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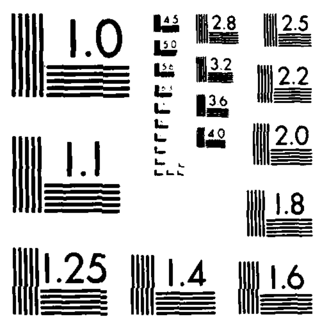

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Pursuit Tracking Performance Decrements Associated with Decreasing Ambient Illumination

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Reduction in ambient illumination alters one's ability to acquire and track moving targets. In this study we have attempted to describe the relationship between decreasing ambient illumination and pursuit tracking performance. Eight male volunteers used an optical tracking device to track targets at a constant angular velocity of 5 mrad/sec under bright and reduced ambient light conditions in the BLASER simulator. Reduction of the ambient light levels was accomplished by inserting neutral density filters into the optics of the tracking device. Volunteers were assigned randomly to a schedule of 6 reduced ambient illumination. Analysis of Variance for the Percent Time-on-Target (%TOT), horizontal Root Mean Square (RMS) error, and Maximum Absolute Error (MAE) revealed highly significant main effects. Ambient light levels below 0.075 cd/m^2 produced large tracking error scores (e.g., %TOT < 68%). The use of direct view optics below luminance levels of 0.18 cd/m^2 could seriously jeopardize the success of the mission.

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ABSTRACT

Reduction in ambient illumination alters one's ability to acquire and track moving targets. In this study we have attempted to describe the relationship between decreasing luminance levels and pursuit tracking performance. Eight male volunteers used an optical tracking device to track targets at a constant angular velocity of 5 mrad/sec under bright and reduced ambient light conditions in the BLASER tracking simulator. Reduction of the ambient light level was accomplished by inserting neutral density filters into the optics of the tracking device. Volunteers were assigned randomly to a schedule of 6 levels of reduced ambient illumination. Analysis of Variance for the Percent Time-on-Target (%TOT), horizontal Root Mean Square (RMS) error, and Maximum Absolute Error (MAE) revealed highly statistically significant main effects. Ambient light levels below 0.075 cd/m^2 produced large tracking error scores (e.g. %TOT < 68%). The use of direct view optics below luminance levels of 0.18 cd/m^2 could seriously hamper the success of the mission.

PREFACE

We would like to express our appreciation to SP4 Charles Barba for his assistance in the conduct of this experiment, Mr. Ken Bloom for the valuable discussions on visual acuity and Virginia Gildengorin, PhD, for her assistance in the design and statistical evaluation of the data.

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Pursuit Tracking Performance Decrements Associated with Decreasing Ambient Illumination

Within the current military arsenal are many weapon systems requiring the operator to acquire and track moving targets. Changes in ambient illumination have been shown to alter the ability to detect, recognize, and identify targets in the field (1). Also, the loss of contrast between the target and background has been suggested as one of the factors contributing to decreased visual performance (2). If the ambient illumination were to change significantly while a soldier was using direct view optics, he might not be able to complete the mission. These changes may be naturally occurring (dust, fog, clouds, and the normal progression of the sun) or man-made (camouflage, smoke, and exploding artillery shells).

Most performance studies concerned with luminance have been conducted with simple and/or complex stationary targets at low photopic to mid-mesopic levels (10-0.6 cd/m^2) (3-5). However, it has been shown that a filter that reduces available light to 0.01% (approx. 0.36 cd/m^2) of the normal daytime ambient level produces severe performance decrements in target detection time and the probability of target detection (1). Also, this same reduced luminance level has been shown to dramatically increase target recognition time and decrease the probability of target recognition (1).

Pursuit tracking is a psychomotor task that involves dynamic visual acuity. Such studies have been conducted with the BLASER simulator and a modified TOW tracking system (6-8). Previous BLASER studies have shown that performance decrements have occurred when an attenuating filter has been placed in the optical pathway of the tracking device. This reduced the average ambient illumination from 260 lm/m^{2}sr (bright light) to 0.35 lm/m^{2}sr (dawn/dusk). The low ambient light level produced tracking performance decrements of 15% to 25% (i.e., if the tracker had a mean percent Time-on-Target (%TOT) score of 95% under the bright ambient light level, his %TOT score would decrease to about 75% under the low ambient light condition).

