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Research Report No. 5

JUNGLE VISION V:

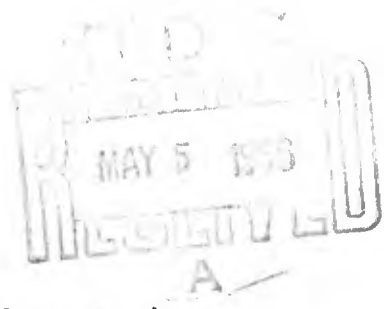
Evaluation of Three Types of Lenses  
as Aids to Personnel Detection in a  
Semideciduous Tropical Forest

by

D. A. Dobbins and C. M. Kindick

December 1965

USATECOM Project 9-6-0069  
DA Project LL013001A91A 00 001  
(An In-House Laboratory Independent Research Project)



US ARMY  
TROPIC TEST CENTER  
Fort Clayton, Canal Zone

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## ABSTRACT

The purpose of this study was to evaluate nonmagnifying yellow, red, and dichroic lenses as aids to personnel detection in a tropical semideciduous forest. Twenty-four US infantry soldiers with normal visual acuity were selected as observers. Four subgroups of six EM each were then assigned to observe either with yellow lenses, red lenses, dichroic lenses, or unaided vision. Each observer was presented 40 randomly appearing human targets in fatigue uniforms who stood motionless within a 180° horizontal field of search. Tests were conducted on two sites during the wet season (August 1965) in the tropical semideciduous forest characteristic of the Pacific slope of the Canal Zone.

None of the lenses facilitated target detectability as measured by 50% visual thresholds, visibility gradients, or total detections when compared to unaided vision. Furthermore, no significant differences among modes of observation were found for target search time, perceived target distance, or practice gradients. Considerable difficulty was experienced with the condensation of moisture on the insides of lenses fitted both in spectacle and goggle type frames.

The two sites used differed significantly, both in intrinsic difficulty of target detectability and in levels of ambient illumination. Illumination, however, was not directly related to visual threshold differences between the sites. Temporal variations in ambient illumination on the same site are also presented.

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## FOREWORD

This is the fifth 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 LL013001A91A, USATECOM Project 9-6-0069, TTC Work Unit #001).

The primary purpose of these studies is to provide a baseline of quantitatively sound data concerning the visual capabilities of the soldier in the jungle. From the standpoint of the test and evaluation mission of the Center, these data afford standards for evaluating tropic tests involving various types of personnel detection aids. Moreover, the test techniques developed for measuring visual thresholds in the field are also applicable for testing equipment designed to enhance visual capabilities. In fact, the present study and one previous study departed from the preceding three by evaluating the feasibility of a commercial visual aid for jungle use.

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

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

The authors acknowledge the technical advice and free materials furnished by Bausch & Lomb, Inc., to make this study possible. The field work of the present study was accomplished under contract by the Weather Engineers of Panama Corporation. M. Gast and R. Ah Chu of the Tropic Test Center assisted in the inventory of vegetation and in the art work.

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

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## BRIEF OF RESULTS

The purpose of this study was to evaluate the effectiveness of non-magnifying yellow, red, and dichroic lenses in aiding personnel detection in the tropical semideciduous forest. These lenses filter out segments of the visible spectrum and are used commercially to enhance color contrast, visual texture, and form perception. A previous study had shown that lighter yellow lenses (not used in the present study) actually degraded visual thresholds in an evergreen rainforest. Even so, there remained a possibility that the different types of lenses used in the present study could enhance target detectability in yet another type of tropical forest, whose vegetation and light levels differ substantially from those of the evergreen rainforest. The potential importance of the application merited further study.

Twenty-four US infantry soldiers with normal visual acuity were assigned to one of four modes of observation: yellow lenses, red lenses, dichroic lenses, and unaided vision. Half of the observers were tested on one jungle site; the remaining half were tested on a separate jungle site. Each observer was presented 40 randomly appearing human targets within a 180° field of search. The targets, who were dressed in standard fatigue uniforms (OG-107), stood motionless on predetermined distance markers facing the observer. Testing was conducted in the tropical semideciduous forest during the rainy season. Target detection performance of observers equipped with the three types of lenses was compared with that of observers with unaided vision. The major results are summarized as follows:

### Effects of Lenses

1. The 50% visual thresholds (i.e., distance at which 50% of the targets were detected), visibility gradients, and total detections did not differ significantly among the four modes of observation. Thus, the employment of lenses neither enhanced nor degraded target detectability as compared to unaided vision. These results were consistent for two jungle sites even though the sites differed significantly in intrinsic difficulty of target detectability and in ambient illumination levels.

2. No significant differences associated with mode of observation were found for target search times, perceived target distances, or practice gradients.

3. A side effect of the study pointed up some difficulties in the use of any goggle or spectacle type optical aid in the humid tropics. Because of the vapor emitted by the human eye into ambient air already near saturation, moisture condensed quickly on the inner surface of the lenses. This effect was only temporarily alleviated by the use of a standard chemical applicant.

It is concluded that nonmagnifying yellow and red lenses with 50% transmission at 460 and 580 millimicrons, respectively, and dichroic

lenses with 0% transmission in the 575-590 millimicrons range cannot be recommended as aids to personnel detection in a semideciduous tropical forest. These lenses afford the observer no visual enhancement beyond that of the naked eye, but introduce the additional problem of lens fogging. This conclusion is not generalized beyond the experimental conditions specified in the present study.

#### Effects Independent of Lenses

4. The two sites differed significantly in difficulty of target detection as measured by the mean 50% visual thresholds. The threshold for Site D was 59.7 feet; the threshold for Site E was 67.4 feet. These results are probably caused by greater variability of eye-level vegetation in the semideciduous forest as compared to the evergreen rainforest.

5. Visibility gradients for all modes of observation on both sites were of the same general conformation (essentially a reverse "S") found in the semideciduous forest in past studies. This gradient appears to be characteristic of this type of vegetation and was independent of the mode of observation.

6. Significant differences in levels of ambient illumination were found between sites. This variation is due to the incomplete and variable canopies encountered in the semideciduous forest. However, targets were more easily detected on the darker site. Thus, the levels of ambient illumination were not proportional to the average visual thresholds for the two sites. The investigators feel that differences in vegetation are so dominant a screening factor as to nullify the effects of illumination within the range of levels encountered in the present study.

7. Continuous recordings of vertical illumination at a fixed location on one site showed highly variable levels from day to day and from hour to hour on the same day. This variation is due to the rapidly changing cloud cover which characterizes the wet season tropics.

## INTRODUCTION

Little quantitative data exist on visual thresholds or visibility gradients 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 the fifth of this series and represents an extension of exploratory work with tinted lenses reported in the fourth study. The present study investigates the feasibility of using several types of commercially available, nonmagnifying lenses as aids to target detection in the jungle.

## BACKGROUND

In the Tropic Test Center's first vision study, Jungle Vision I (1), visual thresholds and gradients were measured in a semideciduous tropical forest during the dry season. In the second study, Jungle Vision II (2), visual thresholds and gradients were investigated in an evergreen rainforest during the wet season. In the third study, Jungle Vision III (3), the effects of seasonal variation on target detectability in an evergreen rainforest were investigated.

In the fourth study, Jungle Vision IV (4), the effects of yellow lenses on target detectability in an evergreen rainforest were explored. The study was conducted toward the end of a severe dry season. Twelve infantry observers (Os) with normal vision, using spectacles fitted with yellow lenses (50% transmission at 510 millimicrons), were each presented 45 randomly appearing human targets within a 180° field of search.

(1) Dobbins, D. A., and M. Gast. Jungle Vision I: Effects of distance, horizontal placement, and site on personnel detection in a semideciduous tropical forest, US Army Tropic Test Center Rep, Fort Clayton, Canal Zone, Apr 1964.

