttressed and woody trees with trunk diameters between eight and fifteen inches. The most common type of tall palm was the four-inch diameter trunk black palm--chunga (Astrocaryum standleyanum), which grew as high as 40 feet. The understory trees were mostly 20 to 30 feet tall, with trunks six to twelve inches in diameter and spaced 15 to 30 feet apart. The underbrush consisted of young canopy trees, various understory bushes and palms, and a relatively large number of lower plants such as Geonoma decurrens, Stromanthe lutea, and Heliconia latispatha.

The criteria for site selection were the same as those used in all preceding studies, including: apparent representativeness of vegetation; relatively flat terrain to prevent terrain features from obscuring targets; and radii positioned in such a manner that no target was completely hidden by tree trunks.

Dependent Variables. Four primary visibility characteristics, or performance measures, were used as points of comparison. These measures are as follow:

a. 50% Detection Threshold. The 50% detection threshold is a distance measure corresponding to the number of feet at which 50% of the targets are detected. It is used because it is a convenient single measure by which the visual proficiency of individual observers and the average visibility of radii, sites, types of forests, or regions may be expressed. It represents the point of maximum visual ambiguity (i.e., the point at which there is a "50/50" chance of detection) for the observer who is detecting targets. It is also a psychophysical measure that has long historical precedent as a means of expressing subjective attributes quantitatively for all sensory modalities. However, the 50% threshold measure is

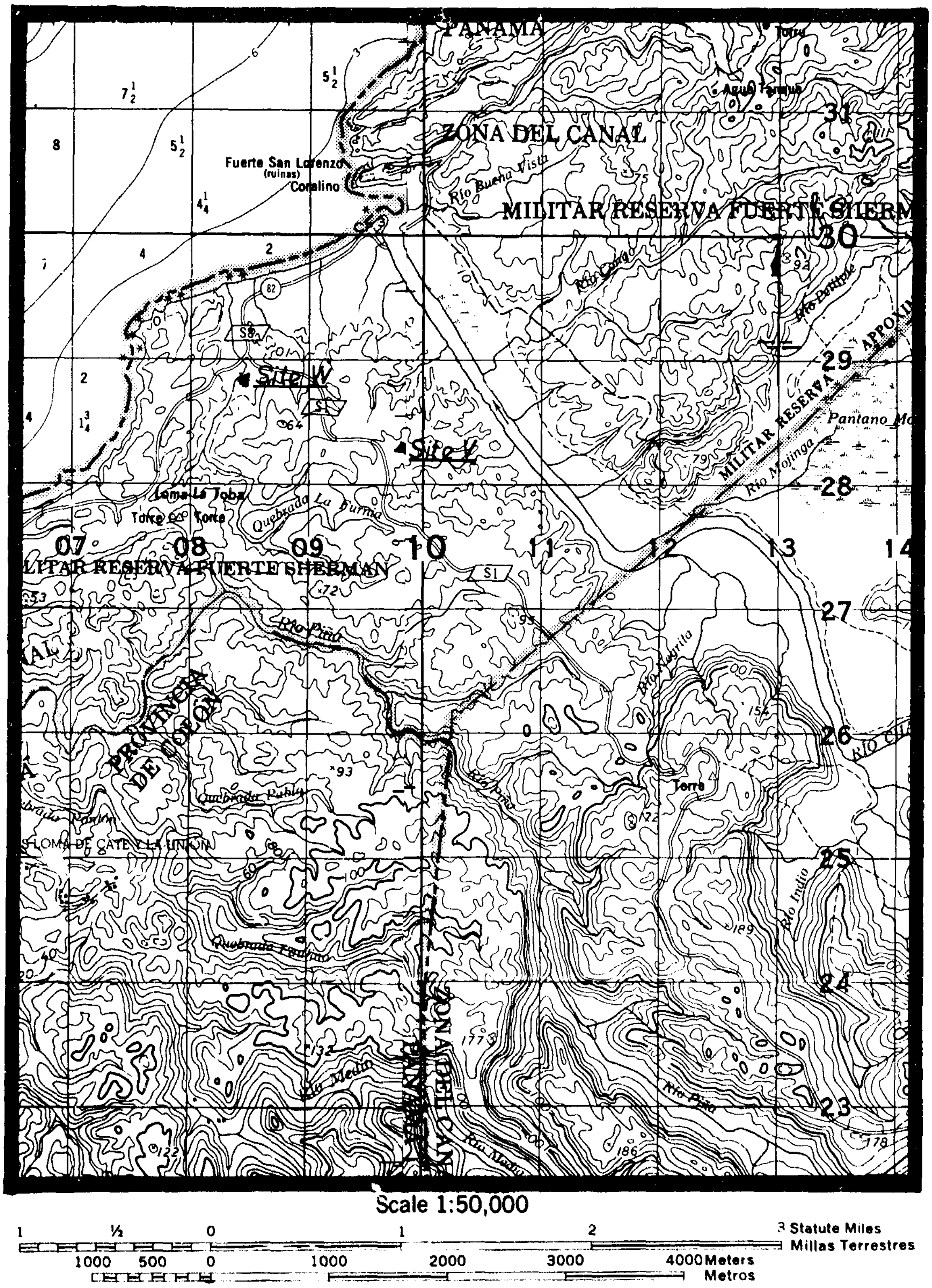

FIGURE 3. SITE LOCATIONS (Palmas Bellas, Panama, Canal Zone. Series E762, Sheet 4143 I, Edition 1-AMS).

deficient when used alone. The visibility gradient must also be described for a complete picture of human sensitivity to the range of physical stimuli presented.

b. Total Number of Detections. This measure is correlated (though not perfectly) with the detection threshold. It is used in this particular study to replace the 50% detection threshold in those cases in which a threshold value would be of questionable reliability. For example, a threshold measure for each observer for a given type target would be based on only 18 observations. Thus, the O's total number of detections, rather than his threshold, was used in such cases. For a given observer, the total number of detections is regarded as an estimate of his overall detection proficiency.

c. Visibility Gradient. Some visibility studies report only a single measure of visibility for a given type of forest, site, or region. This practice may give the casual reader the erroneous notion that targets are visible up to that one distance and not visible beyond that distance. However, within forested areas in particular (4, 5, 6, 7, 8), and in field visibility studies in general (15), it quickly becomes apparent that between the point of perfect detectability and the limits to vision, there exists a gradient of detectability in which the probability of detection will neither be 100% nor 0%. With sufficient replications, this gradient is a militarily significant and an empirically regular aspect of visibility (5, 6). The importance of the visibility gradient may be demonstrated hypothetically as in Figure 5. Gradients (a), (b), and (c) have identical 50% thresholds but very different conformations. Gradient (a) is a simple linear function; (b) is a more complex function in which detectability drops off rapidly beyond the 50% threshold; (c) represents a gradient which has low but persistent detectability over a long range of distance. (A gradient of this type might be expected of an object with a small surface area but high brightness contrast.)

d. Observer Variability. When characteristics such as color, texture, intensity, or duration of the same physical stimulus are varied, it is known that the range of responses elicited from the same observers may also be varied. In standardizing a visibility object to be used to compare region vs. region, forest vs. forest, etc., it would seem appropriate to choose an object that minimizes individual differences among observers. The importance of minimizing such differences is accentuated by the fact that visibility measurements are frequently taken by a very limited number of observers (often two to three investigators). In the present study, all Os were presented with all targets so that a direct comparison could be made between response variations elicited by SVOs and human targets.