In combat, ambient light levels can range from extremely bright (i.e., glare) to very dim (i.e., dawn/dusk approaching darkness). Within the central portion of the range, little change in performance is expected because of the eye's ability to compensate for wide changes in ambient light levels. The manner in which pursuit tracking performance changes under glare conditions has been studied (9,10). Data for stationary target detection and recognition times under reduced ambient light conditions are available (1-5), but changes in pursuit tracking performance under reduced ambient light conditions have not been studied fully.

The purpose of this study was to determine the degree of performance decrement and the rate at which performance declines as the ambient light level is reduced by systematically introducing neutral attenuating filters into the optical pathway of the BLASER tracking simulator

METHODS

Volunteers. Eight male military and civilian volunteers, ranging in age from 23 to 48 years (mean age 32), from Letterman Army Institute of Research (LAIR), Presidio of San Francisco, CA, served as participants Each volunteer was administered a series of visual function tests. Only volunteers with 20/20 visual acuity (corrected if necessary), normal contrast sensitivity function, and normal dark adaptation curves were accepted as participants for this study. Each volunteer was briefed on the purpose of the study and signed a volunteer/informed consent statement before participating in the study.

Apparatus. Pursuit tracking performance was evaluated in the BLASER tracking simulator (6). The simulator consisted of a 1/32 scale model T-62 Warsaw Pact tank target on a terrain board and a full-sized sandbag bunker which housed the optical tracking device. The tank was track-mounted and driven across the terrain in two directions (left-to-right and right-to-left) The tank traversed an arc located approximately [illegible] m from the operator. The visual angle subtended by the tank was 4 mrad (14 min). The optics in the tracking device were designed to duplicate the visual-motor task of tracking a tank at 1 km through 10 power optics in this simulation The target traveled across the terrain for 15 sec at a constant angular velocity of [illegible] mrad/sec. A 0.52-mrad square (1.8 min) aiming patch was affixed to one side of the tank in a center-of-mass position. An infrared light-emitting diode (IR LED) located in the center of the aiming patch was imaged by a television camera mounted coaxially with the optics of the tracking device The IR LED was invisible to the operator. Its signal provided a reference source for the microprocessor and associated software to monitor performance electronically.

The terrain board was illuminated by a bank of fluorescent lights. The only visual access to the terrain board from the bunker was through the optics of the tracking device. Reduced ambient lighting was achieved by placing light attenuating filters into the optical path. The filters were neutral density (ND); that is, each filter attenuated all wavelengths in the visible spectrum by the same amount. For this paper the filters used are identified by their optical density (OD). Optical density is a logarithmic transform of the optical transmission (T) (11).

$$OD = \log_{10} (1/T)$$

A 1.0 OD filter has a transmission of 10% and a 2.0 OD filter has a transmission of 1%. The 6 reduced ambient light levels tested were obtained by inserting filters of 1.5 OD, 2.1 OD, 2.7 OD, 3.3 OD, 3.9 OD, and 4.5 OD.

Tracking data were collected under 2 ambient light levels (bright and dim) on training days and 7 ambient light levels (1 bright and 6 reduced) on the test day. The dim ambient light level on training days was created by inserting a 2.7 OD Wratten filter stack into the optical pathway of the tracking device.

Radiometry. The spectral radiance, total luminance, luminous contrast, and color contrast of the BLASER tank and terrain were measured with an Imaging Spectroradiometer (Optronics Laboratory, Model 740A(740 A-D/740-1C/IBM PC)). These measurements included (a) the spectral radiant transmission and luminous transmission of the tracking device and (b) the perceived spectral luminance and total effective luminance through several neutral density filters. These measurements will be reported in a separate paper.

The spectral absorbance of each of the ND filter combinations was measured over the wavelength range from 380 to 800 nm on a Varian 2300 spectrophotometer. In addition, the 2.7 OD Wratten filter stack, used in previous BLASER low-light studies and on training days, was measured.

Procedure. A brief question-and-answer period and administration of the visual tests were conducted within the Division of Ocular Hazards, LAIR. Each volunteer was assigned to a randomized filter presentation schedule in the order they were accepted into the study. To begin the study, each volunteer was seated in the BLASER bunker.

The tracking sessions began with the target on the left side of the terrain board. Each trial was initiated by the commands "READY" and "GO." On the "READY" command the volunteer aligned the crosshairs of the tracking device on the center of the aiming patch. When the command "GO" was given, he tracked the target in either a left-to-right or right-to-left direction for 15 sec. After each trial the volunteers were instructed to "RELAX" until the next "READY" command. During the inter-trial period (45 sec) the volunteers were given their summary statistics (percent time-on-target and standard deviation scores). All volunteers tracked alternately in both directions (left-to-right and right-to-left).

