Technical Report Documentation Page

1. Report No. FAA-AM-78-28	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle VISUAL PERFORMANCE ASSESSMENT THROUGH CLEAR AND SUNSCREEN-TREATED WINDOWS	5. Report Date 6. Performing Organization Code
7. Author(s) Kenneth W. Welsh, Paul G. Rasmussen, and John A. Vaughan	8. Performing Organization Report No.
9. Performing Organization Name and Address FAA Civil Aeromedical Institute P.O. Box 25082 Oklahoma City, Oklahoma 73125	10. Work Unit No. (TRAIS) 11. Contract or Grant No.
12. Sponsoring Agency Name and Address Office of Aviation Medicine Federal Aviation Administration 800 Independence Avenue, S.W. Washington, D.C. 20591	13. Type of Report and Period Covered 14. Sponsoring Agency Code

15. Supplementary Notes

Work was performed under Task AM-D-78-PHY-111.

16. Abstract

Reflective sunscreen filters are frequently bonded to vehicle windows to reduce interior heat and brightness. The present study was conducted to investigate the optical properties of and visual performance through clear and sunscreen-treated glass panels that served as windows in an observation booth. Five combinations of external and internal brightness levels were used.

Light transmission values through the clear, gold, silver, and bronze panels were 92, 20, 18, and 8 percent, respectively. Visual performance tests were conducted at 6 m (20 ft) on 12 subjects with normal visual acuity and color vision.

Two tasks were conducted under brightness levels on the external display and in the subject's booth, respectively, of 1:1, 5:1, 50:1, 5:5, and 50:5 fL. Visual acuity using Landolt C figures and scores on a contour identification task were minimally impaired for any luminance ratio when the clear (control) panel was used. With the sunscreen panels, scores on both tests decreased as a function of target brightness and panel density.

With one external/internal luminance ratio (5:1), identification of signal light colors was generally impaired while viewing through sunscreen materials. Decreases were particularly evident for green and red lights presented at intermediate and low intensity levels.

17. Key Words Visual Performance Sunscreens Aviation Safety	18. Distribution Statement Document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 14	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

VISUAL PERFORMANCE ASSESSMENT THROUGH CLEAR AND SUNSCREEN-TREATED WINDOWS

I. Introduction.

Metallic-coated sunscreen materials are frequently bonded to windows of cars, trucks, and other vehicles. These reflective materials are recommended by their manufacturers to reduce the buildup of interior heat and reduce ambient brightness within such vehicles. Sunscreen materials have also been used in airplanes, as evidenced by an FAA Aircraft Services Base (ASB) test (ASB Project No. 350088) conducted in 1976-77 to evaluate reduction of the "greenhouse effect" in the cockpit. During the test, heat-reflective Mylar film was laminated to the rear side windows and overhead "eyebrow" windows of the cockpit of a Sabreliner 80 airplane.

The present study was conducted because of reports of visual degradation through the sunscreen-treated cockpit windows during day- and night-flying conditions. The reports included complaints of reduced visibility of the airport environment during circling approaches, difficulty in tracking airplanes from nontreated to treated window panels, and daytime reflections of the cockpit radio instruments from the sunscreen-treated eyebrow windows.

Our results from a laboratory study conducted with three sunscreen materials include spectroradiometric values and scores from several performance tasks conducted under selected illumination conditions.

II. Methods.

Subjects consisted of 10 volunteer males and 2 females with ages ranging from 24 to 64 years (mean 47 years). All subjects had 20/20 distant visual acuity; nine subjects required spectacle correction to achieve optimum vision. In addition, each subject was evaluated with the Farnsworth Lantern (red, green, and white lights) and was determined to have normal color perception under standard testing conditions.

The three sunscreen films used in the study were manufactured by DuPont Corporation and distributed under the names of Solar Master PSL-80 bronze, PSL-80 gold, and M-80 silver. These materials were laminated to 6.35-mm (0.25-in) polished plate glass with outside dimensions of 46 by 61 cm (18 by 24 in). One clear glass panel was ordered without sunscreen material and used to obtain control data. Gold and silver panels were found to have similar spectral transmission characteristics and preliminary tests indicated equal performance levels through both panels. Visual performance data will therefore be presented for two sunscreen panels (bronze and silver) and for the clear noncoated plate glass.

