Technical Research Report 1164

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SEARCH EFFECTIVENESS WITH THE STARLIGHT SCOPE AND 7 X 50 BINOCULARS

John P. Farrell, James H. Banks, and Jack J. Sternberg

COMBAT SYSTEMS RESEARCH DIVISION

BESRL

Behavior and Systems Research Laboratory
Office of the Chief of Research and Development
U. S. Army

June 1970

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Room 239, The Commonwealth Building
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June 1970

Army Project Number 2Q024701A723

Night Operations b-00

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FOREWORD

The NIGHT OPERATIONS Program within the Behavior and Systems Research Laboratory is concerned with problems in optimizing human performance in relation to night vision devices and related sensors. Specific aspects deal with determining: 1) performance effectiveness with sensor systems, 2) factors that affect performance, and 3) means of improving effectiveness. The entire research program is responsive to requirements of the Combat Developments Command and is conducted under Army RDT&E Project 2Q024701A723, "Human Performance in Military Systems," FY 1971 Work Program.

The research described was conducted at Fort Benning, Georgia. It represented a preliminary effort to identify critical factors affecting performance and to develop instrumentation and technologies for subsequent research in the night operations area. The Behavior and Systems Research Laboratory wishes to express the deepest appreciation for the generous cooperation and excellent support provided by many departments at the U. S. Army Infantry School. Special acknowledgement is made of the efforts of the New Weapons Department of the school.

To further the research program, a field unit has been established at Fort Ord, California where, with the support of the Combat Developments Command Experimentation Command, research is currently being conducted with passive night vision devices.

J. E. UHLANER, Director
Behavior and Systems
Research Laboratory

SEARCH EFFECTIVENESS WITH THE STARLIGHT SCOPE AND 7 X 50 BINOCULARS

BRIEF

Requirement:

To conduct an exploratory study with the following objectives: 1) to develop methodology and technology essential to the conduct of scientific field experimentation in search effectiveness in night operations; 2) to identify the critical factors affecting performance and their related parameters; and 3) to assess for operational purposes performance effectiveness with the Starlight Scope and the 7 x 50 binoculars.

Procedure:

Four men were tested nightly, three using the Starlight Scope, and one using the 7 x 50 binoculars. A total of 65 operators (subjects) were tested. Testing was conducted under starlight, half-moon, and full-moon illumination conditions. The 48 targets presented nightly were either soldiers or foam rubber "aggressor" type silhouettes, in a moving and stationary mode, respectively. Operators were told that they were on perimeter defense and that it was their responsibility to detect and shoot all enemy targets in their search sector. The search area was rectangular in shape, 400 meters long and 200 meters wide. Target detection responses were recorded electronically. The data were analyzed to determine performance effectiveness with the two devices and the effect of critical variables on performance effectiveness.

Findings:

The Starlight Scope significantly improves ability to detect targets. However, performance with the Starlight Scope is differentially affected by conditions under which search is performed. At low illumination levels, target detection is greatly attenuated by small decreases in ambient light and also by distances in excess of 200 meters. Length of target exposure also strongly affects performance. Target mode (stationary versus moving) was not found to affect detection percentages, probably because of the wide search area.

The ability to <u>see</u> targets with the Starlight Scope and 7 x 50 binoculars was higher than performance in the actual <u>detection</u> of targets. Overall, one-third of the seeable targets were not found during search.

Search efficiency (rates of targets found to targets seen) was differentially affected by several of the variable conditions studied.

The Starlight Scope was found to be superior under all conditions studied. The binoculars were reasonably effective at short distances, or under high illumination, and with lengthy target exposure. When all these conditions were present at one time, the effectiveness of the binoculars approached that of the Starlight Scope.

Products:

Practical and effective field experimentation methodology and instrumentation were developed which are applicable to a wide range of field experimentation and testing with night vision devices and sensors.

Utilization of Findings:

The study provided baseline performance data on the Starlight Scope and 7 x 50 binoculars as well as identification of factors critically affecting performance and information about the effects to be expected. The findings suggest that improved search techniques will greatly enhance performance with the Starlight Scope.

SEARCH EFFECTIVENESS WITH THE STARLIGHT SCOPE AND 7 X 50 BINOCULARS

CONTENTS

TABLES

FIGURE

BACKGROUND

The U. S. Army has in recent years recognized a need to improve its night operations capabilities. (See, for example, the 1964 study by the U. S. Army Combat Developments Command.)[1] This need had led to the development of sensors which greatly improve night seeing and target acquisition capabilities. The development of these sensors has, in turn created an urgent need for human factors studies to determine and improve the level of human performance with the current generation of sensors and to provide human performance data which can be applied in improving the capabilities of future generations of sensors.

The Behavior and Systems Research Laboratory (BESRL) has established a work unit with the mission of conducting human performance experimentation to improve the capabilities of the combat solider in night operations. Initial research by this work unit was conducted at Fort Benning, Georgia. As this exploratory research was being completed, the U. S. Army Combat Developments Command (USACDC) requested that BESRL research in this area be expanded and accelerated and concurrently requested that the U. S. Army Combat Developments Command Experimentation Command (USACDCEC), Fort Ord, California, support the desired BESRL research. To accomplish the research, the BESRL Field Experimentation Unit was established as a tenant of Fort Ord with primary mission support to be supplied by USACDCEC. Field experimentation with night vision devices is currently being conducted at Fort Ord by this Unit.

OBJECTIVES

The Army has given high priority to the development and fielding of advanced systems for surveillance, target acquisition, and night observation. The effectiveness of any system is complexly determined by the characteristics of the system, the way in which the system is employed, and the behavior of the human being in the system. The system must be evaluated in terms of the interaction of all these factors rather than separately in terms of the effectiveness of the equipment, the method of employment, or the human operator. Systems measurement beds must be developed which permit the determination of the relative contribution of equipment factors, employment factors, human factors, and the interactions of all these to total system effectiveness. When these contributions are understood, suggestions leading to improvement of total system effectiveness become possible.

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[1] Night Operations and the Employment of Night Vision Devices (Unclassified title) U. S. Army Combat Developments Command. November, 1964. SECRET.

To translate these considerations into specific questions, the research conducted by BESRL is designed to provide information which will aid in the solution of the following problems:

Who should use night vision devices and sensors? Individuals differ greatly in their abilities to acquire targets with these devices. To what are these differences attributable? To what extent can these differences be reduced by training? What kind of training is effective? If selection of operators is necessary, on what basis should selection be made?

How should the devices be used? What are the proper search techniques? What are the implications of human capabilities and limitations for employment and deployment of men and device? How large an area can a man effectively search? How long can a man use a device effectively? What are suitable work-rest cycles? If two men are to use devices, should the men be assigned separate or overlapping search sectors?

Which devices should be used and under what conditions? The devices differ in their characteristics and capabilities and are affected differently by changes in environmental-terrain-target conditions. What is the relative performance with the devices under different light levels? On different types of targets? On targets at different distances? On different types of terrain--open versus cluttered with trees, brush, rocks. For different tactical applications?