Research Design. Table I summarizes the research design. Two subgroups of 10 Os each, comparable in visual acuity, were assigned to

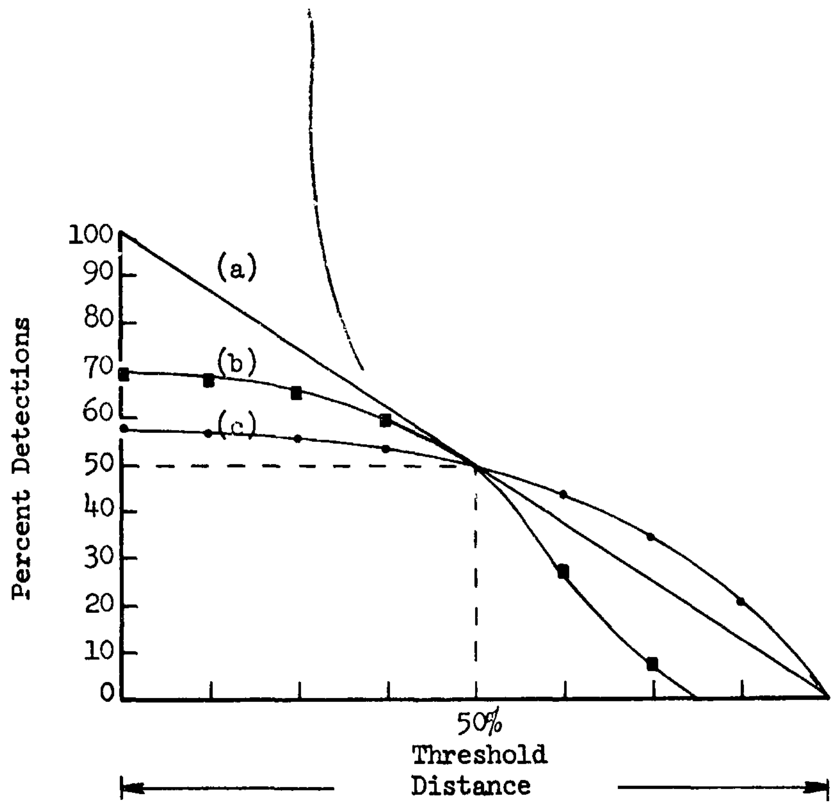

FIGURE 5. Three hypothetical visibility functions with identical thresholds but radically different gradients.

either site "V" or "W" for testing*. Each O observed all six types of targets at all six distances on each of three radii. Thus, each target appeared 18 times per observer. Due to the long testing time involved in presenting 108 targets to each observer, targets were presented in triads. Thus, three targets appeared on each detection trial, one on each radius, in order that the 108 target presentations could be completed in 36 detection trials. A total of 2160 target presentations was made, 360 for each type of target.

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* Due to a scheduling error, only nine Os were actually tested on site V and 11 Os were actually tested on site W. Thus, the total number of observations called for in the design were achieved, but with an imbalance between sites.

TABLE I

Research design of Jungle Vision VI.

Site	Type Target	Radius I (n)*	Radius II (n)	Radius III (n)	Total (n)
V	Human Target	60	60	60	180
	O.D. Silhouette	60	60	60	180
	O.D. Cylinder	60	60	60	180
	Double Disc	60	60	60	180
	Single Disc	60	60	60	180
	Cam. Silhouette	60	60	60	180
Total Site V		360	360	360	1080
W	Human Target	60	60	60	180
	O.D. Silhouette	60	60	60	180
	O.D. Cylinder	60	60	60	180
	Double Disc	60	60	60	180
	Single Disc	60	60	60	180
	Cam. Silhouette	60	60	60	180
Total Site W		360	360	360	1080
Total Both Sites		720	720	720	2160

* n refers to the number of separate targets presented. Since targets were presented in triads, n/3 = the number of separate detection trials.

Appendix A shows the sequence of presentation of target triads. The various target-distance combinations were randomized within radii so that any combination of three of the six target types could appear on a given trial. The constraints were as follow: (a) Each target had to appear six times on each radius, once at each of the six distances, and (b) only one target could appear on any one radius on a given detection trial. With this procedure, it was possible for an observer to be presented either with three of the same type targets, or three different types, or any combination of the six types on a single detection trial.

<u>Procedure</u>. Illumination was taken at all <u>O</u>s' eye levels and at the midpoint of each radius with GE type 213 light meters immediately before and after each <u>O</u> was tested.

Testing was conducted from 27 September 1965 to 13 October 1965. Two Os were tested daily, one at a time. The first O was tested from approximately 0815 to 1000 hours daily. The second O was tested from approximately 1030 to 1215 hours daily.

Testing was alternated between the two sites on every other test day to minimize trampling of underbrush. (See Appendix B for sequence of observers.)

The E read from a standardized set of instructions and informed O that this was a test of his ability to spot different kinds of targets in the jungle. The O was familiarized with the targets by photographs (see Figure 6). The O was also told that triple targets would appear on each detection trial within a 180° field of search, and that he had two minutes to make his three detections. The O was fitted with HEAR-GUARD Model 1200 ear protectors to attenuate audible location and distance cues. (See detailed instructions to Os in Appendix C.)

Before the appearance of the first target, E instructed O to turn around facing away from the site. E announced the number of the detection trial to the three target personnel. Beyond the end of each radius, each target person had concealed one each of the five SVOs. Following the schedule shown in Appendix A, each target person moved the appropriate SVO to the correct distance marker, then returned to the end of his radius, out of sight. Whistle signals from each target person informed E when all visibility objects were emplaced. The E then instructed O to face the site and begin his search. When the schedule called for a human target, the target person walked to the correct distance marker on his assigned radius and stood immobile facing the O.

The O was confined to a marked, four-foot square. He was allowed to bend, twist, crouch, or otherwise position himself, but was not allowed to move his head outside the marked square.