Training. All volunteers received 2 days of training with the BLASER tracking simulator. Day 1 consisted of twenty-two 1-min trials and Day 2 of thirty-two 15-sec trials. On each day under this paradigm, half the trials were presented under the bright ambient light condition and half the trials under the dim ambient light condition.

Test Day. The test day for each volunteer included all 7 ambient light conditions. All volunteers started the test session under the bright ambient light condition. Each session was composed of 35 trials (5 trials/ambient light condition). The presentation order of the neutral density filters was randomized. After the first 5 trials each volunteer was allowed to partially dark adapt for 5 min in the darkened bunker. Time was allotted for dark adaptation during the session if a darker filter followed a lighter filter and the difference in OD was greater than 1.2 (e.g., 2.7 to 3.9). This prevented the data from reflecting adaptation processes to the darker filter. No period of adjustment was allowed when a lighter filter followed a darker filter, except for the normal inter-trial interval. Normal pupillary response to the increased light was judged sufficient.

Test Scores, Statistical Design and Analysis. Horizontal and vertical error scores were collected with the BLASER tracking simulator. The score for each volunteer for each filter condition represented the mean of each block of 5 trials/filter. Means were obtained for percent time-on-target, root mean square (RMS) error, and maximum absolute tracking error (MAE). Time-on-target was defined as the percent of time during the 10-sec data collection window that the operator maintained the crosshairs within the 0.52 mrad square aiming patch. RMS error scores were computed from the following equation:

$$RMS = \sqrt{\frac{\Sigma(X_i)^2}{N}}$$

where: $X_i = x - x_o$

N = Sample size

x = location of the crosshairs at each sample point

x_o = the center of the target aiming point

Horizontal RMS error scores describe how well a tracker is able to keep the vertical crosshair of the reticle over the target patch. RMS error scores reflected the tracker's deviation from the center of the target patch by use of a calibrated center-of-mass aiming point and yielded higher values than the SD error scores. The SD error scores were based on an operator-defined mean-aiming-point and, therefore, will not be presented. This task, in its present configuration, is composed mainly of a strong horizontal component. Therefore, only the horizontal RMS data are presented.

Maximum error scores were generated on-line by a point-by-point comparison of the data for each trial. The maximum error scores were converted to absolute values for use in the Analysis of Variance (ANOVA). The maximum absolute error scores reflect the largest excursion from the center of the aiming patch, without respect to direction of the excursion (lead vs lag).

This study was a single factor design with 7 levels (the control condition and 6 neutral density filter conditions). All analyses were performed with the BMDP Statistical Software Package (12). The ANOVA program P2V includes repeated measures, split-plot, and changeover designs. In the present ANOVA the model was treated as a factorial design with repeated measures. The 0.05 level was used for determining significance in all cases. Post hoc comparisons were made with the Least Significant Differences (LSD) test (13).

An initial analysis of the percent time-on-target (%TOT), RMS, and MAE error scores was performed using program P7D, Description of Groups with Histograms and ANOVA (12), to test for equality of the means between groups (filter conditions). This analysis plotted side-by-side histograms of the data and a one-way ANOVA. The histogram was used to determine if a transformation was to be performed on the data.

The results of program P7D for the %TOT scores revealed the need for transformation of this data set. Since %TOT is a proportion (a binomial distribution), the following formulae were employed to perform the transformation (13):

(a) for cases where $0<X<100$,

$$X' = 2\arcsin(X/100)^{1/2}$$

and (b) for cases where $X=100$ or $X=0$

$$X' = 2\arcsin(X/100 \pm (1/(2N)))^{1/2}$$

where: X' = transformed score

X = raw score

N = number of observations on which X is based.

It was necessary to divide the raw score (e.g., 98.9%) by 100 to yield a proportion between 0.001 and 0.999, since X' assumes values between 0.063 and 3.0873. In formula (b) the value $(1/(2N))$ was additive for cases where $X=0.00$ and subtractive for cases where $X=100.00$.

After performing the LSD test to determine possible correlations between all possible pairs, polynomial regressions, program P5R, were performed on the 3 data sets (12). This program computed the least squares fit of a polynomial in 1 independent variable to the dependent variable and reported polynomials of degrees 1 through N, where N is user defined, with a goodness-of-fit statistic for each equation. For each polynomial degree, program P5R printed the regression coefficient with standard error and t-values for each orthogonal polynomial.