What should be the Basis of Issue (BOI) and Mix of devices? How much is gained in target acquisition if two men with devices of the same type are used? If three men are used? How much is gained by the use of two or more men with different types of devices?

Questions such as these can be answered best by extensive and rigorous experimentation. The results of this experimentation provide information for operational employment, training, selection, and for the development of concepts, doctrine, and organization. Also, the information provided forms a basis for subsequent troop tests. From such experimentation, too, the parametric data essential for effective linear modeling and war games are obtained. In addition, determination of the complex interactions of the man, the device, and the operational situation provides valuable information for the design of future generations of devices.

The present publication is a report of the research conducted at Fort Benning, Georgia. This was the initial research conducted by the work unit in the area of night operations and was primarily exploratory. The devices tested were the Small Starlight Scope (AN/PVS-2) and standard Army 7 x 50 binoculars. The objectives were threefold: first, to develop the methodology and technology essential to the conduct of scientific field experimentation in night operations; second, to identify the critical variables affecting target detection performance and their related parameters; third, to provide information on the operational usefulness of the devices under varying conditions.

Before it was possible to provide information on the effectiveness of the devices a technology was required that would make it possible to collect reliable and valid experimental data under field conditions. Existing instrumentation, procedures, and techniques were not adequate for research of this type. Therefore, the first objective was the development of an appropriate technology--instrumentation, training, testing, control methods and procedures, special experimental techniques.

Instrumentation was necessary which would provide for accurate measures of target detection and search behavior. The instrumentation system of measurement had to be flexible and reliable under widely varying field conditions. It had to provide for simultaneous recording of a variety of data, allow for control and monitoring of the players, and provide a data output that could be rapidly analyzed. Methods and procedures had to be developed which would insure that all subject, supporting, and controller personnel were properly carrying out their assigned missions. Each participant had to be oriented, motivated, and trained for his job. Because of the large number of test and environmental factors and the large number of differing types of personnel involved, a great deal of procedural redundancy, as well as constant monitoring, was required in order to maintain a standardized testing situation. Special experimental techniques had to be developed in order to identify and consider the effects of various factors on performance. An example of such techniques is the "seeability" test described below under Procedure. The "efficiency score," derived from the Seeability measure and search performance data, makes it possible to determine the degree to which failures in target acquisition are attributable to the intrinsic capabilities of the devices and to less than optimal human performance. Identification of the relative contribution of such factors as these to performance reveals which subsystem elements need to be improved in order to improve overall system effectiveness.

In regard to the second and third objectives--to identify critical variables and their parameters and to provide information for operational use--there is no doubt that devices such as the Starlight Scope improve performance. The basic question is to what extent and under what conditions. A number of variables were therefore included in the present experiment because it seemed likely that they represented conditions especially critical to performance. These variables were ambient illumination, distance, target mode, and target exposure times. The parameters--that is, the measure or amount of a variable--were selected to show how changes in the quantity of a variable affect performance. For example, illumination unquestionably affects performance with passive night vision devices; but do changes from starlight to half moon to full moon result in equal amounts of improvement? This information is important for operational use as well as for design of future experiments. For example, if performance under half-moon illumination is about equal to that under full moon, then both conditions need not be included in future experiments, and savings in resources and time would result.

PROCEDURE

Four men were tested nightly, three using the Small Starlight Scope (AN/PVS-2), and one using standard Army 7 x 50 binoculars (M17). Subjects were instructed that they were on perimeter defense and that it was their responsibility to detect and shoot all enemy targets in their search area. Testing was conducted under starlight, half-moon and full-moon illumination conditions. The terrain was an unused small weapons range, heavily covered with grass and brush and containing a number of small bunkers constructed of logs. The search area was rectangular in shape, 400 meters long and 200 meters wide. The distance limit of 400 meters was naturally defined by the crest of a hill. The area was surrounded by dense pine woods, with the width limit being defined by the tree line on each side of the range.

Targets were placed in this area at distances of 50 to 300 meters and over the full width of the range with some targets actually in the tree lines. For purpose of analysis of the effects of distance, targets were in three bands: 50-100 meters (near-distance); 101-200 meters (mid-distance) and 201-300 meters (far-distance). Targets were presented in two modes--moving and stationary. Stationary targets were electrically controlled pop-up foam rubber "aggressor" figures with fatigue trousers added to give a full human silhouette. Pilot tests confirmed that these figures and stationary human targets in the same position were equally difficult. Moving targets were soldiers dressed in fatigues who moved at a walking pace over a ten-foot path parallel to the line of subject cubicles--that is, across the line of sight of the soldiers who were searching. Target exposure time was varied--10, 20, 30, and 90 seconds.

Prior to testing, approximately 60 minutes of training was given. The purpose of this training was to instruct the subject in the use of his device, to teach him what targets looked like when viewed through his device, and to allow him to develop facility in the rapid detection and simulated shooting of the targets. Training was given on an individual basis. During testing, the ability of the soldiers serving as subjects to find targets through search was determined. They were required to search for targets, to depress a "detection" button when they detected a possible target, and to line up the reticle and shoot the target with a "recognition" button when they determined that it was a real target. Azimuth and elevation of a device at time of a response were recorded electronically. During subsequent data analysis, device orientation at time of response was compared with true location (azimuth and elevation) of the exposed target to determine whether the target had actually been "hit." The two responses were used to determine the differential probability of detection and recognition of targets, as well as the time required to go from initial detection of a possible target to recognition and shooting of the target.

At the conclusion of search testing, all targets were presented again, and the ability of each man-device combination to see targets when no search was required was determined. Thus, it was possible to establish the effects of illumination and distance on target "seeability" with the devices. The seeability measure also provided a baseline with which search performance could be compared. This comparison provided a measure of the extent to which overall effectiveness of the devices could be improved by improved work methods and search techniques to be made available to the soldier using the devices.

FINDINGS AND THEIR IMPLICATIONS

The effects on search performance of four variables are reported--ambient illumination, distance, target mode (moving versus stationary), and target exposure time. A fifth variable reported, detection versus recognition, was included in order to determine the differential probability of detection and recognition of targets, as well as the time required to go from initial detection of a possible target to recognition and shooting of the target. In practice, however, the detection and recognition responses were made almost simultaneously. Therefore, detection responses were used for data analysis. The subjects' night vision ability was also measured and compared with performance on the Starlight Scope and the 7 x 50 Binocular devices. The correlation was not significant.

The analyses of the data centered on: 1) the Starlight Scope--to show how performance is affected by illumination, distance, target mode, target exposure time, and their interactions; 2) search efficiency under varying conditions of illumination, distance, and mode; and finally, 3) comparison of the Starlight Scope and binoculars in terms of percent detections under various conditions.

The binoculars have been much used as a night viewing and search aid. Although the general level of performance with the binoculars was not expected to equal that with the Starlight Scope, it was possible that, under some conditions, performance with the two devices might be highly similar and, considering cost-effectiveness trade-offs, the binoculars might be preferred. Additionally, objective measures of the effectiveness of the binoculars would provide valuable information on the level of performance that could be expected when binoculars are the only night viewing aid available.

