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Visual detection of life rafts in the sea presents a difficult task which might be aided by use of appropriate sunglasses designed to reduce glare and atmospheric attenuation while enhancing target-to-background contrast. To evaluate this possibility, target acquisition performance associated with ~~the following~~ several types of sunglass lenses was compared with that of the unaided eye. Hazemaster, Oakley Doc, Cosmetan and N-15. A circular 1:10000 scale terrain model was used to simulate an air-sea rescue operation under conditions of relatively low

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EFFECTS OF LENS COLOR ON TARGET VISIBILITY FOR AIR-SEA RESCUE

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ABSTRACT

Visual detection of life rafts in the sea presents a difficult task which might be aided by use of appropriate sunglasses designed to reduce glare and atmospheric attenuation while enhancing target-to-background contrast. To evaluate this possibility, target acquisition performance associated with the following types of sunglass lenses was compared with that of the unaided eye: Hazemaster, Oakley Doc, Cosmetan and N-15.

A circular 1:1000 scale terrain model was used to simulate an air-sea rescue operation under conditions of relatively low daylight illumination. Observers searched for targets while making simulated banking turns. Performance measures were response time and number of targets found. Results showed the Oakley Doc to be the best and the Cosmetan to be the worst of the lens alternatives. However, no filter was found to be superior to the unaided eye. The data agree with recent target acquisition studies in showing no advantage for yellow sunglass lenses. The results are also consistent with the assumption that supposed enhancement properties of colored lenses may well be offset by losses in light transmission associated with their use.

INTRODUCTION

The air search and rescue operation presents a variety of visual problems which can be effectively researched by means of three-dimensional terrain models and associated simulation techniques. With this approach, both operational realism and experimental control are available. The researcher can reliably specify, control and manipulate those factors which affect visual performance under conditions which are predictive of successful search and rescue sightings in the real world. The terrain model method has been successfully applied to the air-rescue problem (Hilgendorf, 1972) using a small-scale (1:1000) circular model with simulated life rafts and wreckage for targets. Solar illumination, circling aircraft motion and target/terrain features were simulated. The main variable in Hilgendorf's study was the type of sunglass lens used by the observer as an aid to target detection. The alternatives studied were a yellow filter (Kodak #12) and the standard Air Force sunglass (N-15). Although a significantly larger number of targets was acquired using the yellow rather than the standard lens, neither type of sunglass proved to be more effective than the unaided eye.

The present experiment is an extension of the above study with two important changes to provide more complete information on the utility of colored sunglasses: (1) the inclusion of artificial haze to afford atmospheric attenuation, and (2) the introduction of two additional sunglass lenses (Oakley Doc and Cosmetan). The purpose of these changes was to provide a more realistic flight environment and to perform a more complete evaluation of the different types of colored lenses either being used or considered for use by the Air Force. The spectral transmittance of the four lenses used in this study are shown in Fig. 1 and should be referred to in considering their relevancy to target acquisition.

Hazemaster (yellow)

This filter has the sharpest cut-off in transmittance, dropping abruptly from a high of 85% for all wavelengths longer than 520nm to less than 5% for all wavelengths shorter than 480nm. Many papers have dealt with the evaluation of this or similar yellow filters as visual aids (Verplanck, 1947; Ross, 1950; Bierman, 1952; Wyszecki, 1956; Allen, 1964; Richards, 1964; Septon, 1969; Kislin, et al., 1968; Gregg, 1969; Katz, et al., 1970; Heckart, et al., 1971; Hilgendorf, 1972; Luria, 1972). Most of these studies have been motivated by one or more of the following arguments which offer hypothetical support to the enhancement of vision through yellow filters: (1) Longer wavelengths tend to be better focused on the retina than shorter ones. (2) Longer wavelengths are also subject to less scattering by aerosols as well as the ocular media. (3) Wavelengths to which the photopic eye is most sensitive are transmitted by the yellow filter. (4) Light transmitted through a yellow filter is subjectively brighter than white light of equal intensity. (5) Reducing the range of wavelengths transmitted to the eye is theoretically beneficial to visual acuity. (6) The yellow filter should afford increased color contrast and conspicuity in situations where targets reflect long wavelengths and their backgrounds reflect short wavelengths.

Despite the above arguments, little or no empirical data have been collected which show impressive advantages for the visual use of yellow filters. Two studies (Luria, 1972; Kislin, et.al., 1968) have suggested at least limited value through increased color contrast.