(2) Dobbins, D. A., and M. Gast. Jungle Vision II: Effects of distance, horizontal placement, and site on personnel detection in an evergreen rainforest, US Army Tropic Test Center Rep, Fort Clayton, Canal Zone, Nov 1964.

(3) Dobbins, D. A., M. Gast, and C. M. Kindick. Jungle Vision III: Effects of seasonal variation on personnel detection in an evergreen rainforest, US Army Tropic Test Center Rep #3, Fort Clayton, Canal Zone, May 1965.

(4) Dobbins, D. A., M. Gast, and C. M. Kindick. Jungle Vision IV: An exploratory study on the use of yellow lenses to aid personnel detection in an evergreen rainforest, US Army Tropic Test Center Rep #4, Fort Clayton, Canal Zone, Jul 1965.

Testing was conducted on three sites. Results were compared with those of 18 Os tested on the same jungle sites under identical conditions, but without lenses. The comparisons resulted in the following findings:

a. Yellow lenses significantly degraded target detectability as measured by the 50% visual thresholds of individual Os. The average extent of degradation was approximately 10 feet.

b. In terms of percent detections for all distances on all three sites, the group with yellow lenses detected seven percent less targets than the group with unaided vision. The difference was not statistically significant.

It was concluded that the glasses could not be recommended for use under the conditions of the study. These conditions included immobile, stationary targets of low contrast, viewed by ground observers in horizontal free search through eye-level vegetation.

The present study was designed to test three different types of lenses in another major type of tropical forest--the semideciduous. The semideciduous forest is characterized by generally higher levels of ambient illumination but more dense, eye-level vegetation than the evergreen rainforest (1). These differences between forests have yielded different visibility gradients.

#### OBJECTIVES

The objectives of the present study were as follow:

a. To explore the feasibility of using three types of nonmagnifying, tinted lenses to aid personnel detection in a tropical semideciduous forest.

b. To continue accumulation of normative data on visibility in tropical forests.

#### METHOD

Lenses. The following lenses were used in the present study:

a. Yellow lenses fitted in molded neoprene (chemical) goggles with 50% transmission at 460 millimicrons.

b. Light red lenses fitted in spectacles with 50% transmission at 580 millimicrons.

(1) Dobbins, D. A., and M. Gast. Jungle Vision II: Effects of distance, horizontal placement, and site on personnel detection in an evergreen rainforest, US Army Tropic Test Center Rep, Fort Clayton, Canal Zone, Nov 1964.

The rationale for the use of these two lens types was that each of these lenses inhibits transmission of the shorter wavelengths (blues and greens) to different extents. Since the reflected spectrum within the jungle is predominantly green in color, the lenses were considered as good possibilities for enhancing target contrast, target texture, and apparent brightness sufficiently to increase target detectability. These lenses have many commercial applications, to include inspection, hunting, and marksmanship. They are particularly recommended for low illumination environments.

c. Dichroic lenses fitted in spectacles with a sharp cut-off followed by a sharp rise in the yellow-orange (0% transmission from about 575 to 590 millimicrons) portion of the visible spectrum. These lenses are similar to ordinary sunglasses.

The rationale for the use of dichroic lenses was that inhibition of the middle portion of the visible spectrum would accentuate contrast of colors at the extremes even at the expense of inhibiting large portions of both short and long wavelengths. The net effect of these lenses is to make the observer artificially color blind for certain colors, thus forcing him to use form perception as his primary detection cue. These lenses were considered to have a potential usefulness in the semideciduous forest because of its characteristically high levels of ambient illumination.

Observers. Twenty-four Os were tested. Observers were members of the 4th Battalion, 10th Infantry. All Os were pretested with an Ortho-Rater vision tester to insure normal near and far vision.

Comparison of experimental groups by selected attributes is shown in Table I. The groups were approximately comparable in all respects.

Targets. Targets were three contract personnel dressed as US Army soldiers in standard fatigue uniforms (OG-107) without insignia, including jacket, cap, and bloused trousers. The targets had their faces blackened with charcoal. 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.

Experimenter. The experimenter (E), provided by a contractor, controlled testing on all sites. The E gave all instructions to Os, scored detections, and recorded distance estimations and detection times. The E also operated illumination equipment and supervised target deployment.

Independent Variables. Three independent variables were investigated: mode of observation (lenses vs. unaided vision); eight target distances (from 30 to 115 feet) along each radius; and horizontal target placement (five radii) in O's field of search (180°). See Figure 1 for layout of test site. These three variables were replicated across two sites.

TABLE I

Characteristics of observers.

	Yellow Lenses (N=6)	Red Lenses (N=6)	Dichroic Lenses (N=6)	Unaided Vision (N=6)	TOTAL (All Os) (N=24)
Mean Age (years):	21.8	21.5	22.3	21.8	21.9
Age Range (years):	20-24	18-23	18-25	21-24	18-25
Mean Length of Service (months):	34.0	28.2	25.5	24.3	28.0
Range of Grades:	E3 to E4	E3 to E4	E2 to E5	E2 to E3	E2 to E5
No. EM in Combat MOS:	4/6	4/6	6/6	3/6	17/24

Test Sites. Two sites were selected. They were laid out according to Figure 1, with one exception. Radius V of site D\* was only 15°, rather than 30°, from radius IV to avoid irregular terrain. These sites had never before been used in the present series of studies. The use of multiple sites was done from the standpoint of generalizing lens effects.

The two sites were selected to meet the same criteria used in preceding studies, including: apparent representativeness of vegetation; terrain sufficiently flat so as not to interfere with vision; and target radii laid out to insure that no target was completely hidden behind tree trunks.

Both of the sites used for this study were second growth, semideciduous tropical forests. Because the study was conducted during the wet season, the maximum amount of foliage was present. The slight flow of air under the canopy rarely was sufficient to move the leaves at eye level. At both sites, the soil was a brownish clay that was wet and slippery. A mat of partially decomposed leaves about one-half inch thick covered the soil in the undisturbed parts of the courses.

\* All sites used in this series of studies are coded by a simple letter designation. Sites A, B, and C were used in a previous study.