RESULTS

Percent Time-on-Target. The ANOVA was performed on the transformed data set, and the results were highly statistically significant (df=7, F=167.18, $P < 0.001$). The post hoc LSD test performed on the means from the ANOVA is summarized below. (OD's with underlines in common indicate that the result of that comparison was not significant. For example, the 0 OD and 1.5 OD condition were not significantly different from one another, but the 0 OD condition was significantly different from the 2.1 OD condition.) This test showed that as OD increased, %TOT scores decreased significantly. Statistical significance was achieved at the 3.3 OD level.

	OD						
%TOT	0	1.5	2.1	2.7	3.3	3.9	4.5

The means from the ANOVA were also used in the polynomial regression. The results revealed that the data fit a 2nd degree polynomial (Fig. 1) (df=1, F=6.55, $P>0.05$) and accounted for 98% of the variability in %TOT scores (R^2 = 0.98).

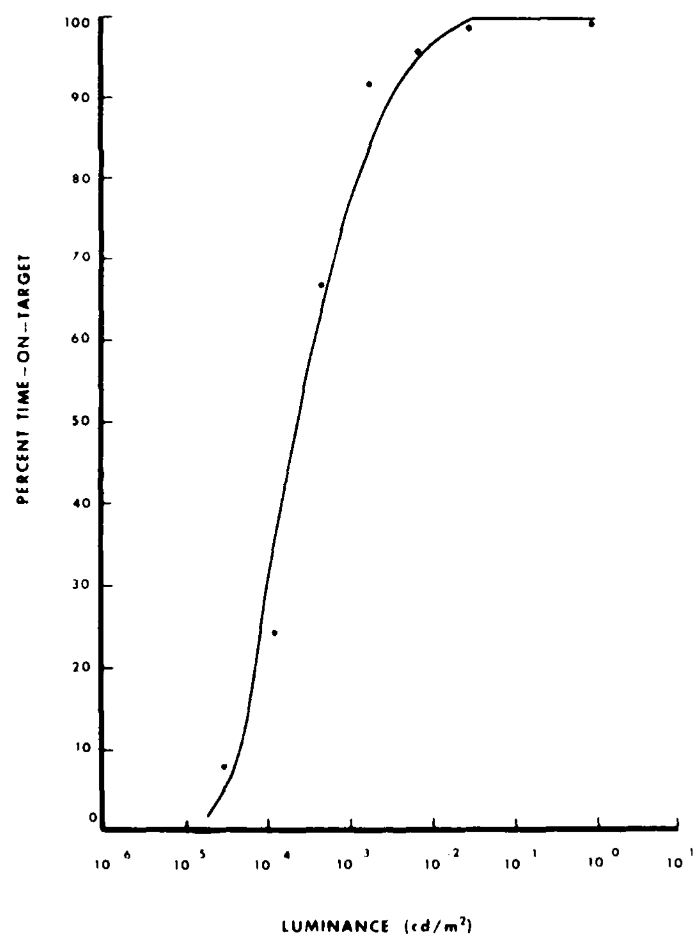

Figure 1. Percent Time-on-Target scores vs luminance. The solid line represents the regression equation from program 5R. The dots represent the mean %TOT for the 7 ambient light levels.

RMS and MAE Error Scores. The results of the 7D analysis for the RMS and MAE error scores indicated that no data transformation was necessary. The ANOVA yielded highly statistically significant results for the RMS (df=7, F=151.31, $P<0.01$) and MAE (df=7, F=300.20, $P<0.001$) error scores. The results of the post hoc LSD tests performed on the means are summarized below:

	OD						
RMS	0	1.5	2.1	2.7	3.3	3.9	4.5
MAE	0	1.5	2.1	2.7	3.3	3.9	4.5

Unlike the %TOT scores, the RMS means did not achieve statistical significance until the 3.9 OD and 4.5 OD levels. The MAE scores were similar, except that statistically significant differences were noted beginning at 3.3 OD.

Again, the means from the ANOVAs were used in the polynomial regressions, and the results revealed the RMS and MAE error scores also were best fit by a 2^{nd} degree polynomial (Figs. 2 and 3) (RMS: df=1, F=6.81, $P>0.05$, $R^2=0.99$; MAE: df=1, F=3.55, $P>0.05$, $R^2=0.99$). In both cases this equation accounted for almost all of the variability in the dependent variables.