The O was required to point when he detected targets. He was given two minutes per detection trial. When the E was skeptical that a target was truly detected, he asked O to identify it by type and scored according to his best judgment. At times, it was necessary for a target person to "wig-wag" a visibility object to determine the validity of a detection. (This procedure was particularly necessary for the O.D. cylinder because several Os mistook large tree trunks for the cylinder.)

The O was not informed as to the correctness of his attempted detections.

After the first trial, E again instructed O to turn around facing away from the site and announced the number of the next detection trial. The preceding sequence was repeated until O had completed 36 trials, i.e., 108 attempted target observations. Total testing time for one O averaged one hour and 45 minutes. One rest pause of five minutes was allowed between the 18th and 19th detection trials.

FIGURE 6. Photograph of experimenter and observer.

RESULTS

Detection Thresholds. Table II compares 50% detection thresholds between human targets and standard visibility objects (SVOs). To achieve the most valid and stable estimate of the threshold for human targets, results from the 360 detection trials taken during the present study were combined with those taken during two previous studies in the same type of forest (5, 6). Thus, the composite detection threshold of 72.3 feet shown for human targets is based on 2370 target observations by 68 enlisted observers at five different test sites in the evergreen rainforest.

All five SVO thresholds were lower (less visible) than the threshold for the human target. The thresholds for the O.D. cylinder, double disc, and O.D. silhouette varied from only 1.3 to 3.7 feet below the human threshold. The thresholds for the single disc and the camouflaged silhouette were substantially below that for the human target.

TABLE II

Comparison of 50% detection thresholds between human targets and standard visibility objects.

Type Target	50% Threshold (ft.)	Diff. from Human Target (ft.)	n**
Human Target	72.3*	---	2370
O.D. Cylinder	71.0	- 1.3	360
Double Disc	70.0	- 2.3	360
O.D. Silhouette	68.6	- 3.7	360
Single Disc	64.3	- 8.0	360
Cam. Silhouette	55.9	-16.4	360

* A composite threshold based on data from the present study combined with data from two past studies.

** Number of detection trials.

The reductions in detectability of the camouflaged silhouette of 16.4 feet and 12.7 feet from the human target and the O.D. silhouette, respectively, are regarded as significant results in an environment where the absolute limit to vision typically lies between 100 and 120 feet.

Total Detections. The total number of detections (in lieu of detection thresholds) were computed for each observer for all targets. A summary of these data, combined for individual Os, is shown in Table III.

TABLE III

Comparison of total detections between human targets and standard visibility objects.

Type Target	Site V	Site W	Total (Both Sites)	(Number detections)
Human Target	51.2%	46.0%	48.3%	174
O.D. Silhouette	49.4%	50.0%	49.7%	179
O.D. Cylinder	45.7%	54.0%	50.3%	181
Double Disc	45.1%	59.6%	53.1%	191
Single Disc	37.7%	50.5%	44.7%	161
Cam. Silhouette	43.8%	41.4%	42.5%	153
TOTAL (All Targets)	45.5%	50.2%	48.1%	

An analysis of variance was performed. There was no significant difference associated with the two different site means (45.5% vs. 50.2%; $F = 0.8$; $df=1/18$; $P > 20\%$).*

There was a highly significant difference among the means of the six types of targets ($F=4.66$; $df=5/90$; $P < 0.1\%$). This result indicates that the various SVOs cannot be assumed to generate an equal number of detections subject only to chance sampling fluctuations. The relatively low detections for the camouflaged silhouette and the single disc, and the relatively high detections for the double disc, were primarily responsible for the statistical significance.

A Duncan's New Multiple Range Test was applied to the set of individual means to test for the statistical significance of each against the other. The 15 paired comparisons formed three clusters:

a. The human target, O.D. silhouette, and O.D. cylinder differed significantly from all other targets but did not differ from one another. Another way of stating this result is that the O.D. silhouette and the O.D. cylinder were the only SVOs that did not generate significantly more or significantly fewer detections than the human target.

b. The camouflaged silhouette and the single disc resulted in significantly fewer detections than all other targets but did not differ from each other. The camouflaged silhouette reduced detections by 12.1% as compared to human targets, and 14.5% as compared to the O.D. silhouettes.

c. The double disc resulted in significantly more detections than all other targets. A summary of these comparisons is shown in Appendix D.

Finally, the interaction between targets and sites was also highly significant ($F=5.33$; $df=5/90$; $P < 0.1\%$). The interaction was caused by the erratic results associated with three of the SVOs--the double disc, the single disc, and the O.D. cylinder--all of which yielded a relatively higher number of detections on site W and relatively lower number of detections on site V. These three SVOs are apparently more sensitive to site variations than are the remaining "man-shaped" targets.** However, in terms of similarity with human targets, these SVOs, used alone, would have exaggerated the differences between the two sites.

Visibility Gradients. Figure 7 compares visibility gradients between human targets and each SVO in turn. In each case, computed regression lines are shown instead of raw data. This was done to minimize sampling

* See definition of statistical symbols in Appendix E.

** This characteristic might be viewed as a "good" or a "bad" aspect of these SVOs, depending upon the objectives of the investigator.

fluctuations. The regression line for human targets is based on 2370 observations of 68 Os, which includes the 20 Os of the present study.

Table IV summarizes quantitative aspects of the various gradients. The linear correlation coefficients between percent detections and target distance are shown in the first column. These coefficients, in the high nineties, confirm that the empirical data for all targets are well fitted by a straight line.

TABLE IV

Comparison of correlation coefficients, regression equations, and discrepancies in visibility gradients between human targets and standard visibility objects.

Type Target	r_{xy}	Regression Equations	Average Discrepancies (Human vs. SVO)
Human Target	-.97	$Y'^{*} = 135.2 - 1.17(X)$	---
O.D. Silhouette	-.99	$Y' = 131.1 - 1.15(X)$	4.7%
O.D. Cylinder	-.98	$Y' = 124.6 - 1.05(X)$	6.0%
Double Disc	-.99	$Y' = 123.9 - 1.00(X)$	6.6%
Cam. Silhouette	-.95	$Y' = 114.3 - 1.02(X)$	11.9%
Single Disc	-.98	$Y' = 104.9 - 0.85(X)$	12.9%