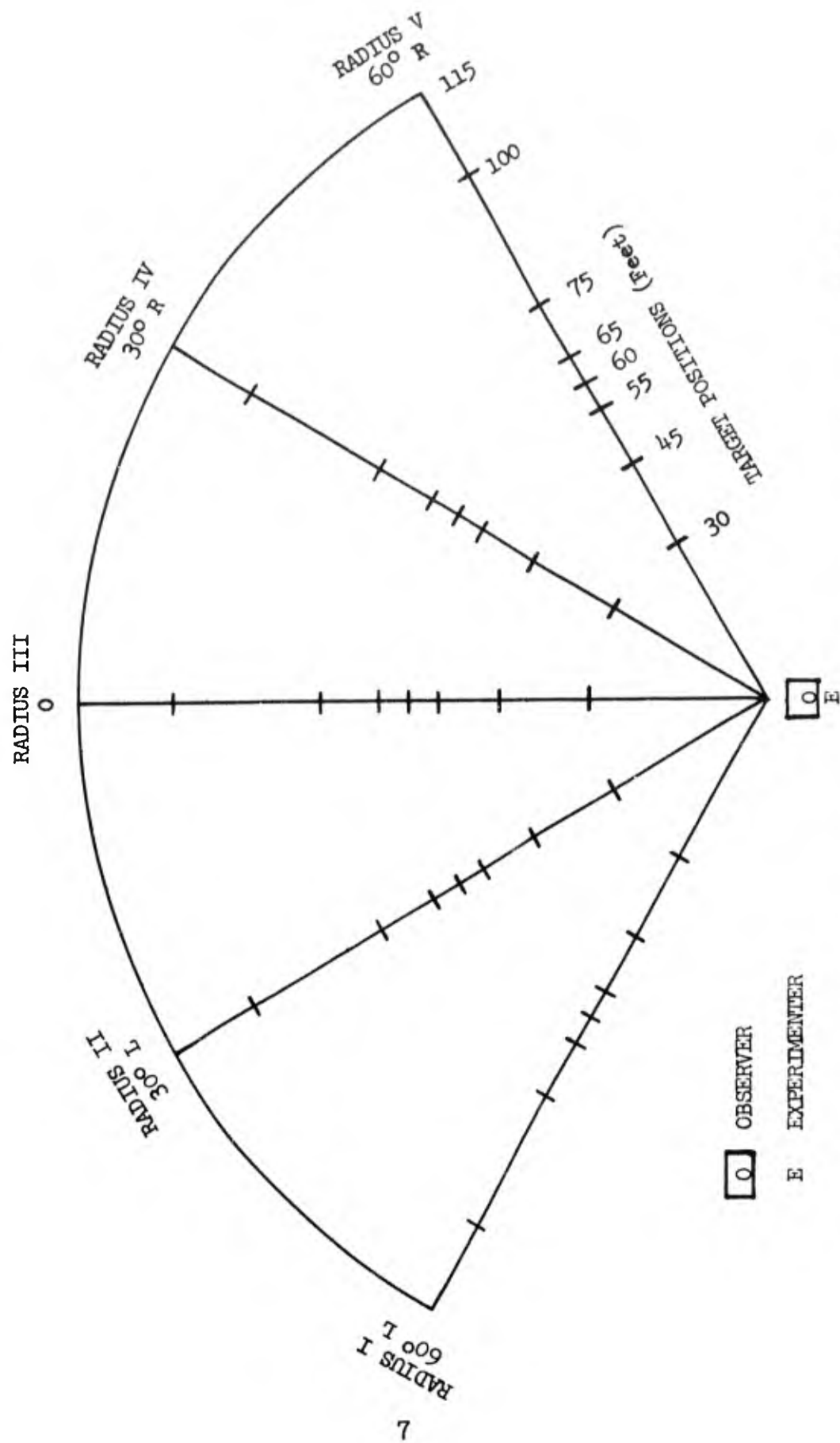


FIGURE 1. SKETCH OF THE TWO TEST SITES SHOWING TARGET DISTANCE AND PLACEMENT.

a. Site D. Site D was located within the Fort Clayton military reservation on a secondary road approximately 0.4 miles from the intersection with highway C-12, at grid coordinates 17P-PV-581957. Radius III of site D faced due west from the observer square. (See Figures 2 and 2A inside back cover of report.) The ground at this site sloped upward from the observer's position. The slope was 5% up to about 50 feet; beyond that, it was 15%.

Most of the trees at the site were less than 60 feet tall, and they formed a very irregular canopy. Espave (Anacardium excelsum), Amarillo (Lafoensia puniceifolia), and Guarumo (Cecropia sp.) comprised most of the larger trees. Completing the upper story were several specimens of wild fig (Ficus insipida). Stilt roots of the Cecropia balanced the bases of these trees as much as five feet above the ground.

Below the top canopy was a second story of randomly spaced trees 25 to 35 feet in height. Caimito (Chrysophyllum cainito), Guacimo Colorado (Luehea seemannii), and young Cecropia were the principal trees represented. Stilt roots had not yet developed on the Cecropia at this level.

Although the crowns of all of the trees were full, there were many openings through which sunlight could reach the ground. Moreover, radii IV and V, between about the 50 and 80 feet target distances, had almost no canopy cover. In this part of the course, as would be expected, the eye-level undergrowth was very dense. Throughout the rest of the site, the eye-level vegetation was fairly evenly spaced and quite uniform. Piperaceae, Rubiaceae, Heliconia, Corozo oleifera, and Caperaceae were predominant among the variety of plants present. Numerous leafy vines, ranging from very thin herbaceous types to two-inch thick woody lianas, crisscrossed the entire area.

b. Site E. Site E was located within the Fort Clayton military reservation on a secondary road approximately 0.6 miles from the intersection with highway C-12, at grid coordinates 17P-PV-601941. Radius III of site E faced in a southeasterly direction from the observer square (see Figures 2 and 2A inside back cover of report). A smooth upward slope of 7% from the observer's position to 115 feet characterized the ground at this site.

Site E was more full than site D at the treetop level. (This resulted in significantly less illumination on the test site. See "Illumination" section.) For the most part, the trees forming the upper story were between 40 and 50 feet tall, with a few reaching as high as 70 feet. Espave (Anacardium excelsum) were the most numerous of the larger trees. Wild fig (Ficus insipida) and Indio Encuero (Bursera simaruba) were present in small numbers.

Plants with numerous small leaves, primarily Rubiaceae, comprised nearly all of the undergrowth at this site. Many of these plants were less than five feet high.

Site E had, on the average, fewer eye-level plants than site D. However, site E contained a large number of lianas. A dozen or more lianas, one to three inches in diameter, extended from the ground to the lower branches of almost every tree.

Dependent Variables. Three performance measures were used. The first measure was the 50% detection threshold, which is the distance that a target is detected on 50% of the trials. The second measure was distance estimation of detected targets. The third measure was search time required to detect a target.

Research Design. The research design is summarized in Table II. Four subgroups of six Os each, comparable in far and near visual acuity, were assigned randomly to one of the four modes of observation. Three Os from each subgroup were then randomly assigned to a different site for testing. Thus, any comparison made among modes of observation includes an equal number of Os, an equal number of observations, and an equal number of observations on each site. An observer tested under any observation mode was presented 40 targets which appeared randomly with respect to target distance and horizontal placement (radii). (See Appendix A for sequence of target presentation.) Target presentations totalled 240 for each mode, equally distributed among ten radii on two test sites. Thus, the only difference in test conditions among the 24 Os was the mode of observation employed, type of lens or unaided vision.

Procedure. Illumination measures were taken at all Os' eye levels and at the midpoint of each radius with a hand-held, GE type 213 light meter immediately before and after each O was tested.

In addition, for the first time in these studies, an attempt was made to continuously record vertical illumination during each test session. The latter measures were taken by means of an Eppley Illuminometer placed in the approximate center of the test sites on a small wooden platform five feet from ground level (see Figure 3). Recordings were made continuously by means of a Speedomax H strip chart recorder located 60 to 75 feet distant, directly behind the E (see Figure 4). The power source was provided from a vibration type, DC-AC inverter supplied by two 12-volt, wet cell batteries connected in series.

Testing was conducted between 9 and 24 August 1965. Two Os were tested daily, one at a time. The first O was tested from approximately 0830 to 1000 hours daily; the second O was tested from approximately 1015 to 1130 hours daily. The sequence of testing is shown in Appendix B. All four observation modes were used during each two-day block of testing to counterbalance possible phase effects.

The E read from a standardized set of instructions and informed O that this was a test of his ability to spot targets in a jungle environment. If the O was to be tested with lenses, he was told that his performance would be compared with that of other observers either wearing

TABLE II

## Research design of Jungle Vision V

Number Observers	Site	Mode of Observation					Total (n)*
		Yellow Lenses					
		Radius					
		<u>I</u>	<u>II</u>	<u>III</u>	<u>IV</u>	<u>V</u>	
3	D	24	24	24	24	24	120
3	E	24	24	24	24	24	120
		Red Lenses					
		Radius					
		<u>I</u>	<u>II</u>	<u>III</u>	<u>IV</u>	<u>V</u>	
3	D	24	24	24	24	24	120
3	E	24	24	24	24	24	120
		Dichroic Lenses					
		Radius					
		<u>I</u>	<u>II</u>	<u>III</u>	<u>IV</u>	<u>V</u>	
3	D	24	24	24	24	24	120
3	E	24	24	24	24	24	120
		Unaided Vision					
		Radius					
		<u>I</u>	<u>II</u>	<u>III</u>	<u>IV</u>	<u>V</u>	
3	D	24	24	24	24	24	120
<u>3</u>	E	<u>24</u>	<u>24</u>	<u>24</u>	<u>24</u>	<u>24</u>	<u>120</u>
24		192	192	192	192	192	960

\*n - Number of observations or detection trials.

different types of glasses or with unaided vision. Each O to be tested with lenses was given a familiarization trial in order to observe the target both with and without the glasses. The O was also informed that targets would appear at any point from nine o'clock to three o'clock (180°). The O was informed that he had two minutes to make a detection. The O was fitted with HEAR-GUARD Model 1200 ear protectors to minimize audible location and distance cues. The O was urged to guess when he was unsure of the location of the target. (See detailed instructions to Os in Appendix C.)