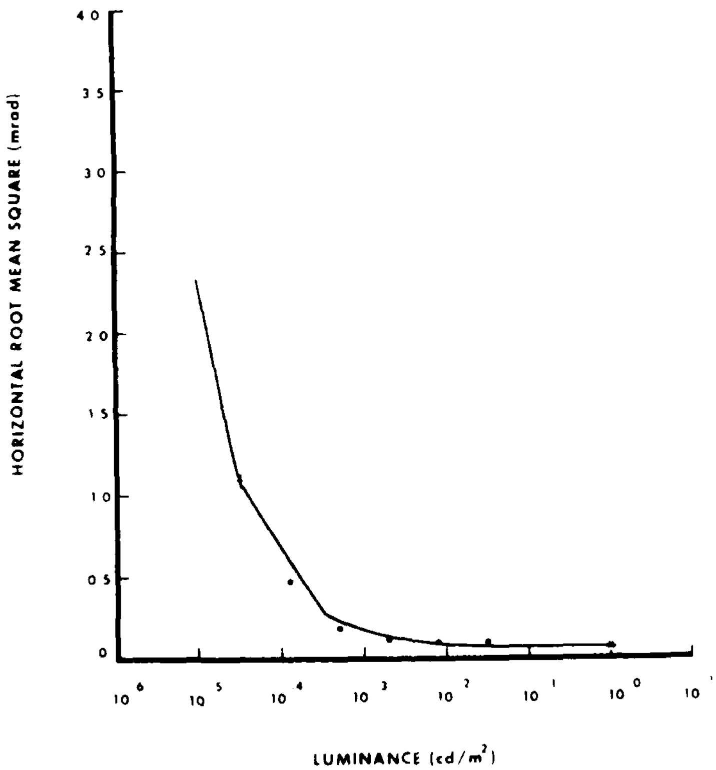

Figure 2. Horizontal RMS error scores vs luminance. The solid line represents the curve described by the regression equation from program 5R. The dots represent the mean RMS error scores for the 7 ambient light levels.

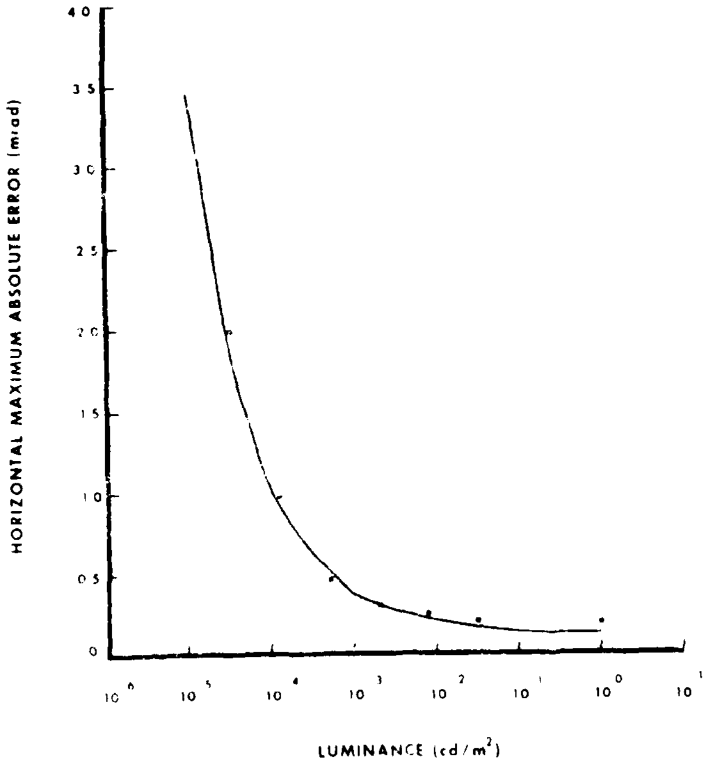

Figure 3. Horizontal MAE scores vs luminance. The solid line represents the curve described by the equation from program 5R. The dots represent the mean MAE scores for the 7 ambient light levels.

Radiometry. The luminous transmittance (LT) of each of the ND filters was calculated from the radiant energy transmission measurements using the relationship:

$$LT = \frac{\int S_\lambda \, T_\lambda \, V_\lambda \, d\lambda}{\int S_\lambda \, V_\lambda \, d\lambda}$$

where:

S_λ = the spectral distribution of the source. A source having the spectral distribution of the terrain illumination was used.

T_λ = Spectral transmission of the ND filter.

V_λ = Photopic luminous efficiency function.

The LT of the tracking optics was also computed. The effective OD of the filters was derived from the LT calculations. These data are presented in Table 1.