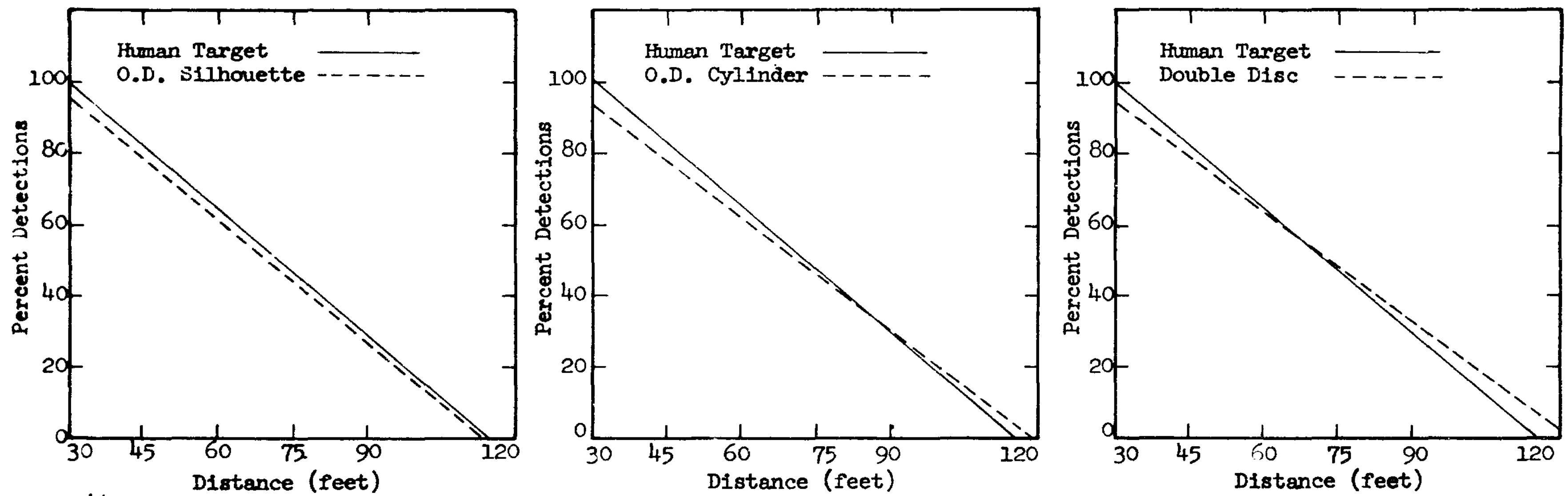
* A composite regression equation based on data from present study combined with data from past studies.

The regression equations predicting detection probability (Y') from knowledge of target distance (X) are shown in the second column. The first quantity in each equation represents the level of the gradient. The second quantity represents the slope, or steepness, of the gradient.

In the third column of Table IV, summary figures are shown which take into account differences both in level and slope. This summary is the simple percentage discrepancy, ignoring algebraic signs, between the predicted detections of the human target and the predicted detections of the SVO, averaged for the six target distances. Examination of Table IV and Figure 7 reveals the following:

The O.D. silhouette most closely approximated the human gradient in level and slope. The average discrepancy in percent detections per distance was 4.7%.

The O.D. cylinder had the second most similar gradient with an average discrepancy of 6.0%. The slope of the cylinder gradient was less steep than the slope for human targets, resulting in slightly lower



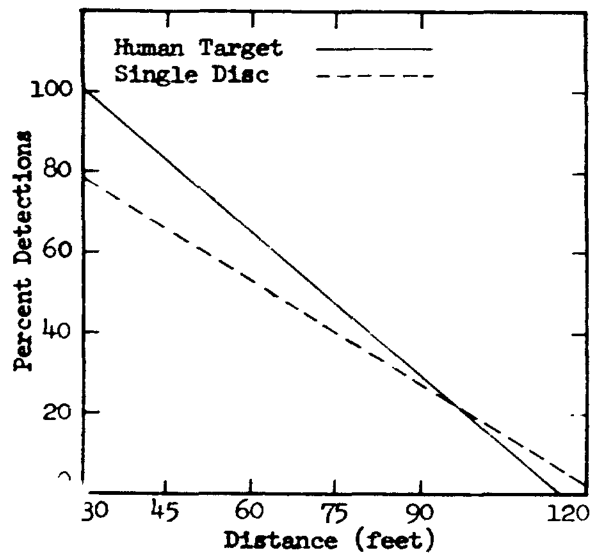
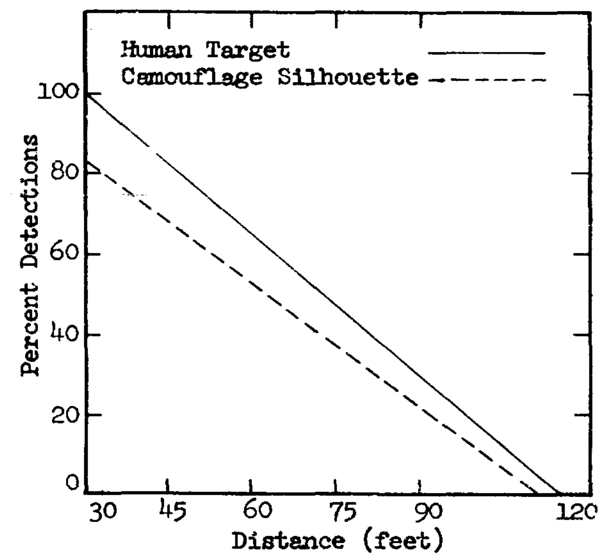


Figure 7. Visibility gradients for human targets compared to each standard visibility object (SVO gradients from combined data of two jungle sites).



detections at nearer target distances and slightly higher detections at distances farther than 90 feet.

The double disc had the third most similar gradient with an average discrepancy of 6.6% per target distance. The slope of this gradient was even less steep, resulting in underestimates of detections at distances nearer than approximately 70 feet and in overestimates beyond that distance.

The camouflaged silhouette ranked fourth in gradient similarity. The level and slope of the gradient were substantially below those of the human targets with an average discrepancy of 11.9% per target distance. The greatest advantage of camouflage cloth in reducing detections occurred at the nearer target distances.

The single disc ranked last in gradient similarity with an average discrepancy of 12.9% per target distance. The gradient of the disc was characterized by relatively low detectability at close target distances combined with a relatively flat slope that caused it to underestimate considerably the human gradient at distances nearer than 75 feet and overestimate it at the farther distances.

TABLE V

Standard deviations and correlation coefficients for human targets and standard visibility objects.

Type Target	Standard Deviations* (# Detections)	F-Ratio $\frac{\sigma_h^2}{\sigma_{svo}^2}$	r h vs. svo (# Detections)
Human Target	1.8	---	---
O. D. Silhouette	2.0	1.28	.81
O. D. Cylinder	2.2	1.48	.49
Cam. Silhouette	2.3	1.64	-.18
Double Disc	3.0	2.75**	.33
Single Disc	3.0	2.70**	.39

* Each standard deviation based on total number of detections of the same 20 Os.

** Significantly greater observer variability than the human target ($P < 5\%$).

Individual Observer Variability. Table V compares the standard deviations among the total number of detections for the 20 Os. (The maximum number of detections for each type target by a single O was 18.)