Figure 3. Illumination sensor on test site.



Figure 4. Recording apparatus for Illuminometer.

Before the appearance of the first target, E instructed O to turn around facing away from the site. The E signalled one target into the first position. The first target took his place at a pre-emplaced distance marker on a predetermined radius as shown in Appendix A, then stood immobile facing the O. The target gave a whistle signal informing E that he was in position. The E then instructed the O to face the site.

The O was confined to a marked three-foot square as shown in Figure 5. 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 and give a distance estimate when he detected a target. He was not informed as to the correctness of his attempted detections.



Figure 5. Observer equipped with lenses and experimenter.

After the first trial, E again instructed the O to turn around facing away from the site and announced to the targets by number code the next radius-distance combination. Two of the three targets were always out of sight while the other assumed the assigned position. The preceding sequence was repeated until O completed 40 observations. One rest pause of five minutes was allowed between the 20th and 21st observations. The average time to complete a single test was approximately one and one-half hours.

Throughout the tests, considerable difficulty was experienced because of lens fogging and perspiration; this was particularly true for the poorly ventilated yellow lenses set in neoprene goggles. This effect is caused by the vapor emitted by the human eye into ambient air already near saturation, which results in condensation on the inner surface of the lenses. Therefore, all lenses were treated with "Anti-Dim" cloth (usually used for protective masks) prior to testing, during the mid-test break, and at any other time during the test at the O's request. The chemical applicant was only temporarily effective.

## RESULTS

Effects of Lenses. Table III shows individual observer 50% detection thresholds by site and mode of observation. Mean thresholds for all lenses averaged for both sites were lower than the threshold for the unaided vision group by several feet. An analysis of variance among the four means showed they did not differ significantly ( $F=1.12$ ;  $df=3/16$ ;  $P > 20\%$ ). Thus, there was no clear-cut superiority associated with any mode of observation, aided or unaided.

Table III also shows generally higher mean thresholds for site E than site D. The difference among overall site means was 7.7 feet. This difference was statistically significant ( $F=8.27$ ;  $df=1/16$ ;  $P < 2.5\%$ ). Thus, the two sites differed in intrinsic difficulty of target detection, regardless of mode of observation. To date, in this series of studies, site thresholds in semideciduous forests have varied significantly (statistically), but not to a large extent in real distance (1).

A nonsignificant interaction between sites and observation modes ( $F=0.84$ ;  $df=3/16$ ;  $P > 20\%$ ) indicates that site differences were consistent for all modes of observation. Separate analyses of variance using percent detections rather than individual thresholds yielded the same results. Furthermore, tests of significance comparing each individual type of lens separately with unaided vision further confirmed no advantage or disadvantage to observing with any specific set of lenses.

Effects of Target Distance. Table IV compares percent detections for each of the eight target distances and the four modes of observation. Results for all individual observers have been combined. The data for combined sites are also shown in Figure 6. Analysis of variance\* indicated no significant differences in percent detections among observation modes ( $F=0.17$ ;  $df=3/4$ ;  $P > 20\%$ ).

(1) Dobbins, D. A., and M. Gast. Jungle Vision II: Effects of distance, horizontal placement, and site on personnel detection in an evergreen rainforest, US Army Tropic Test Center Rep, Fort Clayton, Canal Zone, Nov 1964.

\* With percent detections subjected to inverse sine transformation.

TABLE III

Means and standard deviations of 50% detection thresholds for 24 individual observers by site and mode of observation

		SITE D			
		Yellow Lenses (feet)	Red Lenses (feet)	Dichroic Lenses (feet)	Unaided Vision (feet)
Mean (ft)	Site D	57.5	57.5	58.5*	62.5
		64.8*	61.2	67.0*	57.5
		57.0*	57.5*	57.5	58.8
		59.7	58.7	61.0	59.6
		SITE E			
		Yellow Lenses	Red Lenses	Dichroic Lenses	Unaided Vision
Mean (ft)	Site E	67.5	57.5	62.5	70.0
		67.5	63.7	79.2	67.5
		50.0	72.5	70.0	81.5
		61.6	64.5	70.5	73.0
		BOTH SITES			
		Yellow Lenses	Red Lenses	Dichroic Lenses	Unaided Vision
Mean (ft)	Both Sites	60.7	61.6	65.7	66.3
$\sigma$ (ft)		6.9	5.1	7.4	8.1
		6	6	6	6

\* Threshold computed by least squares.

The main effect associated with target distance was highly significant ( $F=50.47$ ;  $df=7/28$ ;  $P < 0.1\%$ ).

The most important statistical test was the interaction between target distance and mode of observation ( $F=0.67$ ;  $df=21/28$ ;  $P > 20\%$ ). This interaction compares the gradients among the four modes. The results of this test indicated that visibility gradients did not differ significantly from one mode of observation to another. Instead, each of the four modes of observation yielded the complex visibility gradient which has been

TABLE IV

Percent of targets detected by mode of observation at each of eight distances at two semideciduous forest sites (wet season)

Distance (feet)	MODE OF OBSERVATION									
	Yellow Lenses		Red Lenses		Dichroic Lenses		Unaided Vision		All Modes, Both Sites	
	Site D	Site E	Site D	Site E	Site D	Site E	Site D	Site E	Site D	Site E
30	86.5	93.2	59.9	93.3	93.2	100.0	86.6	93.2	88.3	88.3
45	59.9	79.9	53.3	73.3	59.9	79.9	59.9	73.3	67.5	67.5
55	59.9	66.6	66.6	73.3	73.3	73.3	66.6	73.3	69.1	69.1
60	53.3	59.9	53.3	66.6	26.6	66.6	46.6	73.3	55.8	55.8
65	0	46.6	20.0	53.3	6.6	59.9	13.3	73.3	34.1	34.1
75	6.6	26.6	0	26.6	33.3	33.3	0	33.3	20.0	20.0
100	0	0	0	6.6	0	6.6	0	6.6	2.5	2.5
115	13.3	0	0	13.3	6.6	13.3	0	6.6	6.6	6.6
All										
Distances %	35.0	46.0	31.0	50.8	37.5	54.1	34.0	54.1	43.0	43.0
Total Number Detections	42	56	38	61	45	65	41	65	413	413
Total Number Observations	120	120	120	120	120	120	120	120	960	960

previously found in the tropical semideciduous forest (1, 2). This effect is most clearly seen in Figure 6.

Effects of Horizontal Target Placement. There was no reason to suspect that horizontal placement (radii) of targets would yield different results among the four observation modes. The reason for including these data is that the radii thresholds yield an estimate of the naturally occurring variation in visual thresholds (and, indirectly, vegetation characteristics) when an observer stands in a fixed position on a single site in a horizontal search field. As the baseline of data grows in the present series of studies, these radii thresholds will be compared with thresholds for the different sites within and among the distinctive types of tropical forests. Table V shows radii thresholds for the two sites. Analysis of variance indicated that the horizontal placement of targets did not affect thresholds for both sites combined when compared with the average variance within single sites ( $F=0.83$ ;  $df=4/4$ ;  $P > 20\%$ ).

TABLE V

Detection thresholds (50%) in feet for each radius at two tropical semideciduous forest sites (wet season).

Sites	Radii					Mean Feet (All Radii)
	I	II	III	IV	V	
D	56.3	63.8	45.2*	57.9	62.1*	57.0
E	63.4	83.4	77.4*	54.4*	64.6*	68.6
Mean Feet (Both Sites)	59.8	73.6	61.3	56.1	63.3	62.8

\* Threshold computed by least squares.