TABLE 1

Luminous Transmittance of Neutral Density Filters

FILTER	LT (%)	OD
tracking device	0.28	0.54
1.5 OD	0.023	1.62
2.1 OD	0.0062	2.21
2.7 OD	0.0015	2.84
3.3 OD	0.00032	3.50
3.9 OD	0.000076	4.12
4.5 OD	0.000016	4.79
2.7B OD*	0.0013	2.88

* Wratten filter stack.

The terrain and tank luminance values were averaged across areas of measurement. These mean luminance values are presented in Table 2.

TABLE 2

Effective Mean Luminance of Tank and Terrain Features*
(lm/m^2sr)

OD

	0	1.5	2.1	2.7	3.3	3.9	4.5
Tank	12[illegible]	2.85	0.74	0.17	0.038	0.017	0.0019
Terrain	261	5.71	1.49	0.35	0.075	0.018	0.0038

* viewed through neutral density filters

These values were added to the measurements of LeGrand (14), Bartley (15), IES (16) and Riggs (17) and are presented in Figure 4. The mean terrain luminance for the bright ambient light condition lay around an overcast day, and the 4.5 OD filter condition lay approximately midway between a moonlit night with full moon and a starlit night without moon.

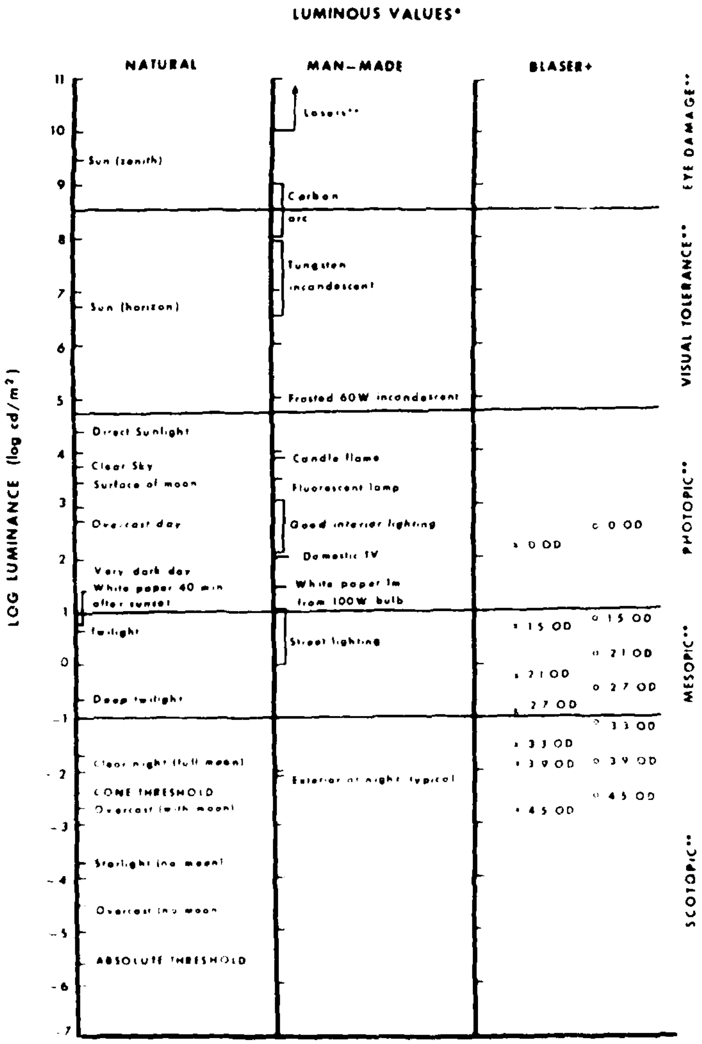

Figure 4. Luminous values of several natural and man-made sources and BLASER tank and terrain.

* From LeGrand (14), Bartley (15), IES (16) and Riggs (17).

** Actual values and ranges depend on spectral makeup of radiation.

\+ Mean luminance values of BLASER target and terrain. (x's = target; o's = terrain).

The tank/terrain contrast was calculated using the formula (16)

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

where: L_b = mean background luminance

L_t = mean target luminance

The means used in the formula were selected from the 0 OD condition. Since neutral density filters were used, the contrast would remain the same at the various ambient light levels created in this study. By this formula the target/background contrast was calculated to be 37%.