Starlight Scope

In general, the performance with the Starlight Scope significantly improves ability to detect targets. Its use is therefore recommended. Performance, however, is differentially affected by a number of variables, and the operational effectiveness of the device must be considered in light of these factors.

Effect of Illumination. Search performance improved with increased illumination. Performance was much more affected by small illumination increases at low light levels than by equal increases in illumination at higher light levels. In fact, beyond half moon illumination, large increases in illumination resulted in relatively little improvement in performance. (Percent detections went from 59% to 68% when illumination increased from half moon to full moon--a relative gain of 15%. Increases in illumination from clear starlight to overcast starlight caused performance to improve from 25% to 38%--a relative gain of 52%.)

Effect of Distance. Overall, performance was significantly degraded, with increasing distance, but the effect of distance was much more severe with low illumination. Under starlight conditions, approximately 60% of targets at distances less than 100 meters were detected compared to approximately 10% at distances of 200-300 meters--a 6:1 ratio. Under full moon, the comparable values were 79% and 56%--approximately a 6:4 ratio. In general, the Starlight Scope was highly effective in detecting personnel targets at distances up to 200 meters. At more than 200 meters it was effective under half moon and full moon and relatively ineffective under starlight. However, without the use of some aid to the eye, targets beyond 200 meters under starlight conditions would have escaped detection. Although Basis of Issue was not investigated in the present experiment, subsequent experiments suggest that using two Starlight Scopes under the test circumstances would result in about 15% detections (as opposed to 10%)--a relative gain of about 50%.

Effect of Movement. Movement did not increase the probability of detection, perhaps because of the wide search area size used in the study. For a tactical situation (such as an interdiction point in which the search area size is narrow), there is little doubt that movement would assist detection. A subsequent BESRL report (in preparation) on the relation of search area size to detection supports this inference.

Effect of Target Exposure Time. This variable was studied for two reasons: 1) to provide data for subsequent research by BESRL and other DA agencies, and 2) to provide operational data. Obviously, in combat, the duration of target exposures will vary immensely. Nevertheless, these data on varying times do provide information necessary to the evaluation of the efficiency of the devices. As expected, increased target exposure time resulted in greater target detection. However, the amount of gain differed with differences in the illumination levels and distance of targets. For the higher illumination levels, performance did not improve markedly with exposure times longer than 30 seconds (percent detections went from 76% to 88% with 30- and 90-second target exposures--a relative improvement of 16%). For starlight, performance continued to improve with increasing exposure time (under clear starlight, percent detections increased from 26% to 48% for 30- and 90-second exposures--a relative improvement of 85%). Increased target exposure time resulted in increased target detections for each of the three distances studied, but the increases were greater for far than for near targets. This finding indicates that far targets have a fair probability (45%) of being detected provided that the target is exposed for a relatively long period of time (90 seconds). As targets in combat are frequently exposed for a brief time, the Starlight Scope would have limited usefulness under these distance conditions. On the other hand, the data show that even for short exposure times, the Starlight Scope is an effective device at the closer ranges.

Search Efficiency

Target difficulty varied as a function of distance and illumination. Under some conditions, some targets in the experiment could never be detected during search because they exceeded the capabilities of the man-device combination to see the target. The percentage detections reported previously was based on the total number of targets presented, whether or not all targets could be seen. These data are meaningful because the differential ability to see targets at different distances and under different levels of illumination is a function of the intrinsic properties of the devices and, as such, is an important contributor to their effectiveness. However, another type of comparison is also meaningful; if the differences in ability to see targets are partialled out, how effective is the device operator in finding targets that he can see? Such an analysis has implications for operational employment of the devices, for engineering, and for improvement of search effectiveness. It was necessary, therefore, to develop a measure of how many targets were actually visible to a given operator on a given night--simply, whether the operator could see the target, whether or not he found it during search.

Under the darkest starlight conditions, only about half the targets could be seen. Under half and full moon virtually all could be seen. The respective search scores were divided by the seeability scores to determine the search efficiency of the operators--that is, considering only targets that they could see, how many did they find? Overall, 65% of the targets which could be seen were actually found; conversely, 35% of the targets which were seeable were not found. Efficiency was considerably lower for starlight than for moonlight conditions and for far targets than for near targets. Why were targets that were visible not found? The most likely explanation is that the loss was due to some aspect of the individual's search behavior. The search problem involved was relatively simple, the terrain being of moderate size and largely open, although covered with brush. On a more complex and larger terrain, search efficiency can reasonably be expected to be even lower. This finding suggests that, without modification of the devices, their effectiveness can be greatly improved through the use of more effective search methods and procedures.

The ability to see targets was less impaired by distance than the ability to find targets. Again, the utilization of more effective search techniques could greatly increase the probability of detection of far targets that, although difficult, can be seen and hence detected during search. For closer ranges, a wider search area can be effectively employed, and highly efficient search techniques are relatively less important.

Comparison of Starlight Scope and 7 x 50 Binoculars

The general level of performance with the binoculars was not expected to equal that with the Starlight Scope but it was possible that under some conditions, considering cost-effectiveness trade-offs, the binoculars might be preferred. Additionally, objective measures of performance with the binoculars were obtained to provide information on the level of performance when binoculars are the only night viewing aids available.

Effects of Illumination and Distance. As expected, search performance with the Starlight Scope was clearly superior to that with binoculars (under starlight, 32% vs 10%, respectively; under moonlight, 72% vs 41%, respectively). With both devices, percent detections decreased with increasing distance. For operational purposes, binoculars are virtually useless under starlight at any distance beyond 100 meters (about 5% of the more distant targets were detected, as opposed to about 25% with the Starlight Scope) and of questionable value for shorter distances (23% detection at distances of less than 100 meters, as opposed to 60% with the Starlight Scope). Under moonlight, substantial numbers of targets (about 50%) were detected with the binoculars at distances up to 200 meters, but performance was still inferior to that with the Starlight Scope (about 80% detections). Beyond 200 meters, detections dropped off sharply with binoculars (to 25%), but less so with the Starlight Scope (59%).

Effects of Illumination and Target Exposure Time. Performance with both devices improved with increasing target exposure time. Under starlight, the binoculars were relatively ineffective (22% detections) even with targets exposed for as long as 90 seconds (compared to 54% detections with the Starlight Scope). Under moonlight, substantial numbers of targets were detected with the binoculars even with exposures as short as 20 seconds (34% detections) or 30 seconds (41% detections). When targets were exposed for as long as 90 seconds, performance with binoculars (72% detections) approached the level of effectiveness with the Starlight Scope (85% detections).

General Level of Effectiveness of the Two Devices. The binoculars were reasonably effective under conditions of high illumination, particularly at distances less than 200 meters, and with long target exposure times their effectiveness approached that with the Starlight Scope. Under these conditions, they could be used for surveillance activities with some confidence. Under starlight conditions, their value was low. As these specialized and restricted conditions cannot reasonably be expected to occur with a high frequency under operational conditions, use of the binoculars is limited and cannot be recommended if a device such as the Starlight Scope is available. If such a device is not available, the binoculars probably serve as a significant aid in surveillance activities, at least under moonlight illumination.