Distance Estimation. Table VI compares the effects of observation modes on observer distance estimates. All 24 Os tested in the present study voluntarily used the metric system in their estimates. An analysis of variance was performed on the median distance estimates from 30 feet

(1) Dobbins, D. A., and M. Gast. Jungle Vision I: Effects of distance, horizontal placement, and site on personnel detection in a semideciduous tropical forest, US Army Tropic Test Center Rep, Fort Clayton, Canal Zone, Apr 1964.

(2) Dobbins, D. A., and M. Gast. Jungle Vision II: Effects of distance, horizontal placement, and site on personnel detection in an evergreen rainforest, US Army Tropic Test Center Rep, Fort Clayton, Canal Zone, Nov 1964.

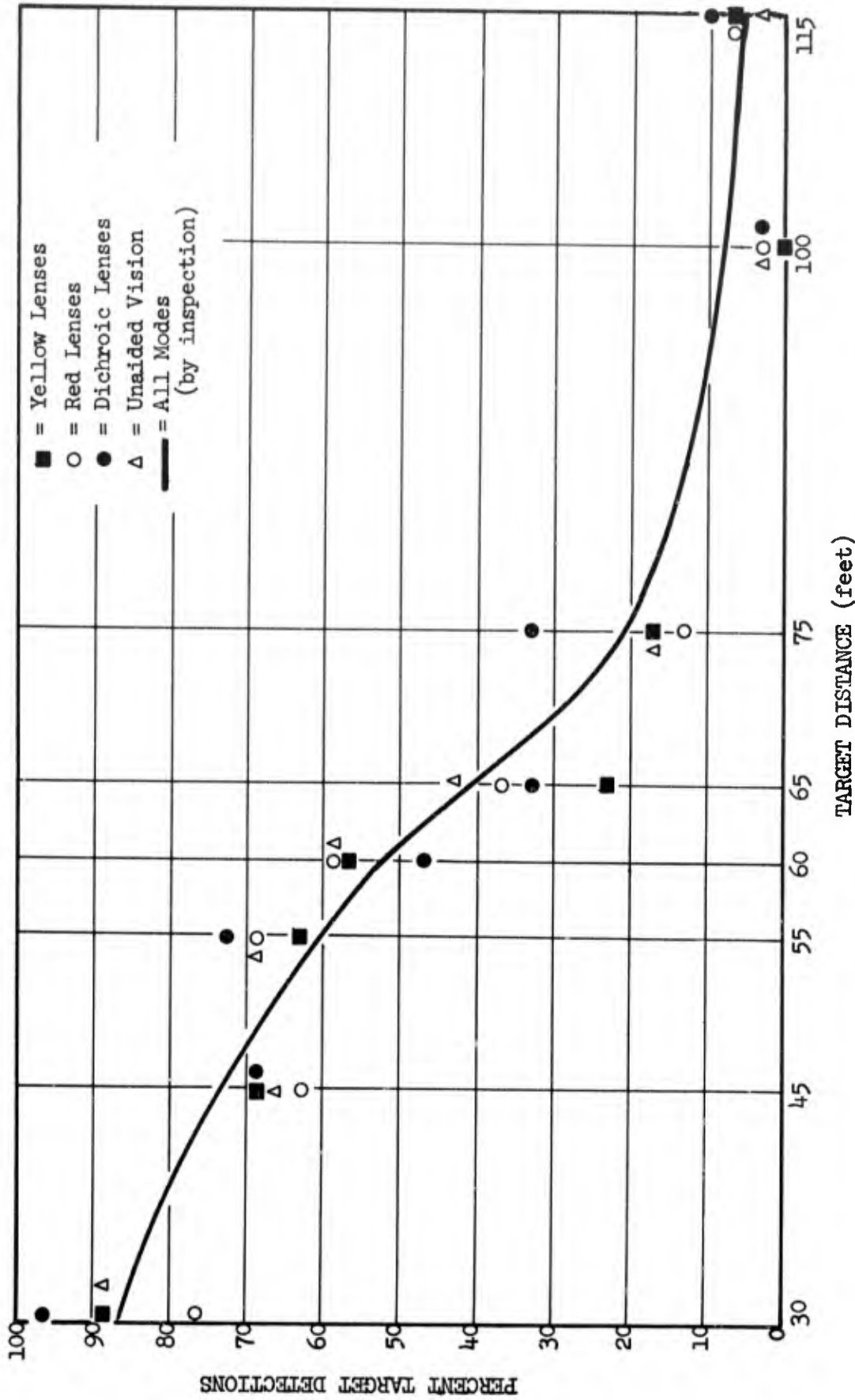


FIGURE 6. COMPARISON OF TARGET DETECTABILITY BETWEEN THREE TYPES OF LENSES AND UNAIDED VISION IN A TROPICAL SEMIDECIDUOUS FOREST (WET SEASON).

through 65 feet. There were no significant differences due to mode of observation employed by the estimators ( $F=0.29$ ;  $df=3/12$ ;  $P > 20\%$ ). Thus, the use of lenses did not affect perceived target distances. This finding is contrary to a past study, in which it was found that distance estimates of Os using yellow lenses were significantly higher than Os with unaided vision.

TABLE VI

Actual target distances and observer estimates made with several types of lenses and unaided vision

Actual Distance (feet)	Median Estimated Distances									
	Yellow Lenses		Red Lenses		Dichroic Lenses		Unaided Vision		All Modes	
	N**	ft	N	ft	N	ft	N	ft	N	ft
30	27	33.2	23	33.2	29	33.0	27	33.2	106	33.1
45	21	64.6	19	49.1	21	49.0	20	64.7	81	56.8
55	19	81.6	21	65.2	22	64.8	21	65.4	83	69.2
60	17	81.7	18	81.8	14	81.8	17	81.9	66	81.8
65	7	65.3	11	98.2	10	81.7	12	90.0	40	83.8
75	--	*	--	*	--	*	--	*	--	*
100	--	*	--	*	--	*	--	*	--	*
115	--	*	--	*	--	*	--	*	--	*

\* Insufficient data cases beyond 65 feet.  
 \*\* Number of estimates.

Similar to past studies, however, it was found that Os using the metric system tended to overestimate true target distance, and that the average error increased progressively with true target distance. In the present study, average overestimation ranged from only 3.1 feet to 18.8 feet for the 30-foot and the 65-foot distances, respectively.

Detection Time. Table VII shows the effects of modes of observation on the search time to detect targets. An analysis of variance revealed that there were no significant differences in search time associated with mode of observation ( $F=0.23$ ;  $df=3/12$ ;  $P > 20\%$ ). Thus, the use of the lenses did not affect the amount of time required to detect targets.

Between 30 feet and 65 feet, search time increased from approximately 16 seconds to 34 seconds for all modes of observation combined. The increase was marginally significant ( $F=2.50$ ;  $df=4/12$ ;  $P < 10\% > 5\%$ ).

Practice Effects. Table VIII compares practice effects among the four modes of observation. The average number of detections for successive blocks of five trials was computed for each group. However, the means of these blocks are statistically contaminated by varying difficulties within

TABLE VII

Mean time in seconds required for target detection at different distances by mode of observation.

Observation Mode	Target Distance								All Distances (Mean Sec.)
	30	45	55	60	65	75	100	115	
Yellow Lenses	16.1 (27)	20.5 (21)	19.4 (19)	24.9 (17)	40.7 (7)	*	*	*	24.3 (91)
Red Lenses	12.0 (23)	23.2 (19)	31.1 (21)	41.1 (18)	21.7 (11)	*	*	*	25.8 (92)
Dichroic Lenses	18.6 (29)	23.9 (21)	22.9 (22)	10.6 (14)	37.6 (10)	*	*	*	22.7 (96)
Unaided Vision	17.0 (27)	17.6 (20)	22.3 (21)	14.2 (17)	36.9 (12)	*	*	*	21.6 (97)
All Modes (Mean)	15.9 (106)	21.3 (81)	23.9 (83)	22.7 (66)	34.2 (40)	*	*	*	23.6 (376)

( ) Number of detections per distance.