DISCUSSION

Among the variables that are purported to influence pursuit tracking performance, luminance, target size, and color were selected as the most critical (18,19). Luminance appears to be the most important factor, since it directly affects vision (20) and also target contrast (21). It has been shown that targets at low luminance levels (1-4) or targets against heterogeneous backgrounds (19), i.e. ground and foliage, are more difficult to detect.

In this study we examined the effects of systematically decreased ambient illumination on pursuit tracking performance. It was obvious (Figs. 1-3) that the lowest ambient light level (1.6×10^{-5} cd/m^2) would produce the largest tracking error scores. However, the shape of the performance curve that described the deterioration in tracking performance as ambient light level decreased was unknown. Sheard (22) reported that visual acuity improved rapidly as background illumination increased until the background reached an intensity of 1 foot-candle (3.4 cd/m^2); and then visual acuity increased at a slower rate as background illumination was increased. Since the performance of a pursuit tracking task includes dynamic visual acuity, it was expected that the same relationship should exist in the present study. This was in fact the case. As evidenced in Figures 1-3, tracking performance showed a slow and steady decline as the ambient luminance decreased until the ambient luminance reached approximately 3.8×10^{-2} cd/m^2. At that point the rate of tracking performance decreased rapidly. This value is lower than Sheard had reported, but may be attributable to the use of a dynamic target in this study as opposed to a static acuity target in Sheard's study.

Motion cues enhance the ability to detect targets at lower ambient light levels.

Osterberg (23) described the distribution of cones and rods in the retina. As one moves away from the center of the fovea, there is a rapid decline in the number of cones. The cones in the central fovea are connected to individual optic nerve fibers (15) that permit fine resolution, the ability to discriminate detail at photopic levels. Conversely, there is a rapid increase in the number of rods, which reach a maximum density at about 20° from the center of the fovea, and then drop off in the farther periphery. Unlike cones, rods are not capable of resolving fine detail, and it has been shown that several rods are connected to a single optic nerve fiber, which in the farther periphery would transmit a fuzzy silhouette to the brain (16). Randall et al. (24) plotted visual acuity as a function of degrees of eccentricity from the center of the fovea. At 0°, visual acuity was highest, approximately 20/17 (Snellen notation). At 20°, visual acuity decreases to about 20/100.

As luminance decreases, visual cues such as borders and contours become less apparent and eventually disappear completely. This represents the shift from foveal (photopic) vision to a mix of foveal and parafoveal (mesopic) vision and to peripheral (scotopic) vision. As this shift occurs the clarity of photopic vision gives rise to the indistinctness of scotopic vision. Also, the size of the pupil increases with the decline in luminance. Smaller pupils at high levels of luminance and wider pupils at lower levels of luminance fulfill a number of optical optimizations. First, small pupils reduce normal ocular aberrations when good cone vision (photopic) permits high resolution of fine detail and the light level exceeds that required for maximum visual acuity (24). Second, large pupils allow the maximum amount of available light to reach the retina at scotopic levels when rod vision is incapable of resolving fine detail (16). As an object's retinal image appears farther from the fovea, visual acuity decreases. As luminance levels decrease and approach 10^{-3} cd/m^2, the cones become less and less effective. Rod activity begins slightly above this level. Therefore, at the lower luminance levels in this study, peripheral receptors were the primary means of "seeing" the target.

The increased use of the peripheral receptors leads to an increase in scanning to "see" the target. An increase in scanning also yields higher error scores.

Scanning seems to reflect an attempt by the tracker to locate the crosshair's center-of-mass while fixating on the crosshairs. The movement of the target complicates this stratagem because the target tends to drift in and out of the foveal region as the tracker attempts to "match" his eye movements with that of the target. As the target enters the foveal region, the target or crosshairs may fade out (25), causing the tracker to move his eye or the tracking device, thereby producing a scanning type movement. Scanning (or drifting) has been shown to decrease visual acuity in monocular tasks (26).

CONCLUSION

We have (a) established a baseline curve for pursuit tracking performance at several luminance levels and (b) equated our laboratory luminance values with outdoor luminance values. It was demonstrated that as luminance levels decrease, pursuit tracking performance with direct view optics becomes increasingly more difficult. Tracking performance became highly unstable at luminance levels below 0.18 cd/m^2. It is conceivable, at this point, that direct view optics would become essentially useless. However, our data are based on a medium contrast target and the same size target. Lower contrast targets and targets of varying size would alter the point at which tracking performance with direct view optics becomes unreliable. As target/surround contrast becomes lower and target size decreases we would expect the "cut-off" point to be raised.