Oakley Doc (pink)

This filter transmits 85-90 percent of all visible wavelengths beyond 690nm. Below this value its transmittance is rapidly reduced reaching a minimum of 10% at 510nm and then building up to a smaller peak of about 40% at 390 nm. This type of lens was formerly used in the flying goggles of the U.S. Navy and has been gaining acceptance among USAF pilots (Everson and Levene, 1973). Since more of the shorter wave lengths are cut out by this pink filter than are blocked by the yellow filter, one might attach even greater importance to those arguments (see 1 and 2 above) which suggest advantages for long wavelength transmission. Another possible advantage in the present study is contrast enhancement of the fire-orange life raft against its simulated ocean background.

Cosmetan (brown)

This filter has a relatively flat and low spectral transmittance, with a maximum transmission of about 20 percent in the 600-700nm region. It was reported (Watson and Greenberg, 1962) to have been the most useful lens evaluated as a visual aid in the Arctic, though ineffectual under whiteout conditions.

N-15 (gray)

This filter represents the standard Air Force sunglass. Like the Cosmetan, it has transmissivity of less than 20 percent over the visual spectrum except for a peak value of about 25 percent at 400nm.

One advantage of any sunglass (especially the Cosmetan and N-15) is the provision for glare reduction in proportion to the amount of light absorbed. However, as has been stated (Richards, 1964), "The same proportionate amount of seeing is removed and the seeing loss is more important than the glare reduction." This argument would lead one to suppose that unaided vision may be as effective (or more so) for target acquisition than any of the above types of filtered vision. Data supporting this view appear in a number of studies (Allen, 1961; Dobbins and Kindick, 1961; Watson and Greenberg, 1962; Hilgendorf, 1972; Hart, 1974).

METHOD

Subjects

The subjects were 50 male college students screened for normal visual acuity and color vision. Prior to the experiment, they were given standard recognition training with duplicates of the experimental targets on a small terrain table.

Experimental Facility and Procedure

The experimental facility consisted of a large light-tight room with a central partition which sealed off an aerosol chamber (containing the terrain model) from the area where the observer, experimenter and aerosol equipment were located.

Terrain Model and Targets. The circular terrain model was ten feet in diameter and could revolve at variable fixed speeds on a motorized turntable. Its conically shaped surface was composed of hydrographic, desert and mountainous features. The targets to be acquired were six fire-orange life rafts. Four of these were located in a large bay and 2 in a small mountain lake. The scale factor for both targets and terrain was 1:1000 and their spectral reflectance was designed to be representative of real-world counterparts.

Illumination. The only source of illumination in the aerosol chamber was a 2,000 watt Colortran 176-047 (3200° K) xenon quartz lamp in a Berkley-Colortran Multi-Beam housing. The housing was mounted to an overhead shaft which revolved with the model. The luminous intensity of this simulated sun (as measured by a Spectra Brightness Spot Meter) was about 5,000 candlepower and the level of illumination at its point of incidence with the terrain was approximately 35 ft. candles. This level of illumination represents relatively low sunlight brightness. Higher brightness would have been desirable (to more adequately test the glare reduction properties of the sunglasses) but could not be obtained because of prevailing equipment constraints.

Aerosol Generation and Measurement. Stearic acid was selected as an effective experimental model to represent water vapor as a real-world aerosol. The following criteria were considered in its selection: (1) similarity to water in light scattering efficiency; (2) adequacy for the short light path required for the scaled-down model, (3) capability for uniform control and specification of the shape, size, concentration and stability of the dispersed particles; (4) safety and acceptability for experimental use.

A modified La Mer Generator with a recording nephelometer was used to provide controlled input of the stearic acid particles to the aerosol chamber. This device provided photometric determination and readout for both the scattering coefficient of the aerosol and associated visibility measures. Throughout the experiment aerosol generation was controlled so that the nephelometer reading remained constant at a 5-mile visibility setting. Homogeneous dispersion within the aerosol chamber was maintained by two circulating fans.

Observer Station. The observer was seated in a cubicle with a front plexiglass window facing the center of the model (one foot from its outer edge). The window was continuous with the air-tight partition and provided an extended downward view of the model. The observer's eye level and field of view were fixed by a head and chin rest so that he viewed the right half of the model at a simulated 1500-ft altitude. The left eye was covered so that search would not benefit from stereoscopic cues which are not available at equivalent real-world viewing distances. The interior of the cubicle was draped with dark curtains which kept out ambient light while reducing glare and reflections within the cubicle. Curtains covering the window were opened for the duration of each trial.