The SVOs were ranked as follows in terms of similarity to the observer variability elicited by human targets: O.D. silhouette (most similar), O.D. cylinder, camouflaged silhouette, with the single disc and the double disc tied as the least similar.

F-ratios were computed comparing the variance of each SVO in turn with the human target. It was found that the single disc and the double disc elicited significantly greater response variability than the human target. These two targets, offering smaller surface areas and higher color contrast, accentuated the distribution of individual differences in target detectability.

Although the standard deviation yields an index of the spread of individual responses, it yields no information concerning the relative detection proficiency of Os from one target to another. Pearson product-moment correlation coefficients were computed between total detections per O for human targets and each SVO in turn. The coefficient for the O.D. silhouette was high; the coefficient for the O.D. cylinder was moderate. The double disc and single disc yielded low but positive coefficients. The camouflaged silhouette showed essentially no relationship.

Thus, individual differences in detection proficiency were highly transferrable from human target to O.D. silhouette and moderately transferrable to the O.D. cylinder. Apparently, different Os used different detection cues for the remaining SVOs, resulting in the low coefficients obtained.

SUMMARY AND CONCLUSIONS

Table VI summarizes the results of the preceding four comparisons of the detectability characteristics between human targets and SVOs. Ranks indicate the similarity of the SVO to the human target, e.g., rank "1" is most similar, "5" least similar. Fractional ranks indicate ties. An average rank has been computed in the last column as a gross index of overall similarity.

a. O.D. Silhouette. The O.D. silhouette ranked overall as the SVO most similar to the human target. It ranked first in total detections, gradient, and observer variability. It ranked third in 50% detection thresholds even though an absolute difference of only 3.7 feet separated it from the human threshold. Of particular importance was the high similarity of the visibility gradients. The silhouette is considered interchangeable with the human target in visibility studies conducted in jungle vegetation.

b. O.D. Cylinder. The O.D. cylinder was the second most similar SVO to the human target. It ranked first in 50% detection thresholds and

TABLE VI

Summary of comparisons between human targets and standard visibility objects (ranks).

Type Target	50% Detection Thresholds	Total Detections	Visibility Gradient	Observer Variability	AVERAGE RANK
	Points of Comparison				
O.D. Silhouette	3.0	1.0	1.0	1.0	1.5
O.D. Cylinder	1.0	2.0	2.0	2.0	1.8
Double Disc	2.0	4.0	3.0	4.5	3.4
Single Disc	4.0	3.0	5.0	4.5	4.1
Cam. Silhouette	5.0	5.0	4.0	3.0	4.2

second in total detections, gradient, and observer variability. Its gradient was an excellent approximation to that of the human target. The only disturbing aspect of this SVO was its tendency to accentuate site differences. This result may have been peculiar to the present study, however, and was given no weight in the ranking. The cylinder is considered an adequate substitute for the human target for visibility studies in the jungle.

c. Double Discs (White). The double disc ranked third in overall similarity. It ranked second on the 50% detection threshold, third in gradient, fourth in total detections, and tied for last in observer variability. It differed significantly from the human target and all SVOs in total detections, and differed significantly from the human target in observer variability. The visibility gradient was only slightly less satisfactory than that of the O.D. cylinder. The double disc's chief dissimilarities, as compared to human targets, were in eliciting too many detections, too wide a range of individual observer differences, and in accentuating site differences. With some change in configuration--possibly varying the diameters of the discs, their heights, or color contrast--the SVO might substitute for the human target in jungle visibility work. The adaptation used in the present study is not considered an adequate substitute.

d. Single Disc (White). The single disc ranked fourth overall.* Its highest rank was third in total detections. It ranked fourth in detection thresholds, last in gradient, and tied for last in observer variability. It yielded significantly fewer total detections than the human

* The single disc ranked third overall if only the data from the present study are considered excluding data from previous studies. See last paragraph of this section.

target. Observer variability was significantly greater than that of the human target. Its gradient was characterized by a low level and flat slope and showed little correspondence to the human gradient. This SVO also accentuated site differences. The single white Secchi disc is not considered an adequate substitute for the human target in jungle visibility work.

e. <u>Camouflaged Silhouette</u>. The camouflaged silhouette ranked last in overall similarity. Although it ranked third in observer variability, it ranked very low in all points of comparison dealing with detectability. It ranked last in total detections, last in 50% thresholds, and fourth in gradients. It differed significantly from three SVOs and the human target in terms of total detections. Its gradient clearly demonstrated the effectiveness of the camouflage cloth in reducing visual detections even though <u>O</u>s knew exactly what they were looking for. It was particularly effective in inhibiting detections at the nearer target distances employed. Its low detectability was also consistent from one site to another. The camouflaged silhouette cannot be considered as a substitute for the O.D. garbed human target. In fact, this SVO differed drastically on most points of comparison from the remaining four SVOs.

The reader might reasonably question the use of the composite human target data on two of the comparisons--50% thresholds and visibility gradients, and the use of the data from the present study only on the remaining two comparisons--total detections and observer variability. Remaking the comparisons, using data from the present study only, results in only one change in the "average rank" shown in Table VI. The single white disc changes from rank four to rank three. The double disc drops to rank four. The sole reason for the change in ranks is the lower 50% threshold (66.0 ft) for the human threshold in the present study compared to the composite (72.3 ft). These adjusted ranks are 1.5, 2.0, 3.4, 3.9, and 4.2 for the O.D. silhouette, O.D. cylinder, single disc, double disc, and camouflaged silhouette, respectively. It is believed that the comparisons made using composite data are more reproducible based on strictly statistical considerations. However, it would probably be unjustified to select either of the disc type targets as superior to the other.

DISCUSSION

The O.D. silhouette is considered interchangeable with O.D. clothed human targets. The O.D. cylinder, slightly less desirable, is also considered an adequate substitute. The remaining SVOs--double discs, single disc, and camouflaged silhouette--are not considered adequate substitutes. The two SVOs with both surface area and color more similar to the O.D. clothed human target also provided detection data more similar to the human target. The two SVOs with smaller surface areas and higher color contrast tended to be less detectable than human targets at nearer distances and more detectable at the farther target distances.

From their field observations, the investigators believe that the explanation is simple. At nearer distances, the larger O.D. SVOs with their greater visual angles are not totally obscured by jungle vegetation, and thus remain detectable; however, as these SVOs are moved farther away from the O, the target form is broken up by the vegetation and the low color contrast becomes the dominant factor, making these SVOs relatively less detectable. The smaller, higher contrast SVOs are more easily obscured totally by smaller clumps of vegetation at the nearer distances; however, as these SVOs are moved farther away, an extremely small portion of the white disc(s) contrasted with the green surroundings is an effective cue for detection. In short, the evidence suggests that size of target is the more important detection cue at nearer target distances; color contrast is more important at farther target distances.