\* Insufficient data cases to compute reliable means.

each block caused by randomized sequences of target distances. Accordingly, an analysis of variance model was used that extracted the overall variance due to practice blocks (confounded with target distance) and lenses. The remaining interaction, observation mode by practice blocks, was not statistically significant ( $F=1.03$ ;  $df=21/140$ ;  $P > 20\%$ ). This interaction indicates that there were no significant differences in practice gradients associated with modes of observation.

TABLE VIII

A comparison of practice effects between modes of observation.

Block of Five Trials	Mean No. Detections per Observer				Mean Actual Distance (feet)
	Yellow Lenses	Red Lenses	Dichroic Lenses	Unaided Vision	
1st	1.2	1.5	2.0	2.0	63.0
2nd	1.5	1.8	1.8	2.0	72.0
3rd	2.8	1.8	3.0	2.5	68.0
4th	1.3	1.7	1.8	1.8	80.0
5th	1.7	1.5	1.2	1.3	74.0
6th	2.2	2.5	2.5	2.5	69.0
7th	2.7	2.7	3.0	2.0	62.0
8th	2.7	3.0	3.2	3.3	57.0

## Illumination.

a. Photometric Data. Table IX shows a summary of mean illumination measures taken on the sites with hand-held photometers both at the eye level of the observer and at the midpoint of the radii. Mean light levels ranged from about 42 to about 59 foot-candles (fc) on site D, and from about 26 to 35 fc on site E. Site E was, on the average, about 18 fc darker. An analysis of variance was performed using the 288 separate illumination measures. There was a significant difference between illumination levels on sites D and E ( $F=11.82$ ;  $df=1/280$ ;  $P<0.1\%$ ). However, this variation in light level was equally distributed among the four observation modes by the balanced design; thus, no particular type of lens had any advantage or disadvantage over the others with respect to the amount of available light (observation mode:  $F=0.29$ ;  $df=3/280$ ;  $P>20\%$ ). Nor was there any significant tendency for a particular lens group to have an illumination advantage on any particular site (mode by site interaction:  $F=0.02$ ;  $df=3/280$ ;  $P>20\%$ ).

It should be noted that target detection was significantly better on site E than site D despite the fact that site E was significantly darker. These findings add strength to the investigators' belief that illumination is a minor factor in jungle visibility when different sites are being compared. Vegetation seems to be by far the more potent obscurative factor of the two, and capable of overcoming large differences in ambient light. However, the effects of a significant rise in illumination on the same site are still equivocal and have not been consistent from one study to another.

b. Illuminometer Data. Earlier in the report, it was mentioned that a continuously recording illuminometer was used in addition to the hand-held photometers. Due to equipment difficulties, the data were incomplete. However, Figure 7 shows the march of illumination in 7.5-minute intervals across a fixed location on one site for five test days. Variations noted are thus independent of vegetation differences. The predominant pattern is the upward trend as the sun moves toward its zenith. (The illumination sensor was in a vertical position.) However, there is considerable variation in the pattern from one day to another. For example, illumination for Day No. 1 is linear with little fluctuation. Day No. 3 is erratic, showing many peaks and valleys. Day No. 4 is essentially curvilinear. The wet season cloud cover accounts for these temporal variations in illumination. Thus, illumination may rise gradually from 40 fc to 116 fc in approximately three hours (Day 1), or from 36 fc to 178 fc (Day 5), or begin at 25 fc, go as high as 130 fc, then drop to 58 fc (Day 4)--all in the same period of time. These data show that illumination patterns are highly variable from one day to another day, or from one hour to another on the same day, in only one spot in a tropical semideciduous forest site in the wet season.

Observation of Figure 7 leads to an obvious question. Did the typical rise in illumination during the two consecutive visibility tests affect detection performance? When the mean 50% thresholds were computed for all

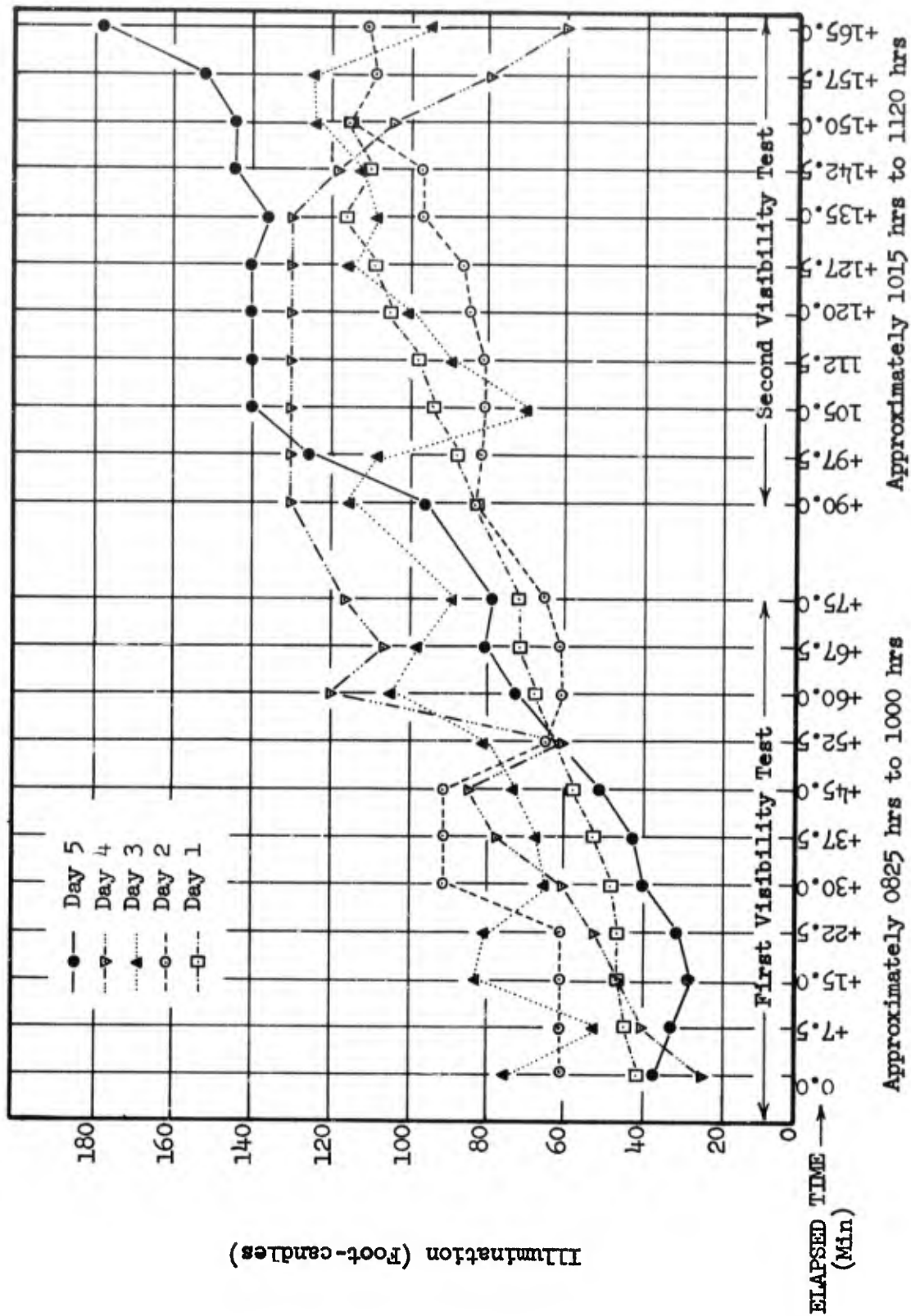


FIGURE 7. MARCH OF VERTICAL ILLUMINATION ACROSS A FIXED POINT ON ONE JUNGLE SITE (SITE D) AS A FUNCTION OF TIME OF DAY, FOR FIVE DAYS (WET SEASON).