TECHNICAL SUPPLEMENT

METHODOLOGY

Apparatus

The apparatus employed can be classified into three categories: night vision devices, the data acquisition system, and ancillary equipment.

Night Vision Devices. The night vision devices consisted of the Starlight Scope (AN/PVS-2) and 7 x 50 (M17) binoculars. As the standard reticle in the binoculars was not visible at night, it was removed and a hypodermic needle was inserted through the reticle slot. The needle was so positioned that the tip appeared in the center of the eyepiece. A small light bulb was inserted into the base of the needle. The bulb was powered by a battery and its brightness controlled by a potentiometer. On moonlight nights, the needle appeared to be a stake-type reticle, but on starlight nights only a small spot of light at the tip of the needle was visible. Brightness was kept at a low level which did not appreciably affect dark adaptation. This modification made it possible to accurately aim the binoculars at targets.

Data Acquisition System. The data acquisition system had three components: 1) the tripods which supported the device platforms and the viewing devices; 2) the device platforms; and 3) the electronic control and data recording apparatus. Four heavy duty tripods were used in line, each tripod being set in concrete for stability. The device platforms consisted of a metal casing attached to the tripod head, the viewing devices being attached to the platforms. The platforms rotated with respect to a fixed base and were adjustable for elevation. Each platform contained a shaft encoder which indicated to within 0.1° the azimuth orientation of the instrument and two microswitches for indication of elevation, the front microswitch being depressed when the instrument was lowered to view close areas and the rear microswitch being depressed when the instrument was raised to view far areas. Each platform also contained two "trigger" or target acquisition microswitches for recording subject responses. These microswitches were designed and located so that their use did not interrupt searching or disturb orientation of the device. The data recording van contained an electronic logic system and an electronic printer which recorded target acquisition data, including type of target acquisition response (detection or recognition), response time, device azimuth orientation to 0.1°, and device elevation orientation (near or far) when a response was made, and subject number.

Ancillary Equipment. Communication equipment included a speaker which was used by the test director to instruct subjects when they were in the test booths and radios which were used for communication between

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the test director and the experimenter at the test booths, the test director and the engineer in the data recording van, and the test director and the human targets.

The Army Night Seeing Tester (ANST-II) was used to test the night vision of the subjects. This instrument and its use is described in BESRL Technical Research Report 1120.[2]

Photometric readings were obtained with a Gamma Scientific Corporation Model 2020 photometer[3] with a S-11 photocathode and a cosine filter which gave an integrated reading, in foot candles, of illumination from the upper hemisphere. Readings were taken at regular intervals throughout the experiment.

Targets

A total of 24 target locations were used in the experiment. Twelve of the targets were soldiers wearing unstarched fatigues. During testing, these targets walked slowly back and forth over a ten-foot path, parallel to the line of subject booths. The other 12 targets were "pop-up" manikins controlled electrically by the test director. The manikins were foam rubber "aggressor" figures, with fatigue trousers added to give a full silhouette of a standing man. A number of other targets were tested in pilot studies to determine whether their probability of detection was equivalent to that of a human soldier in fatigues, but only the manikins met the criterion. Targets were located in three bands: 50-100 meters (near-distance); 101-200 meters (mid-distance); and 201-300 meters (far-distance). A complete description of the targets appears in Table 1.

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[2] Uhlaner, J. E. and J. Zeidner. The Army Night Seeing Tester--Development and Use. BESRL Technical Research Report 1120. May 1961.

[3] Commercial designations are used only for precision in describing the experiment. Their use does not constitute indorsement by the Army or by the Behavior and Systems Research Laboratory.

Table 1

DESCRIPTION OF TARGETS

Target	Distance in meters	Range	Azimuth in Degrees	Mode
1A	293	Far	35	Moving
1B	251	Far	28	Moving
1C	220	Far	30	Stationary
2A	256	Far	59	Stationary
2B	240	Far	40	Stationary
2C	234	Far	48	Moving
3A	259	Far	69	Stationary
3B	234	Far	73	Stationary
3C	218	Far	78	Moving
4A	156	Mid	9	Moving
4B	147	Mid	23	Stationary
4C	126	Mid	16	Stationary
5A	153	Mid	43	Moving
5B	128	Mid	62	Moving
5C	119	Mid	52	Stationary
6A	179	Mid	84	Moving
6B	126	Mid	94	Moving
6C	117	Mid	80	Stationary
7A	84	Near	20	Stationary
7B	57	Near	5.5	Moving
8A	79	Near	56	Stationary
8B	55	Near	43	Moving
9A	82	Near	93	Moving
9B	61	Near	88	Stationary

Ambient Illumination Conditions

Testing was conducted under three ambient illumination conditions: starlight, one-quarter to half moon (half moon), and three-quarter to full moon (full moon). Clear and overcast starlight conditions are presented separately because of differences in both photometric readings and performance for the two conditions. Suprisingly, illumination was higher under overcast starlight than under clear starlight. The test site was a few miles from the population center of Fort Benning. Light from illuminated areas of Fort Benning and nearby Columbus, Georgia, presumably reflected from the underside of the cloud cover and raised the illumination level. Under higher ambient illumination conditions, this phenomenon was not as marked and did not produce differences in performance, although the general level of illumination was probably raised. The photometric readings (in foot candles) under each of the four conditions are given below.

Clear Starlight	1.5×10^{-4} to 2.8×10^{-4}; mean = 1.9×10^{-4}
Overcast Starlight	4.7×10^{-4} to 7.7×10^{-4}; mean = 6.3×10^{-4}
Half Moon	1.0×10^{-3} to 3.2×10^{-3}; mean = 2.4×10^{-3}
Full Moon	4.4×10^{-3} to 2.0×10^{-2}; mean = 1.0×10^{-2}

Terrain

The terrain was an unused small weapons range at Fort Benning, Georgia. It was thought that this range was distant enough from lighted areas of the post to minimize the problem of skyglow but, as indicated above, the problem was not completely eliminated. The terrain had light to moderate clutter which consisted of small bunkers, a few trees, and low to high brush and grass. The range was rectangular in shape, about 400 meters long and 200 meters wide, and was surrounded by pine woods. The distance limit of the search area was naturally defined at 400 meters by the crest of a hill. The width limits were shown by dim lights on either side of the range defining an area of 100 degrees and by the tree line on each side. Targets were placed over a 300-meter distance and a full 200-meter width, with some targets actually in the tree lines.

Subjects

The subjects were 65 enlisted men from the 197th Infantry Brigade at Fort Benning, Georgia. All had a combat military occupation speciality. Age ranged from 19 to 38 years with a mean age of 24 years. Four subjects were usually tested each night, three using the Starlight Scope and one using binoculars. The number of subjects tested on each device and under each illumination condition is shown in Table 2.