RECOMMENDATIONS

We studied pursuit tracking performance decrements associated with decreasing ambient illumination by attenuating the available light to the tracker's eye. This attenuation reduced all wavelengths equally. It is of utmost importance to study the relationship of color and luminance to pursuit tracking performance.

REFERENCES:

1. Home R. The effects of colour and luminance filtering on military acquisition. 01 Division, Royal Signals and Radar Establishment, Malvern, Worcestershire, England. (personal communication)

2. van der Willt GJ, Waarts RG. Contrast detection and its dependence on the presence of edges and lines in the stimulus field. Vision Res 1983;23:821-830.

3. Blackwell HR. Contrast thresholds of the human eye. J Opt Soc A 1946;36:624-643.

4. Teichner WH, Mocharnuk JB. Visual search for complex targets. Hum Factors 1979;21:259-275.

5. Nelson MA, Halberg RL. Visual contrast sensitivity functions obtained with colored and achromatic gratings. Hum Factors 1979;21:225-228.

6. O'Mara PA, Stamper DA, Beatrice ES, Lund DJ, Jones RL, Serenbetz R, Hannon JP. BLASER: A simulator for the investigation of biomedical factors influencing laser-designator operators. Presidio of San Francisco, CA: Letterman Army Institute of Research, 1979: Technical Note No. 79-10TN.

7. Stamper DA, O'Mara PA, Beatrice ES, Lund DJ. Tracking performance with a viscous-damped mount under simulated conditions of varied ambient light levels and velocities. Presidio of San Francisco, CA: Letterman Army Institute of Research, 1980: Institute Report No. 82.

8. Levine RR, Stamper DA, Lund DJ, Stuck BE, Cheng DW. Field evaluation of laser protective materials on TOW tracking performance under bright and dim ambient light levels (U). Presidio of San Francisco, CA: Letterman Army Institute of Research. 1983; Institute Report No. 184.

9. Levine RR, Lund DJ, Stuck BE, Stamper DA, Beatrice ES. Project Morningstar. Effects of glare produced by low-level helium-neon radiation in human pursuit tracking performance (U). Presidio of San Francisco, CA: Letterman Army Institute of Research. 1985; Institute Report No. 203.(SECRET)

10. Stamper DA, Lund DJ, Stuck BE, Penetar DM. Project Morningshine (U). Presidio of San Francisco, CA: Letterman Army Institute of Research. 1986; (in preparation).

11. Gray DE, ed. American Institute of Physics Handbook. 2nd edition. New York: McGraw-Hill Book Co., 1963:6-6.

12. Dixon WJ, Brown MB, eds. BMDP Statistical Software. Los Angeles, California: University of California Press, 1985.

13. Winer BJ. Statistical principles in experimental design. New York: McGraw-Hill Book Co., 1971:199.

14. LeGrand Y. Light, color and vision. Alva, Scotland: Robert Cunningham and Sons, Ltd, 1957.

15. Bartley SH. The psychophysiology of vision. In: Stevens SS, ed. Handbook of experimental psychology. New York: Wiley and Sons, 1951:921-984.

16. International Engineering Society. IES lighting handbook. 5th ed. New York. International Engineering Society, 1972:Chapter3;3-39.

17. Riggs LA. Light as a stimulus for vision. In: Graham CH, ed. Vision and visual perception. New York: Wiley and Sons, 1965:1-38.

18. Steinman RM. Effect of target size, luminance and color on monocular fixation. J Opt Soc A 1965;55:1158-65.

19. Bloomfield JR, Graf CP, Graffunder K. Visual factors in target disruption. [Abstract] NTIS 1975.

20. Luckiesh M. Light, vision and seeing. New York: D van Nostrand, 1974.

21. Zoethout WD. Physiological Optics, 4th ed. Chicago: Professional Press, 1947.

22. Sheard C. Some factors affecting visual acuity. Am J Physiol Optics 1921;2:1168-184.

23. Osterberg G. Topography of the layer of rods and cones on the human retina. Acta Ophthalmol 1935;Suppl 29:1-102.

24. Randall HG, Brown DJ, Sloan LL. Peripheral visual acuity. Arch Ophthalmol 1966;75:500-504.

25. Pirenne MH. Visual acuity. In: Davson H, ed. The eye. The visual process. Vol 2. New York: Academic Press, 1962:184-187. (Section 3, chapter 9, part 2)

26. Ratliff F. The role of physiological nystagmus in monocular acuity. J Exp Psychol 1952;43:163-172.

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