TABLE IX

Average illumination in foot-candles taken on test sites

(a) Eye level of observer

Mode of Observation	Site D		Site E		Both Sites	
	<u>fc</u>	<u>N*</u>	<u>fc</u>	<u>N</u>	<u>fc</u>	<u>N</u>
Yellow Lenses	51.8	6	26.3	6	39.0	12
Red Lenses	41.7	6	31.2	6	36.4	12
Dichroic Lenses	59.2	6	34.5	6	46.8	12
Unaided Vision	<u>45.5</u>	6	<u>27.5</u>	6	<u>36.5</u>	12
Mean fc	49.5		29.8		39.6	

(b) 55-foot markers on five radii

Yellow Lenses	46.8	30	32.0	30	39.4	60
Red Lenses	46.7	30	29.4	30	38.0	60
Dichroic Lenses	51.9	30	35.2	30	43.5	60
Unaided Vision	<u>45.7</u>	30	<u>31.6</u>	30	<u>38.6</u>	60
Mean fc	47.7		32.0		39.9	
All Modes (Weighted Mean)	48.6	144	30.9	144	39.7	288

\*N refers to number of illumination measures taken.

Os tested first in the morning and Os tested second, the thresholds were 60.0 and 66.0, respectively. When subjected to a t-test, it was found that the t-ratio of 2.01 with 23 df barely missed significance at the 5% level. Due to the marginality of this ratio and the relatively small number of Os involved, the results will be considered suggestive only. Future work with more extensive data will be required to make a definitive statement.

## CONCLUSION

Nonmagnifying yellow and red lenses with 50% transmission at 460 and 580 millimicrons, respectively, and dichroic lenses with 0% transmission in the 575-590 millimicrons range did not facilitate personnel detection in a semideciduous tropical forest. These lenses neither enhanced nor degraded target detectability when evaluated against the performance of other comparable observers who used the naked eye only. However, the spectacles and goggles did introduce the additional problem of lens fogging. This conclusion is not generalized beyond the specific experimental conditions of the present study, which included: fixed observer position; motionless,

standing, human targets; low target-background contrast; horizontal field of search; and thick, eye-level vegetation in a semideciduous tropical forest.

APPENDIX A

Order of target presentation

<u>Distance</u> (feet)	<u>Radius</u>				
	<u>I</u>	<u>II</u>	<u>III</u>	<u>IV</u>	<u>V</u>
30	14	9	17	5	28
45	31	13	3	36	33
55	35	38	40	8	18
60	25	29	10	22	21
65	2	34	37	30	39
75	15	12	27	24	1
100	7	20	32	4	16
115	23	11	26	19	6

APPENDIX B

Sequence of observers tested by site,  
test day, and experimental condition.

<u>Test Day</u>	<u>Site D</u>	<u>Test Day</u>	<u>Site E</u>
1	YL; Li	2	RL; UV
3	YL; UV	4	Di; RL
5	UV; RL	6	YL; Di
7	RL; Di	8	UV; YL
9	Di; YL	10	RL; UV
11	RL; UV	12	YL; Di

YL = Yellow lenses  
Di = Dichroic lenses  
RL = Red lenses  
UV = Unaided Vision

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APPENDIX C

Instructions given to the O by E prior to the 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 AND DETECT TARGETS THROUGH THE JUNGLE FOLIAGE. YOU WILL SEE ONE OF THESE FELLOWS (demonstrate) STANDING UP FACING YOU BETWEEN NINE O'CLOCK (point) AND THREE O'CLOCK (point), AT DIFFERENT DISTANCES FROM YOU. THESE ARROWS SHOW YOU THE FIELD OF SEARCH (point). THERE WILL BE ONLY ONE TARGET AT A TIME----YOU WILL STAND---- FACING ME----AND WHEN I GIVE YOU THE SIGNAL, YOU ARE TO TURN AROUND IN THIS MARKED BOX (point) 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 A MAN, POINT IN HIS DIRECTION AND TELL ME HOW FAR AWAY YOU THINK HE IS----YOU WILL HAVE TWO MINUTES TO FIND HIM. IF YOU DON'T SPOT HIM IN TWO MINUTES, I WILL TURN YOU AROUND AND SCORE A MISS---- IF YOU THINK YOU SEE HIM, BUT ARE DOUBTFUL, GO AHEAD AND GUESS----THERE WILL BE 40 TRIALS IN ALL, AND THE TEST WILL LAST ABOUT AN HOUR AND A HALF. \*(FOR YOUR TEST, YOU WILL WEAR THIS PAIR OF GLASSES. WE WILL COMPARE THE RESULTS OF YOUR TEST WITH OTHER OBSERVERS WHO WILL WEAR DIFFERENT TYPES OF GLASSES OR NONE AT ALL. LET ME KNOW IF THE GLASSES FOG UP OR GET SWEATY. NOW PUT ON THE GLASSES AND LOOK AT THE TARGET AGAIN.) 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 only to observers who wore lenses. Those Os who used lenses were shown the targets both with and without the glasses for familiarization.

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## APPENDIX D

### 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.
- t-test:** This test yields the probability that variation between a pair of means may be attributed to chance.
- 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 ( $\sigma$ ):** This is a measure of the variability of individual values in a frequency distribution around the mean value.
- Median:** The midpoint of a series of numerical values; it represents a point on a continuum rather than an algebraic average.
- 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.
- Inverse sine transformation:** A transformation frequently applied to percentage values prior to analysis of variance to reduce correlation between means and variances.

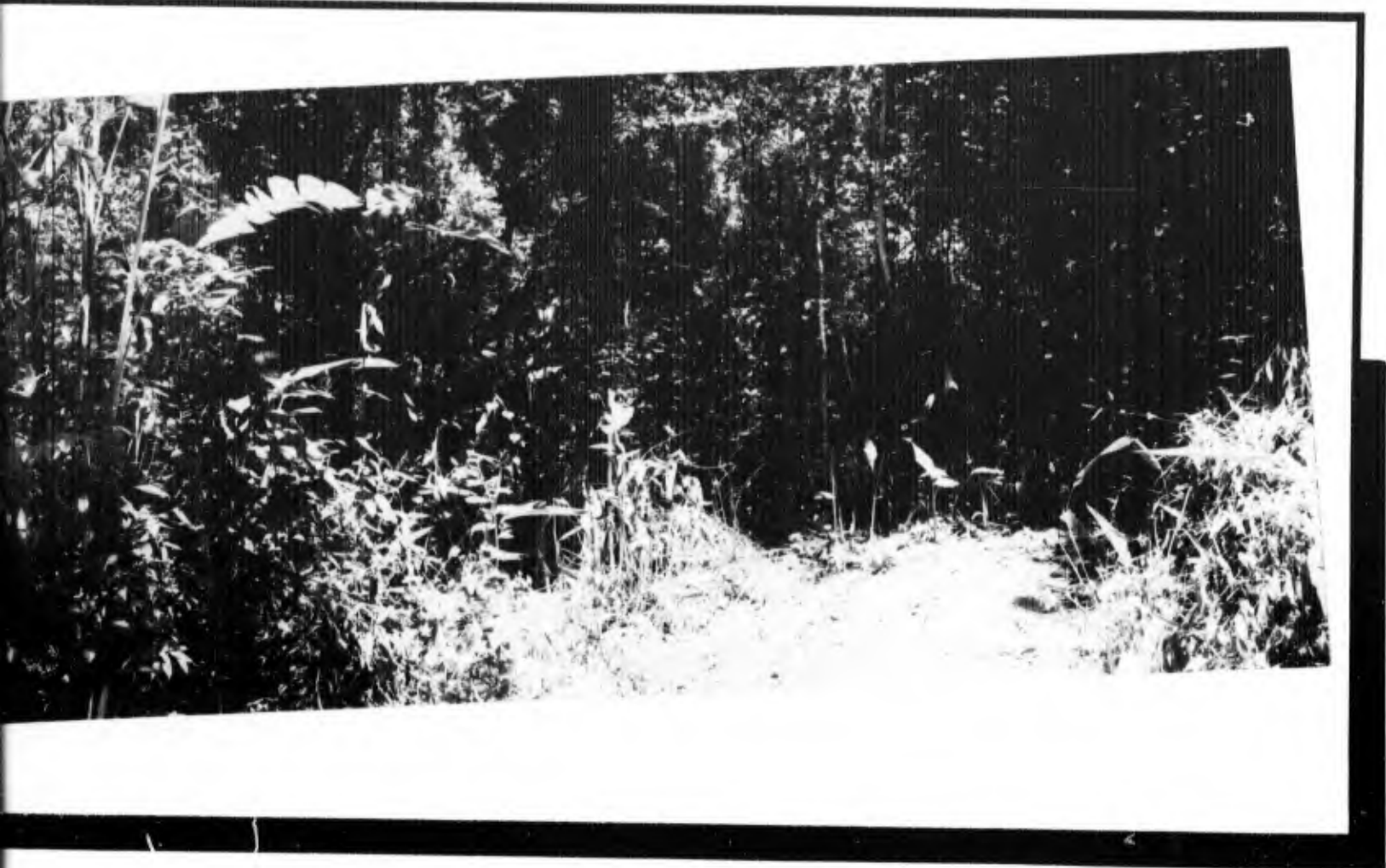
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a. View of site D from observer's position.