The camouflaged silhouette stands apart from all other SVOs in its detectability characteristics. In spite of its large surface area and human conformation, the mottled pattern effectively obscured the silhouette outline even at the nearer target distances employed.

After the present study was completed in draft form, it was brought to the attention of the authors that the 1948 pattern camouflage had received an earlier evaluation in a combat environment. Atkinson (3) concluded that the pattern was effective for combat operations in Vietnam based on questionnaire responses of ARVN unit commanders and individual soldiers. The quantitative data from the present study, together with the opinions of combat personnel in the ARPA study, should leave little room for doubt as to the value of the 1948 pattern in jungle operations.

Illumination. Table VII shows mean illumination measures taken with hand-held photometers both at the O's position and at each 60-feet distance marker on the three radii. Mean illumination for site V ranged from 17 foot-candles (fc) for the first group of Os tested in the mornings, to 34 fc for the second group tested. Corresponding means for site W were 15 to 21 fc. The reporting of means alone, however, obscures a wide range of illumination (from two fc to 100 fc) found on the sites. A t-test computed to compare mean illumination differences between sites was not significant ($t=1.46$; $df=18$; $P > 20\%$). This finding suggests that the different number of detections found for three of the SVOs at the two sites was caused by detectability characteristics of targets and/or vegetative differences, not the amount of incident light.

Another t-test was computed between the amount of light present for the first group of Os tested versus that present for the second group of Os tested later in the morning (a period of approximately 3-1/2 hours). The means (16.8 fc, first group, vs. 25.1 fc, second group) were significantly different ($t=2.44$; $df=18$; $P < 5\%$). To determine whether this small but statistically significant rise in illumination influenced detection performance, a t-test was then computed between the total number of detections for Os tested first versus Os tested second in the mornings.

These means (51.2 detections, first group, vs. 52.9 detections, second group) did not differ significantly ($t=0.96$; $df=18$; $P > 30\%$). Thus, the rise in illumination on both sites did not result in a corresponding rise in detections.

TABLE VII

Mean illumination in foot-candles taken on test sites (wet season).

(a) Eye level of observer

	Site V		Site W		Both Sites	
	fc	N*	fc	N	fc	N
First Test (0815 hrs to 1000 hrs)	17.7	10	19.9	12	18.9	22
Second Test (1015 hrs to 1200 hrs)	23.8	8	21.1	10	22.3	18

(b) 60-feet markers on radii

	Site V		Site W		Both Sites	
	fc	N*	fc	N	fc	N
First Test (0815 hrs to 1000 hrs)	17.4	30	15.2	36	16.1	66
Second Test (1015 hrs to 1200 hrs)	34.1	24	19.7	30	26.1	54
Weighted Mean	23.6	72	18.1	88	20.5	160
Range of Illumination	2-100 fc		5-50 fc			

* N refers to the number of illumination measures taken.

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The technique for selecting significant words, proposed by Oswald (47), has the following main features: (1) Insignificant viz. common words are deleted and only words that are significant in the context of the document are retained. (2) The retained words are frequency counted. (3) Next, every juxtaposition (of two or more words) involving a high-frequency word is recorded as a significant word group. The recording of such groups begins with those that contain the single word of highest frequency and continues until six successive Uniterm words, in order of descending frequency on the Uniterm frequency list, produce either no significant groups or no new significant groups. This rule produces auto-indexes whose lengths, although differing, usually lie within the limits of 1 to 3 percent of the total vocabulary of any given article.

Finally, special consideration should be given to the text condensation and index editing method by consolidating concept related words which are spelled in the same way at their beginning, such as elliptic and ellipticity. The procedure proposed by Luhn (32) is a statistical analysis routine consisting of a letter-by-letter comparison of pairs of succeeding words in the alphabetized list. From the point where letters failed to coincide a combined count was taken of the non-similar subsequent letters of both words. When this count was six or below, the words were assumed to be similar notions; above six, different notions. Although this method of word consolidation is not infallible, errors up to 5 percent did not seem to affect the final results.

1.2.2. Indexing by Assignment

This type of indexing presupposes categorization or classification of documents as the first step in the selection of indexing terms. Various approaches to automatic document categorization will be briefly surveyed here.

Maron's (36) method starts with selecting statistically cue words' from a sample population of documents previously assigned to certain categories by human indexers. The complete corpus consisted of 405 different documents and was divided into two groups. Group 1 contained 260 abstracts which appeared in the March and June issues of the 1959 IRE Transactions on Electronic Computers, and was the basis for the statistical data necessary to make the subsequent predictions. Group 2 consisted of 145 abstracts which appeared in the September 1959 issue of the Transactions and was used to test the system.

A classification system of 32 categories was created similar to, but not identical with, the classification system used in the IRE Transactions, and each one of the 260 documents of Group 1 was carefully read and "sorted" into one or more of the categories. In the majority of instances a document was indexed under a single category, but in about 20 percent of the cases a document was indexed under two categories, and in only a few cases under three categories. The highest number of documents in a single category was 37, and the lowest was 2.

Next, every word in each of the documents of Group 1 was keypunched. There was a total of over 20,000 word occurrences with an average of 79 words per document, and a total of 3,263 different words. The 55 most frequently occurring logical type viz. common words (e.g. the, of, a, etc.) accounted for 8,402 of the total (20,515) occurrences. Thus, less than 2 percent of the words accounted for over 40 percent of the total occurrences. They were rejected as candidates for cue words.

The most frequently occurring non-common words were considered next. This list contained words such as "computer,""system,""data," "machine," etc. They also were rejected as possible cue words because it was felt that they had little discriminating power to be cues for the specification of subject content within the general field of computers. Of the total 3,263 different words, 2,120 or 65% occurred less than three times in the 260 documents. They were also rejected as possible cue words because they were too specific (provided they were indicative of the contents of the document at all). This left just over 1,000 different words with neither a very high nor very low relative frequency of occurrence. A listing was made showing the number of times each of these 1,000 words occurred in the documents belonging to category 1, category 2, etc. Each word on the list was checked to determine whether or not it "peaked" in any of the 23 categories. If a word did peak it was felt that the word would be a good cue. If the distribution was flat for a given word, then it was rejected. An attempt was made to find at least one word to peak in each of the 32 categories. In this way, 90 different words were finally selected as cue words.