Table 2

NUMBER OF SUBJECTS

Illumination Condition	Starlight Scope	7 x 50 Binoculars
Clear Starlight	13	5
Overcast Starlight	12	
Half Moon	12	8
Full Moon	15	
Total	52	13

Procedure

Orientation of Subjects. Upon arrival at the test site, the subjects were brought into a building without being permitted to view the terrain prior to the training and test sessions. No subject had prior experience on the particular terrain used. The subjects were introduced to the experimenters and the importance of the research as well as the necessity of their wholehearted participation was explained. Every attempt was made to motivate the subjects at this time and to keep them motivated throughout the evening. The subjects were then dark adapted and the Army Night Seeing Test was administered. The subject assigned to the 7 x 50 binoculars was given red goggles to preserve his dark adaptation and was instructed to put them on before he entered a lighted area.

Training. A training session of approximately one hour was given to the subjects each evening. This session had three purposes: 1) to instruct the subject in the use of his device; 2) to teach him the appearance of targets viewed through the device; and 3) to allow him to develop facility in the rapid detection and simulated shooting of the targets. Training did not commence until at least the End of Evening Nautical Twilight (EENT), when the sun was 12° or more below the horizon. Training was conducted by the test director with the assistance of the engineer who remained in the experimental control center to monitor subject's response. Throughout training, tape-recorded instructions were given to the subjects over the loudspeaker. If any point was not clear, the test director was informed during the frequent pauses in the tape and the tape delayed until all subjects understood the instruction thoroughly.

During the first part of training, instructors helped the subjects adjust tripod height and diopter setting, and instructed them on the use of the detection and recognition "firing" buttons. Subjects were to press the left-hand button as soon as they detected a possible target (detection response). They were then to line up the center of the reticle with the center of mass of the target and to press the right-hand button when they had determined that it was a real target (recognition response). The use of two responses was intended to give measures of the probability of both detection and recognition, and the difference in time between the two. In practice, recognition responses almost invariably followed detection responses within one or two seconds. Thus, the distinction between the two types of response was not meaningful in this situation and, for purposes of analysis, only the detection responses were used. For purposes of analysis, a response was defined as a hit when azimuth orientation indicated that the device was within ±3° of true target azimuth and elevation orientation indicated that the device was pointed at the correct distance zone. All the Starlight Scopes were prefocussed at 175 meters which gave reasonably sharp focus for all targets. Subjects were not allowed to change the focus during the experiment as it was felt that the time required for focussing and the probability of bad focussing outweighed any possible advantages.

In the second part of training, moving and stationary targets were presented, one at a time, in different parts of the field. Subjects were told where to look for the targets and to fire on the targets, using the appropriate procedures, when they were located. The engineer in the data recording van compared subject responses with a catalog of actual target locations and informed the test director which subjects had failed to locate the target and/or had not followed the appropriate procedures regarding the target. The test director, in turn, informed the appropriate instructor that his subject had failed to locate the target, or fire, or both. The instructor then assisted his subject and reviewed the instuctions on "firing."

When all subjects thoroughly understood the procedures and had become familiar with the appearance of targets viewed through the instrument, they were given 30 minutes of additional practice in locating targets, without assistance, to allow them to develop skill in rapidly locating and shooting the targets. At the conclusion of training, the subjects were given a rest period. Photometric readings were taken at this point and at regular intervals throughout the evening.

Testing. Data collection did not begin until after the End of Evening Astronomical Twilight (EEAT), when the sun was 18° or more below the horizon, and was ended prior to the Beginning of Morning Astronomical Twilight (BMAT), before the sun approached 18° below the horizon. When testing was conducted under moonlight conditions, data collection did not begin until the moon had ascended to 15° above the horizon and testing always ended before the moon descended beyond 15° above the horizon.

In the search experiment, target exposure times were 10, 20, 30, and 90 seconds. Subjects were told the length of target exposure at the beginning of each group of targets and a buzzer sounded each time a new target was presented. In the 10- and 20-second conditions, eight targets were presented in each condition. After four targets were presented, subjects were given a 3- to 4-minute break while the targets were relocated; then the second group of four targets was presented. In the 90-second condition, eight targets were presented with a short break between target presentations. The particular targets presented in the 10-, 20-, and 90-second conditions were randomized across nights with the restriction that all targets occur an equal number of times. In the 30-second condition, all 24 targets were presented each evening, order of presentation being systematically varied across evenings. In this condition, a break was given after each group of three successive targets. The order of the conditions was counterbalanced across nights. Subjects were given a 15- to 20-minute rest at regular intervals during the experiment to warm up and get coffee.

At the conclusion of the search experiment, all targets were presented again to determine the ability of each man-device combination to see targets when no search was involved. In this seeability test, each instrument was aimed and locked on a specific area of the terrain. The subjects were required to report whether or not they saw a target and, if they saw a target, to tap the arm of the instructor assigned to them at the moment the target went down. The time of target disappearance varied and was not known to the subjects. As a further precaution against false reports, on three trials the instruments were aimed at terrain locations without targets. All 24 target locations were tested, plus three false trials for a total of 27 trials. This experiment was a measure of target visibility with ambient illumination with device and subject held constant. It thus provided a baseline seeability measure against which search performance could be evaluated.

RESULTS

Results are presented and discussed in terms of target detection performance with the Starlight Scope as affected by varying conditions, search efficiency, and relative effectiveness of performance with the Starlight Scope and 7 x 50 binoculars. Factors entering into the analyses are ambient illumination, target distance, target mode (moving versus stationary), and target exposure time. Both percentage of targets detected and seeability of targets were compared for the Starlight Scope and the 7 x 50 binoculars. All differences reported as significant are at least at the .01 level.

Effect of Illumination on Target Detection. As the Starlight Scope is a passive night vision device, level of illumination was expected to be one of the most critical determiners of performance. Table 3 shows the percentage of targets detected under each illumination condition. Performance under clear and overcast starlight conditions is presented separately because of differences in both photometric readings and performance for the two conditions. As explained above, the higher illumination observed under overcast starlight presumably resulted from the reflection off the underside of cloud cover of light from Fort Benning and Columbus, Georgia.

Table 3

EFFECT OF ILLUMINATION ON PERCENT TARGETS DETECTED WITH THE STARLIGHT SCOPE

Illumination Condition	Percent Detected
Clear Starlight	25
Overcast Starlight	38
Half Moon	59
Full Moon	68
Overall	48

As expected, performance improved significantly with increasing illumination. Performance was much more affected by small illumination increases at low light levels then by equal increases at higher light levels. In fact, beyond half-moon illumination, large increases in illumination resulted in relatively little improvement in performance. Percent detections went from 59% to 68% when illumination increased from half moon to full moon, a relative gain of 15%. Increases in illumination from clear starlight to overcast starlight caused performance to improve from 25% to 38%, a relative gain of 52% (See Figure 1).