Experimental Procedure. A total of fifty subjects were utilized. Forty of these were divided into four groups of ten, each group performing with only one type of sunglass. The remaining ten subjects made up a fifth (control) group using only the unaided eye. Each subject was run in a single trial during which he was instructed to search for, name and locate the types of targets that he had viewed during the training period. This task was performed over a period of 115 seconds during which time the model made two complete revolutions in a clockwise direction. The effect of this rotational sequence was to simulate a segment of a search-and-rescue mission wherein an observer at a 1500-foot altitude circles the same area twice at a flight radius of 6000 ft. Simulated speed was 388 knots and simulated slant range to the moving targets varied from 2000 to 9000 ft.

Two performance measures were taken for each trial: (1) response time, i.e., the time elapsing from the start of the trial to the correct sighting of a particular target (a response time of 115 seconds was assigned to all targets that were either missed or erroneously identified) and (3) number of targets found, i.e., correctly located and identified.

RESULTS

The results are summarized in Table 1 which shows mean performance scores per trial for each viewing condition. Columns in the table show means for the number of targets found and the response time per target.

The data of Table 1 were evaluated by analysis of variance. For the response-time data, a two-factor mixed design (with repeated measures on targets) was used; whereas a one-way analysis sufficed for the number of targets found.

The ANOVA indicates that the visibility of the fire-orange life rafts is affected by the type (or absence) of sunglasses used by the observer. This is most clearly shown by the response time measure, where the main effect of viewing condition becomes highly significant ($P < .001$) and is strongly suggested ($P < .06$) by the number of targets found. The factor of targets is also highly significant ($P < .001$) for response time measures. This is largely due to the high conspicuity of a 20-man raft in the bay area.

Having demonstrated that life raft visibility varies significantly with viewing conditions, specific comparisons were made among the mean performance measures (shown in Table 1) for the four alternative sunglasses and the unaided eye. These comparisons were made with the Duncan Multiple Range Test and a $p \leq .05$ statistical level was used as the criterion for significance of differences. The Cosmetan filter is significantly inferior in mean response time to all other filters and the unaided eye. Two other significant differences show that both the N-15 and the yellow lens also are inferior to the eye. When the same comparisons were made for the number of life rafts found, only two significant differences were identified. These show both the Oakley Doc filter and the unaided eye to be significantly more effective (i.e., yield a larger number of sightings) than the Cosmetan filter.

DISCUSSION

Based on these data and those of a previous study (Hilgendorf, 1972), one would hesitate to recommend the use of colored filters as visual aids in a search and rescue operation. Given the type of simulation provided in these studies (i.e., a terrain board and flight environment for testing target acquisition at a relatively low level of daylight illumination), no significant enhancement of target visibility (over unaided vision) was found through either clear or hazy atmosphere for any of the filters tested. Since one of the candidate lenses was the Hazemaster, this result supports the widely replicated finding that a yellow filter does not enhance visual performance despite a number of plausible arguments for its use.

In particular, there was no evidence to support the contention that either the Oakley Doc or Hazemaster lens offer superior haze penetration because of reduced transmission over the shorter wavelengths (these contributing most of the light scattering effect).

Another hypothesis, which the experiment was designed to test, was that the Oakley Doc filter would provide the best spectral window for increasing the contrast (and hence the visibility) of fire-orange life rafts on a gray ocean background. Although this filter was somewhat more effective than the others tested, it was, nevertheless, never superior to the unaided eye and therefore cannot be recommended as a visual aid under the conditions of this study.

Perhaps the clearest finding from the evaluation was the relative ineffectiveness of the Cosmetan lens. It was significantly poorer than either the Oakley Doc or the unaided eye with regard to the number of life rafts sighted.

In summary, these data support the conclusion that none of the lenses tested are more effective for target acquisition than the unaided eye. This leads to the recommendation that they should not be used as visual aids under the conditions simulated in this experiment. It would appear in these cases that light reduction through transmission loss (inherent in all filters) has offset any enhancement characteristics supposedly designed into the alternative filters.

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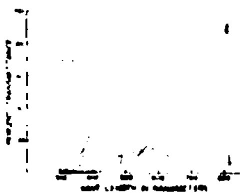

Figure 1. Spectral transmittance curves for the sunglass lenses.

A, Oakley Doc; B, Hazemaster; C, Cosmetan; D, N-15.

TABLE 1. Mean Performance Scores per Trial for the Five Viewing Conditions

Viewing Condition	Number of Targets Found	Response Time Per Target (Secs)
Unaided Eye	1.6	94.3
Oakley Doc Lens	1.7	96.8
Yellow Lens	1.3	98.6
N-15 Lens	1.1	100.2
Cosmetan Lens	.9	105.0