2



3



b. View of site E from observer's position.

FIGURE 2. VIEWS OF TWO SEMIDECIDUOUS FOREST SITES



5



6

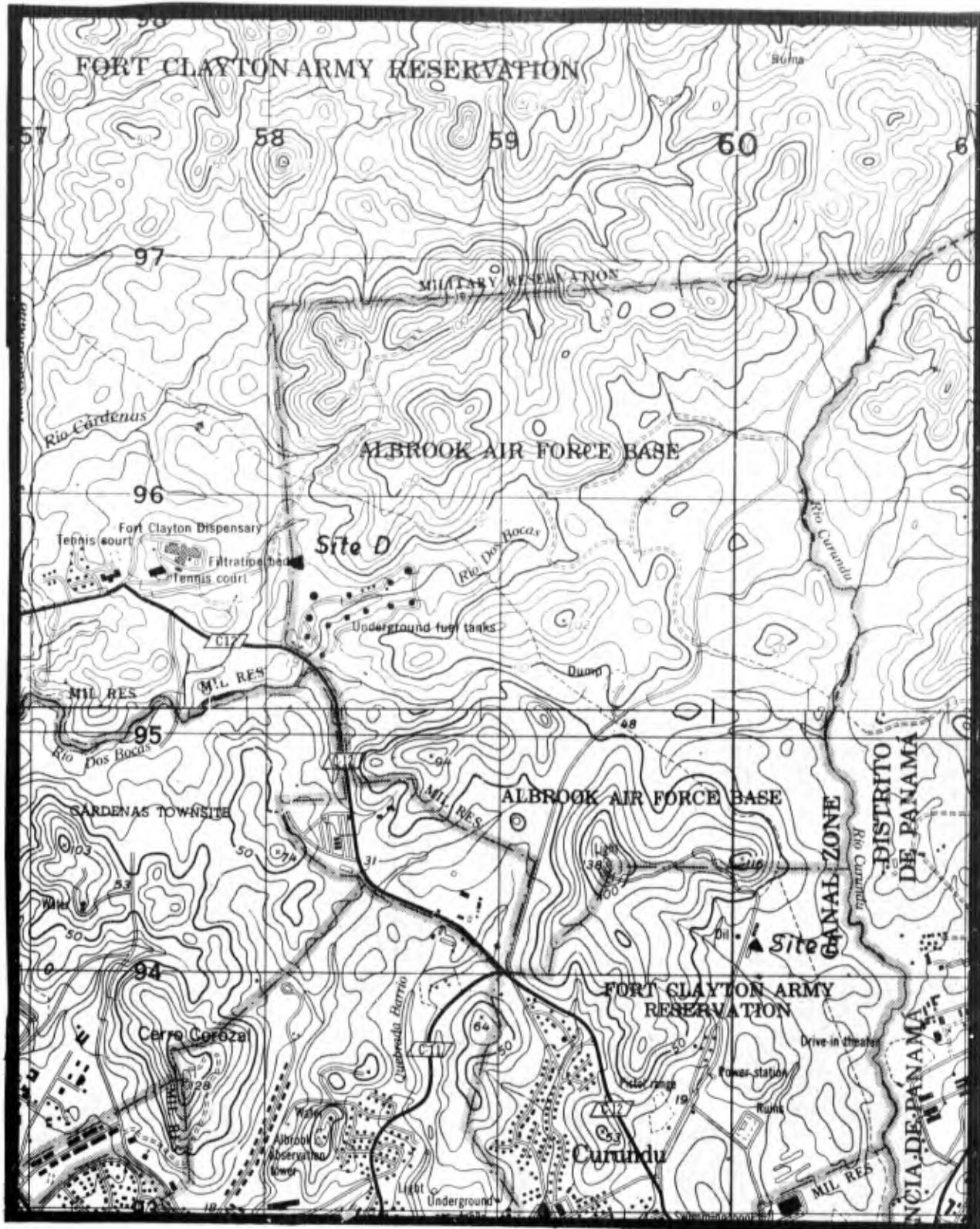


FIGURE 2A. SITE LOCATIONS. (SCALE: 1:25,000. Fort Clayton, Canal Zone, Panama. Series E866, Sheet 4243 II SE, Edition 1-AMS.)

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1. ORIGINATING ACTIVITY (Corporate author)		2a. REPORT SECURITY CLASSIFICATION	
US Army Tropic Test Center, Fort Clayton, Canal Zone		UNCLASSIFIED	
		2b. GROUP	
3. REPORT TITLE			
JUNGLE VISION V: EVALUATION OF THREE TYPES OF LENSES AS AIDS TO PERSONNEL DETECTION IN A SEMIDECIDUOUS TROPICAL FOREST.			
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
December 1965		37	4
8a. CONTRACT OR GRANT NO. DA-96-519-SCAR-2303		9a. ORIGINATOR'S REPORT NUMBER(S)	
b. PROJECT NO. DA 11013001A91A		Research Report #5	
c. TECOM Proj. No. 9-6-0069		9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	
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13. ABSTRACT			
<p>The purpose of this study was to evaluate nonmagnifying yellow, red, and dichroic lenses as aids to personnel detection in a tropical semideciduous forest. Twenty-four US infantry soldiers with normal visual acuity were selected as observers. Four subgroups of six EM each were then assigned to observe either with yellow lenses, red lenses, dichroic lenses or unaided vision. Each observer was presented 40 randomly appearing human targets in fatigue uniforms who stood motionless within a 180° horizontal field of search. Tests were conducted on two sites during the wet season (August 1965) in the tropical semideciduous forest characteristic of the Pacific slope of the Canal Zone.</p> <p>None of the lenses facilitated target detectability as measured by 50% visual thresholds, visibility gradients, or total detections when compared to unaided vision. Furthermore, no significant differences among modes of observation were found for target search time, perceived target distance, or practice gradients. Considerable difficulty was experienced with the condensation of moisture on the insides of lenses fitted both in spectacle and goggle type frames.</p> <p>The two sites used differed significantly, both in intrinsic difficulty of target detectability and in levels of ambient illumination. Illumination, however, was not directly related to visual threshold differences between the sites. Temporal variations in ambient illumination on the same site are also presented.</p>			

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Military Personnel, Detection Human Detection Target Detection Tropical Regions Optical Detection Ambient Illumination Vision Test Methodology Jungles Performance, Human						

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