Then the problem was conceived as follows: Given that a document, say D_1, contains one or more cue words W_i, what is the probability that D_1 belongs to each of the categories C_1, C_2, C_3, and so on. Maron used the well known Bayes prediction equation to calculate these probabilities. For one cue word W_i, the equation is:

$$P(C_j|W_i) = \frac{P(C_j) \cdot P(W_i|C_j)}{P(W_i)}$$

$P(C_j)$ is the so-called a priori probability that a document will be indexed under the j-th category and $P(W_i|C_j)$ is the probability that if a document is indexed under the j-th category it will contain word W_i. For any W_i, the denominator $P(W_i)$ is a constant and hence the equation may be rewritten as follows:

$$P(C_j|W_i) = k \cdot P(C_j) \cdot P(W_i|C_j)$$

where k is a scaling factor. The value of $P(C_j)$ is estimated by counting the number of index entries that are made under the j-th category and dividing this by the total number of index entries. The values of $P(W_i|C_j)$ are estimated by counting the number of occurrences of the i-th word which belong to documents that were indexed under the j-th category and dividing through by the total number of cue word occurrences in all documents belonging to the j-th category.

In the general case where a document contains different cue words, W_k, W_m, ... W_s, the probability that the document belongs to the j-th category is computed as follows:

$$P(W_k, W_m, \ldots\ldots\ldots W_s, C_j) = k \cdot P(C_j) \cdot P(C_j, W_k) \cdot P(C_j, W_m) \ldots P(C_j, W_s)$$

The values of the left hand side of the above equation are called "attribute numbers." Thus, 32 attribute numbers are obtained for each document, one for each of the 32 categories.

It turned out that in the initial group of 260 documents, 12 documents contained none of the 90 cue words, and hence no automatic indexing was possible for these 12 documents. Also there was an error preventing one of the remaining documents from being automatically indexed. This left 247 documents. In 209 of the 247 cases (84.6%), the category with the greatest attribute number in each output list was a correct category. If the document had at least two cue words, then the probability that the category with the greatest attribute number is a correct one was 91 percent. In Group 2, which was the new input to be tested, of a total of 145 documents, 20 contained no cue words, and 40 contained only one cue word. This left 85 documents, each containing at least two different cue words. In 44 (51.8%) of these 85 cases the machine printed the correct category at the top of the output list, i.e. the category with the greatest attribute number was the correct category. The probability that the machine will print out the correct category in one of the first three positions was 80 percent.

A modified approach to evaluate the "goodness" of the cue words was proposed by Trachtenberg (59). It involves calculating for each potential predictor or cue word (a) the non-correlation factor of word occurrence category, or the uncertainty of category given the occurrence of a word W_i in a document

$$H_i = -\sum_j p_{ij} \log p_{ij} \qquad 0 \leq H_i \leq \log k$$

where p_{ij} is the probability that a document with the word W_i falls into the category C_j,

and (b) a special measure involving the log of the ratio of the a posteriori to the a priori probability, viz.

$$M_i = \sum_j p_{ij} \log \frac{p_{ij}}{p_j}$$

A word that has a high value for M_i and a low value for H_i would be selected as the cue word.

Similar procedures were proposed to treat word frequency information. The corresponding equations are:

$$H_i\ (f_s) = -\sum_j p_{ij}\ (f_s) \log p_{ij}(f_s)$$

$$M_i\ (f_s) = \sum p_{ij}\ (f_s) \log \frac{p_{ij}\ (f_s)}{p_j}$$

where f_s is the range of the values of relative frequency of a word appearing in a document to the total number of words in that document, and $p_{ij}(f_s)$ is the probability that the document falls in category C_j given that the

APPENDIX A

Sequence of appearance of the 36 target triads.

Detection Trial	RADIUS I	RADIUS II	RADIUS III
1	Sc/60*	H/120	o/50
2	S/50	00/50	H/90
3	C/30	Sc/120	S/120
4	00/75	H/90	H/30
5	Sc/50	C/60	C/30
6	00/120	H/75	00/50
7	o/50	00/60	Sc/50
8	H/75	S/120	H/75
9	S/120	S/75	Sc/60
10	S/60	Sc/30	00/60
11	00/60	S/60	o/75
12	H/90	C/50	S/75
13	o/30	H/30	S/30
14	o/120	00/120	C/60
15	C/75	00/75	H/60
16	C/60	o/50	S/60
17	00/50	Sc/60	C/75
18	Sc/30	o/90	S/90
19	H/60	Sc/50	o/60
20	H/120	S/90	S/50
21	00/90	o/120	00/120
22	H/50	Sc/90	00/75
23	C/120	H/50	H/120
24	S/30	o/30	Sc/75
25	Sc/75	C/30	C/90
26	00/30	00/30	Sc/90
27	H/30	C/90	H/50
28	S/90	00/90	Sc/120
29	o/90	Sc/75	o/120
30	o/75	C/120	C/50
31	Sc/90	S/30	o/90
32	C/90	C/75	00/90
33	S/75	S/50	Sc/30
34	o/60	o/75	00/30
35	C/50	H/60	o/30
36	Sc/120	o/60	C/120

Legend:

S= O. D. Silhouette
o= Single Disc
00= Double Disc
Sc = Silhouette, camouflaged
C= O. D. Cylinder
H= Human Target

* Numbers refer to target distances in feet.

APPENDIX B

Sequence of Observers
Tested on Two Different Sites

Observer Number	Site	Test Day
1	W	1
2	W	1
3	V	2
4	V	2
5	W	3
6	W	3
7	V	4
8	V	4
*9	W	5
10	V	6
11	V	6
12	W	7
13	W	7
14	V	8
15	V	8
16	W	9
17	W	9
*18	V	10
19	W	11
20	W	11

* one observer only: second not available for test.

APPENDIX C

Instructions given to O by E prior to start of each test session.

*THIS IS A RESEARCH TEST OF THE US ARMY TROPIC TEST CENTER. WE ARE TRYING TO FIND OUT HOW WELL YOU CAN SEE DIFFERENT KINDS OF TARGETS THROUGH THE JUNGLE FOLIAGE. YOU WILL STAND IN THIS MARKED SQUARE (demonstrate). TARGETS WILL APPEAR FROM NINE O'CLOCK (point) TO THREE O'CLOCK (point)--AS MARKED BY THESE TWO ARROWS. (Show pictures of targets.) SIX TARGETS IN ALL WILL BE USED, INCLUDING THE SILHOUETTE (point), CAMOUFLAGED SILHOUETTE (point), CYLINDER (point), SINGLE WHITE DISC (point), DOUBLE DISC (point), AND LIVE HUMANS (point). THERE WILL ALWAYS BE THREE TARGETS AT A TIME. FOR EXAMPLE, THERE MIGHT BE THREE SILHOUETTES AT THE SAME TIME OR ONE CYLINDER, ONE SINGLE DISC, AND A HUMAN TARGET--IN SHORT, ANY COMBINATION OF THREE TARGETS. THEY WILL BE SPREAD OUT AT ANY POINT BETWEEN NINE O'CLOCK AND THREE O'CLOCK AND WILL OFTEN APPEAR AT DIFFERENT DISTANCES FROM ONE ANOTHER. SO, REMEMBER TO SEARCH THE ENTIRE AREA.