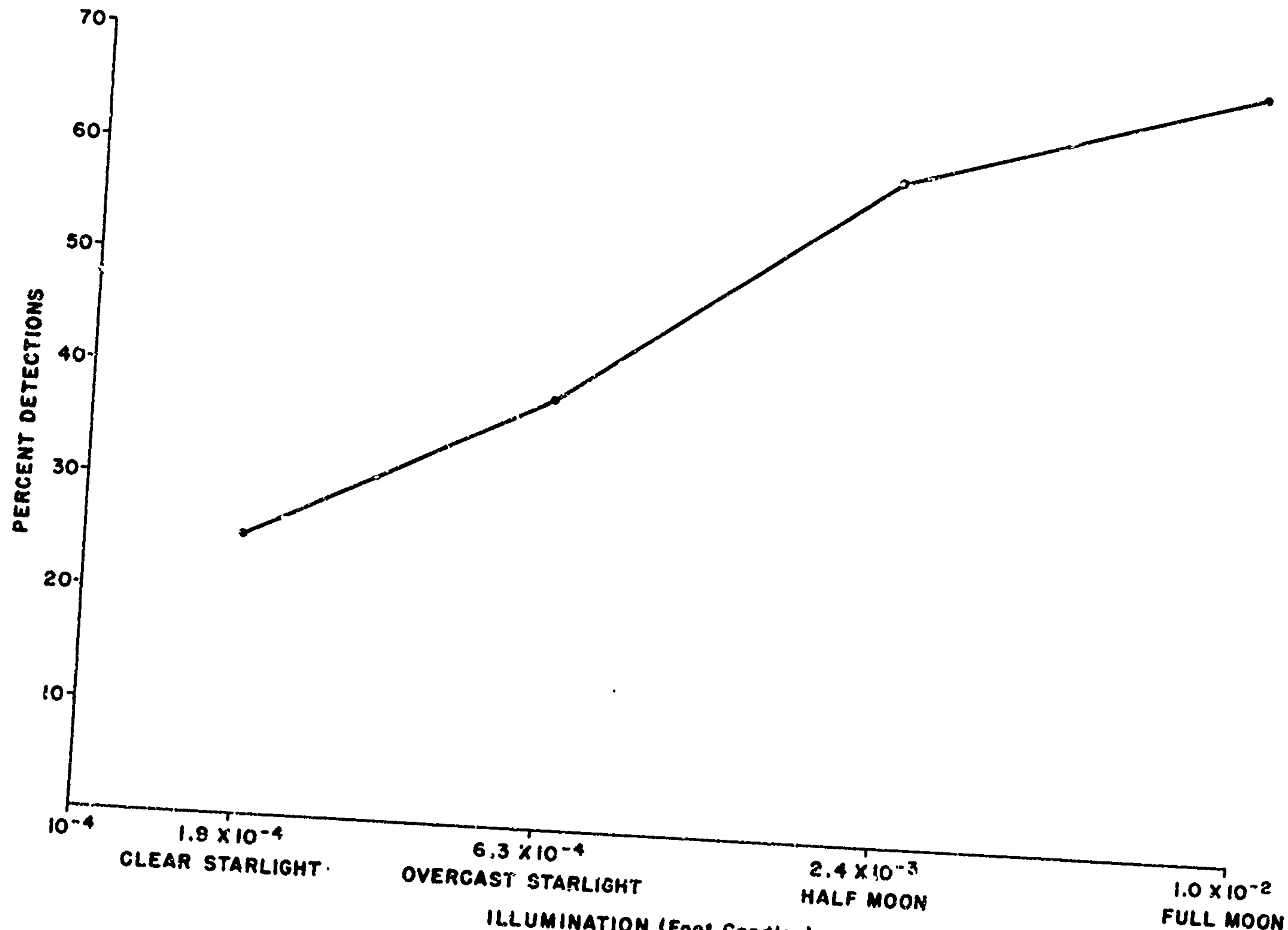

Figure 1. Relation between illumination and percent targets detected

Effect of Distance. Three distance bands were used: 50-100 meters (near), 101-200 meters (mid), and 201-300 meters (far). The number of targets presented each night in each band was 12, 18, and 18, respectively. Table 4 shows the percentages of targets detected at each distance and for each illumination condition. The percentages given in Table 4 were calculated by dividing the number of near, mid, and far targets detected by the number of targets presented for each distance. The percentages of targets detected, over all distances, are appropriately weighted. A word of caution--the overall figures for illumination used in this table as well as other tables are simply an arithmetic average of four experimental illumination conditions and do not describe average values for any given month or moon cycle. For example, there are more starlight nights in a month than any other specific moonlight condition. The overall data, however, has value as a simplified ready approximation.

Table 4

EFFECT OF DISTANCE ON PERCENT TARGETS DETECTED
WITH THE STARLIGHT SCOPE

Illumination Condition	Distance			Overall[a]
	Near	Mid	Far	
Clear Starlight	49	27	8	25
Overcast Starlight	69	42	12	38
Half Moon	73	67	42	59
Full Moon	79	72	56	68
Overall	68	53	31	48

[a] Weighted by number of targets presented per night at each distance 12, 18, and 18 for near, mid, far distances, respectively.

In general, performance was significantly impaired with increasing distance. However, the degree of degradation was significantly different for the different illumination conditions. Under clear starlight, 49% of the near targets were detected and 8% of the far targets, an absolute decrease of 41%, or a relative decrease of 84%. For overcast starlight, the absolute and relative decreases were 57% and 83%, respectively. The values for half moon were 31% and 42% and for full moon, 23% and 29%. Thus, the effect of distance was much greater under lower than under higher illuminations. Table 4 also shows a marked difference in percent detections of near-distance and mid-distance targets for low illumination (49% and 27%, respectively, for clear starlight) and little or no difference for high illumination (79% and 72%, respectively, for full moon).

In general, the Starlight Scope was highly effective in detecting personnel targets up to 200 meters. At more than 200 meters, it was effective at higher illumination levels, but relatively ineffective at lower illumination levels. With the naked eye, however, it would probably have been impossible to detect any targets at this distance under starlight illumination.

Effects of Target Mode--Moving versus Stationary. Target mode was included as one of the variables for study because it is commonly believed that moving targets are more easily detected than stationary targets. The percentage of moving and stationary targets detected, under each illumination condition, is shown in Table 5. Unexpectedly, the differences in percent detections were small and not statistically significant. One possible explanation lies in the size of the area to be searched. In the present experiment, subjects were searching a wide area and were, therefore, more or less continuously moving their devices. Under these conditions, movement of the target would be less conspicuous than under conditions in which the device was held relatively stationary and a target moving across the device field of view would produce an obvious disruptment of a static environment. In a subsequent experiment, this hypothesis was confirmed when more moving than stationary targets were detected in a search area 25° wide but not in a search area 75° wide.

Table 5

EFFECT OF TARGET MODE ON PERCENT TARGETS DETECTED WITH THE STARLIGHT SCOPE

Illumination Condition	Target Mode	
	Moving	Stationary
Clear Starlight	24	27
Overcast Starlight	36	39
Half Moon	60	58
Full Moon	64	72
Overall	47	50

Effects of Target Exposure Time. In combat situations, targets vary from very brief appearances to almost continuous exposure. However, for the present study, the exposure times were established at 10, 20, 30, and 90 seconds. As the number of target presentations (by experimental necessity) had to be limited, the number of targets presented each night were 8, 8, 24, and 8 for the 10-, 20-, 30-, and 90-second periods, respectively.

Table 6 shows the percentage of targets detected for each exposure interval under each illumination condition. Significantly more targets were detected with increasing length of target exposure and with increasing illumination. For the higher illumination conditions, performance did not improve markedly with exposure times longer than 30 seconds. Under full moon, for example, performance went from 76% to 88% for 30-second and 90-second target exposures, respectively--an absolute improvement of 12% and a relative improvement of 16%. For the lower illumination conditions, performance continued to improve markedly with increasing target exposure time. Under clear starlight, for example, the percent of targets detected went from 26% to 48% for 30-second and 90-second target exposures, respectively--an absolute improvement of 22% and a relative improvement of 85%. Thus, a significant interaction existed between illumination and exposure time.

Table 6

EFFECT OF TARGET EXPOSURE TIME ON PERCENT TARGETS DETECTED WITH THE STARLIGHT SCOPE

Illumination Condition	Target Exposure Time (Seconds)			
	10	20	30	90
Clear Starlight	12	14	26	48
Overcast Starlight	22	25	39	61
Half Moon	26	50	65	81
Full Moon	33	56	76	88
Overall	23	37	53	70

Target exposure time also was analyzed as a function of distance (Table 7). As expected, increased target exposure time resulted in increased target detections for each of the three distances studied. There were, however, differential effects in that increased target exposure time increased the percent target detections more for far targets than for near targets. For example, for near targets, 40% and 97% of the targets were detected with 10- and 90-second target exposures, respectively--a relative gain of 142%. For far targets, the comparable values are 12% and 45%--a relative gain of 275%. The inference from this result is that far targets have a fair probability (45%) of being detected provided that the target is exposed for a relatively long period of time (90 seconds). Since targets in combat frequently are exposed for a brief time, the Starlight Scope would have limited usefulness under those conditions. On the other hand, the data show that even for short exposure time, the Starlight Scope is an effective weapon for the closer ranges.

Table 7

EFFECTS OF DISTANCE AND TARGET EXPOSURE TIME ON PERCENT TARGETS DETECTED WITH THE STARLIGHT SCOPE

	Target Exposure Time (Seconds)			
Distance	10	20	30	90
Near	40	53	73	97
Mid	23	45	55	77
Far	12	18	35	45

Search Efficiency

Target difficulty varied as a function of distance and illumination. Thus, under some conditions in the present experiment, some targets could never be detected during search because they exceeded the capabilities of the man-device combination to see the target. The percentage detections reported above was based on the total number of targets presented, whether or not all targets were visible. These data are meaningful because the differential ability to see targets at different distances and under different levels of illumination is a function of the intrinsic properties of the devices and, as such, is an important contributor to their effectiveness. However, another type of comparison is also meaningful. If all targets are seeable, how efficient is the device operator in finding targets? Information of this type has implications for operational employment of the devices for engineering, and for improvement of search effectiveness. It was necessary, therefore, to develop a measure of how many targets were actually visible to a given operator on a given night. (This is, it was to be simply whether the operator could see the target, whether or not he found it during search.) At the completion of search testing, therefore, all targets were presented again with instructions indicating target location. The operator was then tested, with precautions against false reports, to determine whether or not he could see the target. This measure constituted the Seeability Index. The percentage of targets detected during search was then divided by the percentage that could be seen in order to obtain an Efficiency Score. The Efficiency Score thus reflects the percentage of targets found during search, considering only those that could be seen.

The search scores, seeability index scores (targets capable of being seen), and the resulting efficiency scores (ratio of search scores to the seeability scores) under the various illumination conditions are presented in Table 8. Search scores shown in this and the subsequent table are for 30-second target exposures. Both search and seeability index scores increased significantly with increasing illumination, search scores going from 26% to 76% and seeability scores from 48% to 97%. As expected, significantly more targets could be seen than were found. The efficiency scores show that at low light levels the ability to find targets was more impaired than the ability to see targets--only about 50% of the targets that could be seen were found. At higher light levels, efficiency improved considerably--about 75% of the targets that could be seen were found. The differential effect of illumination on the search and seeing tasks was significant.

Table 8

SEARCH, SEEABILITY INDEX, AND EFFICIENCY SCORES[a]
(30-Second Target Exposures Only)

Illumination Condition	Search Score	Seeability Index Score	Search Efficiency Score
Clear Starlight	26	48	54
Overcast Starlight	39	86	45
Half Moon	65	95	68
Full Moon	76	97	78
Overall	53	81	65

[a] Percentage scores.

While efficiency improved with increasing illumination (from about 50% to about 75% for starlight and moonlight conditions, respectively), overall only 65% of the seeable targets were found. The search problem involved was relatively simple, the terrain being largely open although covered with brush, and of moderate size. On a more complex and larger terrain, the efficiency can reasonably be expected to be even lower. The finding that 35% of the targets which were seeable were not found suggests that this loss is due to some aspect of search behavior. It is assumed that the loss could be attenuated with improved search techniques.

Search efficiency is also affected by distance. Table 9 shows these effects of target distance for each illumination condition. For all illumination conditions, efficiency decreased with increasing distance; that is, the ability to find targets during search was significantly more impaired by increasing distance than was the ability to see targets. The utilization of more effective search techniques could, again, greatly increase the probability of detection of the far targets that, although difficult, can be seen and hence detected during search. For closer ranges, a wider search area can be effectively employed and highly efficient search techniques are relatively less important.

Table 9

EFFECTS OF DISTANCE AND ILLUMINATION ON SEARCH EFFICIENCY SCORES[a]
(30-Second Target Exposures Only)

Illumination Condition	Distance		
	Near	Mid	Far
Clear Starlight	66	50	31
Overcast Starlight	70	45	17
Half Moon	74	69	48
Full Moon	80	73	60
Overall	73	62	45

[a]Percentage scores.

Earlier in the report it was shown that target mode--moving versus stationary--did not affect the probability of detection during search. However, it was possible that mode could differentially affect the ability to see a target. The effect of target mode on seeability scores is shown in Table 10. As was found for the search scores, movement had no effect on the ability to see the targets. Efficiency, therefore, was also not affected by target mode.

Table 10

EFFECTS OF ILLUMINATION AND TARGET MODE
ON SEEABILITY SCORES[a]

Illumination Condition	Mode	
	Moving	Stationary
Clear Starlight	55	42
Overcast Starlight	82	89
Half Moon	92	95
Full Moon	96	97
Overall	82	81

[a]Percentage scores.

The general level of performance with the binoculars was not expected to equal that with the Starlight Scope, but it was possible that under some conditions, considering cost-effectiveness trade-offs, the binoculars might be preferred. Additionally, objective measures of performance with the binoculars were obtained to provide information on the level of performance that could be expected for situations in which binoculars are the only night viewing aids available.

Fewer soldiers were tested with the binoculars than with the Starlight Scope. In order to have an adequate number of subjects in each illumination condition, it was necessary to combine subjects from the clear and overcast starlight conditions, and from half- and full-moon conditions. The tables presented in this section, therefore, show only two illumination conditions--starlight and moonlight.