WHEN THE TEST BEGINS YOU WILL STAND--FACING ME (demonstrate)--AND WHEN I GIVE YOU THE SIGNAL, YOU ARE TO TURN AROUND AND SEARCH FOR THE TARGET. YOU MAY CROUCH, KNEEL, OR EVEN LIE DOWN, PROVIDING YOU DON'T MOVE YOUR HEAD OUT OF THE BOX (demonstrate).

IF YOU SPOT ANY OF THE TARGETS, POINT AT IT AND TELL ME WHAT IT IS. IF YOU HAVEN'T SPOTTED ALL OF THEM IN TWO MINUTES, I WILL TURN YOU AROUND AND SCORE ONLY THE NUMBER YOU SPOTTED. IF YOU THINK YOU SEE TARGETS, BUT ARE DOUBTFUL, GO AHEAD AND GUESS--THERE WILL BE 36 TRIALS IN ALL, AND THE TEST WILL LAST ABOUT TWO HOURS. WE ARE GOING TO ASK YOU TO WEAR THIS PAIR OF EAR PROTECTORS DURING THE TEST. YOU MAY SMOKE IF YOU WISH. WE WILL HAVE A BREAK HALFWAY THROUGH THE TEST. ARE THERE ANY QUESTIONS?

* Read the Capitalized Material Only.

APPENDIX D

Significance Test applied to the mean number of detections per observer for the six types of targets (Duncan's New Multiple Range Test)

	Targets							
	Sc	o	H	S	C	OO	Shortest Significant Ranges	
Means	7.65	8.05	8.70	8.95	9.05	9.55	1%	5%
Sc 7.65	----	.40	1.05**	1.30**	1.40**	1.90**	R_2 = .563	.425
o 8.05		----	.65**	.90**	1.00**	1.50**	R_3 = .587	.447
H 8.70			----	.25	.35	.35**	R_4 = .604	.462
S 8.95				----	.10	.60**	R_5 = .616	.473
C 9.05					----	.50*	R_6 = .625	.481

Legend: Sc = Camouflaged Silhouette; O = Single Disc; H - Human Target; S = Silhouette; C = O. D. Cylinder; OO = Double Disc.

* 5% Confidence Level
** 1% Confidence Level

Previous pages were blank, therefore not filmed.

APPENDIX E

Definitions of Statistical Symbols

F-ratio:	This ratio is derived from the analysis of variance. The analysis of variance yields the probability that the variation in a set of means may be attributed to random sampling from a common, normally distributed population. In small samples, the F-ratio is also used to compare differences between two standard deviations by comparing their variance ratios.
Duncan's New Multiple Range Test:	Following analysis of variance, the investigator frequently wishes to determine whether specific means from a set of means differ from one another. Duncan's method allows for such determinations using as the standard error of the mean the square root of the error mean square from the analysis of variance.
Probability (P):	This symbol refers to the level of confidence which may be placed in the statistical significance of values derived from many different types of statistical tests and measures.
Degrees of Freedom (df):	Degrees of freedom are related to the number of observations entering into a particular test of significance. To some extent, the degrees of freedom determine the level of confidence placed in the results of the analysis.
Standard Deviation (σ):	This is a measure of the variability of individual values in a frequency distribution around the mean value.
Coefficient of correlation (r_{xy}):	The Pearson Product-Moment correlation coefficient is a measure of the extent to which variables tend to vary together. A coefficient of ".00"

indicates the variables fluctuate independently of each other. A coefficient of ± "1.00" indicates that the variables are perfectly related.

Regression line ($Y' = a+bX$): This is a predicted function of line which yields the best average fit of empirical data to the line. In a two-variable linear equation, there are two parameters involved--the level ("a" coefficient) and the slope ("b" coefficient).

Weighted mean: This is the grand mean of a series of individual means weighted by the total number of observations entering into the computation of the individual means.

a. View at site V from observers position.

2

b. View of site W from observers position.

FIGURE 4. VIEWS OF TWO EVERGREEN RAINFOREST SITES.

m

4

Unclassified

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) US Army Tropic Test Center Fort Clayton, Canal Zone	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE JUNGLE VISION VI: A COMPARISON BETWEEN THE DETECTABILITY OF HUMAN TARGETS AND STANDARD VISIBILITY OBJECTS IN AN EVERGREEN RAINFOREST.

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

5. AUTHOR(S) (Last name, first name, initial)

Dobbins, D. A., and C. M. Kindick

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
February 1966		15

8a. CONTRACT OR GRANT NO. DA-96-519-SCAR-2303	9a. ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT NO. DA 1L013001A91A	Research Report #6
c. USATECOM 9-6-0069	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d. Work Unit: USATTC #001	

10. AVAILABILITY/LIMITATION NOTICES Each transmittal of this document outside the agencies of the US Government must have prior approval of the US Army Test and Evaluation Command.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
Only data collection done by contract --this is In-House-Research	US Army Tropic Test Center Fort Clayton, Canal Zone

13. ABSTRACT The purposes of this study were (a) to compare the interchangeability of human targets and several standard visibility objects in jungle visibility studies, and (b) to quantitatively evaluate the effectiveness of one US Army camouflage pattern in reducing visual detection in the jungle.

Twenty US Infantry soldiers with normal vision were presented 108 targets at distances ranging from 30 feet to 120 feet on two sites in a Canal Zone evergreen rainforest. Observers were presented 18 each of the following targets: olive drab silhouettes, olive drab cylinders, double white discs, single white discs, silhouettes camouflaged by the USAERDL four-color 1948 pattern, and human targets in fatigue uniforms. Tests were conducted in September and October, 1965, toward the latter part of the wet season.

Comparisons between human targets and standard visibility objects were made using four criteria: 50% detection thresholds, total number of detections, visibility gradients, and observer response variability. Quantitative comparisons showed that both the olive drab silhouette and the olive drab cylinder closely approximated the detectability of the human targets; of the two objects, the silhouette was considered superior. Neither the double white discs nor the single white disc closely approximated the detectability of human targets. The evidence suggested that target size was the more important detection cue at near distances, and color contrast the more important at farther distances.

The USAERDL four-color camouflage cloth effectively and significantly reduced detections by ground observers in jungle vegetation.

DD FORM 1 JAN 64 1473

Unclassified

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Standard Visibility Objects						
Camouflage cloth						
Human Detection						
Target Detection						
Tropical Regions						
Ambient Illumination						
Vision						
Test Methodology						
Jungles						
Performance, human						
Visibility measurement						

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