Effects of Illumination and Distance. The effects on performance of illumination and distance, for 30-second target exposures, are shown in Table 11. As expected, performance with the Starlight Scope was significantly better than with the binoculars. The effects of distance and illumination were the same for both devices--a significant decrease in performance with increasing distance and significant increase with increasing illumination. For operational purposes, then, binoculars are virtually useless under starlight at any distance beyond 100 meters (about 5% detections) and of limited value for shorter distance (23% detections). However, under moonlight, substantial numbers (about 50%) of targets are detected at distances of up to 200 meters. Beyond 200 meters, the percent detections drops sharply (to 25%) even under moonlight. These values are for 30-second target exposure times; some improvement in performance would be expected with longer target exposure times. Also, it is reasonable to assume improvement if the search area size were reduced.

Table 11

EFFECTS OF ILLUMINATION AND DISTANCE ON PERCENT TARGETS DETECTED WITH THE STARLIGHT SCOPE AND 7 X 50 BINOCULARS (30-Second Target Exposures Only)

Illumination Condition	Starlight Scope Near	Mid	Far	Overall[a]	Binoculars Near	Mid	Far	Overall[a]
Starlight	60	36	11	32	23	7	4	10
Moonlight	85	76	59	72	56	46	25	41
Overall	73	55	35	53	38	32	17	29

[a]Weighted by the number of targets presented each night by distance: 6, 9, and 9 for near, mid, and far distances, respectively.

Effects of Illumination and Target Exposure Time. The percent detections for the Starlight Scope and binoculars, by target exposure time and illumination conditions, is shown in Table 12. Again, performance with the Starlight Scope was significantly better than with the binoculars. Performance with the two devices improved significantly with increased illumination, but the improvement was significantly greater for binoculars than for the Starlight Scope. With binoculars, 10% of the targets were detected under starlight and 41% under moonlight--a ratio of about 1:4. With the Starlight Scope, the comparable values were 31% and 64%--a ratio of about 1:2. In spite of the greater improvement found for the binoculars, performance with the Starlight Scope was considerably better than with binoculars, especially under starlight conditions (31% vs 10% for Starlight Scope and binoculars, respectively).

Table 12

EFFECTS OF TARGET EXPOSURE TIME AND ILLUMINATION ON PERCENT TARGETS DETECTED WITH THE STARLIGHT SCOPE AND 7 X 50 BINOCULARS

Target Exposure Time (Seconds)	Starlight Scope			Binoculars		
	Star-Light	Moon-Light	Over-all	Star-Light	Moon-Light	Over-all
10	16	30	23	0	20	12
20	20	54	37	7	34	24
30	32	72	53	10	41	29
90	54	85	70	22	72	53
Overall	31	64	48	10	41	29

Target exposure time was significantly related to performance, with more detections made as exposure time increased. Under starlight, differences between performance with the Starlight Scope and with binoculars are considerable, even for the longer exposure times--54% and 22% for the respective devices, with a 90-second target exposure. Under moonlight, the differences are less and, for the 90-second exposure time, performance with the binoculars closely approximates that with the Starlight Scope (72% and 85%, respectively). Operational implications are that, for the experimental distances used under high illumination levels when targets can be expected to be exposed for lengthy periods, the binoculars can be expected to perform in surveillance activities almost as well as the Starlight Scope. These conditions, however, are infrequent and therefore severely limit the use of the binoculars.

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) Behavior and Systems Research Laboratory, Arlington, Va.	2a. REPORT SECURITY CLASSIFICATION Unclassified
	2b. GROUP

3. REPORT TITLE

SEARCH EFFECTIVENESS WITH THE STARLIGHT SCOPE AND 7 X 50 BINOCULARS

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

5. AUTHOR(S) (First name, middle initial, last name)

John P. Farrell, James H. Banks, and Jack J. Sternberg

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
June 1970	39	2

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S) Technical Research Report 1164
b. PROJECT NO. DA R&D Proj. No. 2Q024701A723	
c. Night Operations	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d. b-00	

10. DISTRIBUTION STATEMENT

This document has been approved for public release and sale; its distribution is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	US Army Combat Dev Cmd, Fort Belvoir, Va. US Continental Army Cmd, Fort Monroe, Va. Office, Chief Res & Develop., Wash., D. C.

13. ABSTRACT

The NIGHT OPERATIONS program within the Behavior and Systems Research Laboratory is concerned with problems in optimizing human performance in relation to night vision devices and related sensors. To further this research, BESRL established a field unit at Fort Ord, California where, in conjunction with the Combat Developments Command Experimentation Command (CDCEC), experimentation has been conducted directed toward enhancement of the performance of the combat soldier in night operations. The first of a series of reports on BESRL's research effort in this area (Technical Research Report 1163), describes the experimental evaluation, conducted at Fort Ord, with four passive night vision devices, and presents results of the assessment of operator performance with these devices in target detection and search tasks. The research described in the present report was conducted at Fort Benning, Georgia and represents an exploratory study having the following objectives: 1) to develop methodology and technology essential to conduct of scientific field experimentation in search effectiveness in night operations; 2) to identify critical factors affecting target detection performance and their related parameters; and 3) to assess the operational usefulness of the Starlight Scope (AN/PVS-2) and the standard Army 7 x 50 Binoculars (M17).

A total of 65 operators were tested, four men each night, three using the Starlight Scope and one using the 7 x 50 binoculars. Subjects were required to detect targets (soldiers or "aggressor" type silhouettes) presented in two modes. Responses were recorded electronically. Data obtained were analyzed to determine performance effectiveness with the two devices, and the effects of illumination (starlight, half moon, full moon), distance (50 - 300 meters), target mode (moving vs stationary), target

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

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Security Classification

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
*Night observation						
Surveillance Systems						
*Night vision devices						
*Sensors						
*Sensor systems						
*Binoculars						
*Scope, starlight						
*Ambient light levels						
Target modes						
Target distance						
Moving targets						
Static targets						
*Target Detection						
BOI (Basis of Issue)						
*Search techniques						
Search area						
Field experimentation						
Research methodology						
Operator performance						
Terrain - Target factors						
Instrumentation						
MIX						
Seeability Index						
Detection Scores						
Search Scores						
Military psychology						

Unclassified
Security Classification

DD Form 1473

13. ADSTRACT - Continued

exposure time (10, 20, 30 and 90 seconds), and their interactions on search performance. Results showed the Starlight Scope to be superior under all conditions studied and to effect significant improvement in target detection ability. Detection performance with the Starlight Scope, however, was differentially affected by several of the variables studied. The binoculars were reasonably effective under high illumination (full moon), particularly at short distances (less than 200 meters); with lengthy target exposure, their effectiveness approached that with the Starlight Scope. Under these conditions, binoculars could be used with some confidence in surveillance activities; under starlight conditions, their value would be limited. In addition to providing baseline performance with the Starlight Scope and the 7 x 50 binoculars, the study resulted in development of practical and effective experimental technology and instrumentation applicable to a wide range of field experimentation and research in night operations.

B05788