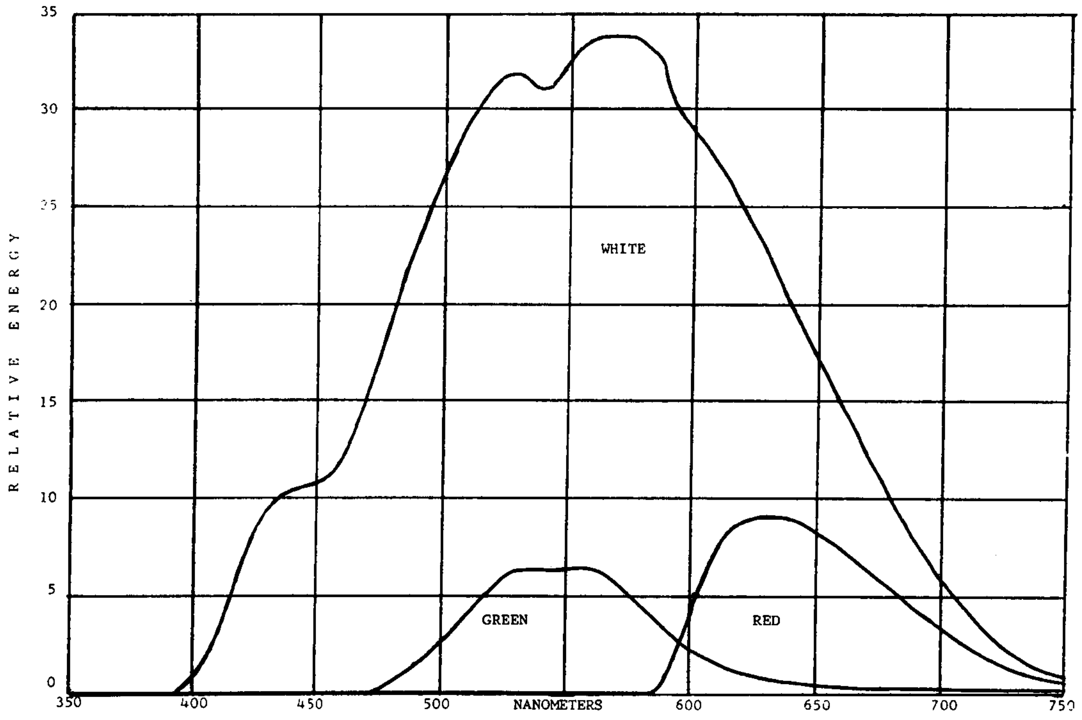
Subjects viewed the test displays from a distance of 6 m (20 ft) while seated in an observation booth. The subjects' heads were supported by a chin rest while they looked perpendicularly through the central portion of the viewing window.

Visual performance was evaluated under selected luminance levels that were controlled separately for the display area and the observation booth. The display area was illuminated by three daylight-blue bulbs (G.E., 100W) positioned in a triangular array and directed toward the target. Luminance levels were adjusted by a variable power source to provide 1.0, 5.0, and 50.0 fL on the display. Brightness levels in the observation booth were obtained by directing light from a single daylight-blue bulb through the diffusing side window of the booth. The center of the window was located approximately 30.5 cm (12 in) above the subject's line of sight. Luminance levels in the enclosure were adjusted to 1.0 and 5.0 fL as measured from a standard reflectance plaque held against the inside surface of the viewing window while the photometer was located at a position approximating the location of the subject's head. Data were obtained with brightness level ratios on the display and in the booth respectively of 1:1, 5:1, 50:1, 5:5, and 50:5 fL.

Two visual performance tasks were conducted under each of the five luminance ratios noted above. The first test device consisted of 12 Landolt C figures with three figures for each of four acuity levels (20/40, 20/30, 20/25, and 20/20). Subjects were asked to identify the location of the gap of each Landolt C figure (up, down, left, or right). The display was presented twice at each external/internal brightness ratio with figures positioned after each presentation. Subjects who failed to identify all 20/40 figures were arbitrarily given a score of 20/50 for the purpose of computation.

The second test consisted of four display cards presented at all luminance ratios. Each card measured 30 cm (12 in) on a side and was divided into four equal squares. Two squares on each card were constructed from dark-gray paper (Pantone No. 432) and two from light-gray paper (Pantone No. 428). Centered within each square was a single square or diamond test figure subtending a visual angle of 10 arc min; i.e., 17.5 mm measured diagonally and 12.35 mm on each side. To obtain various figure-to-ground contrast ratios, test figures displayed on dark-gray backgrounds were lighter shades of gray (Pantone Nos. 422, 428, 430, and 431). Test figures displayed on light-gray squares were dark shades of gray (Pantone Nos. 422, 430, 431, and 432). Luminance values used to calculate figure-to-ground contrast ratios are specified as the brightness difference between target and background divided by the background brightness. During the evaluation, two test figures (one diamond and one square) representing each contrast ratio were presented for all sunscreen panel and brightness combinations. Subjects were instructed to respond to the test figures only when they were distinguishable.

The third test using the modified Edridge-Green Lantern was conducted at one external/internal luminance ratio (5:1). While viewing through each sunscreen or the clear panel, subjects attempted to identify a red, green, or white light presented for 3.0 seconds. Lights were displayed in random order in combinations of each of three intensity levels and three aperture sizes. Intensity levels were controlled by three neutral density filters in the body of the lantern and were measured with the Pritchard Spectra photometer. The circular apertures were 1.0, 1.4, and 1.7 mm (0.040, 0.055, and 0.067 in), respectively, in diameter and are equivalent in angular size to a 16-cm (5.5-in) signal light at 838, 610, and 500 m (917, 667, and 547 yd), respectively. A Gamma Spectroradiometer, Model 2900MR, was used to determine light energy distribution curves for each of the three signal light colors used in the study (Figure 1). All values are based on the Edridge-Green Lantern after modification for 120V operation with a G.E. 75W soft-white bulb. Shown in Figures 2-4 are the



SPECTRAL CHARACTERISTICS OF: Three Edridge-Green Signal Lights Used in the Study

RECORDED ON GAMMA SCIENTIFIC, INCORPORATED MODEL 2900 SCANNING SPECTRORADIOMETER. DATE: April 1978

FIGURE 1. Relative spectral energy distribution curve for each of the three signal light colors.

SPECTRAL CHARACTERISTICS OF: White Signal Light Through Clear and Sunscreen-Treated Glass

RECORDED ON GAMMA SCIENTIFIC, INCORPORATED MODEL 2900 SCANNING SPECTRORADIOMETER. DATE: April 1978

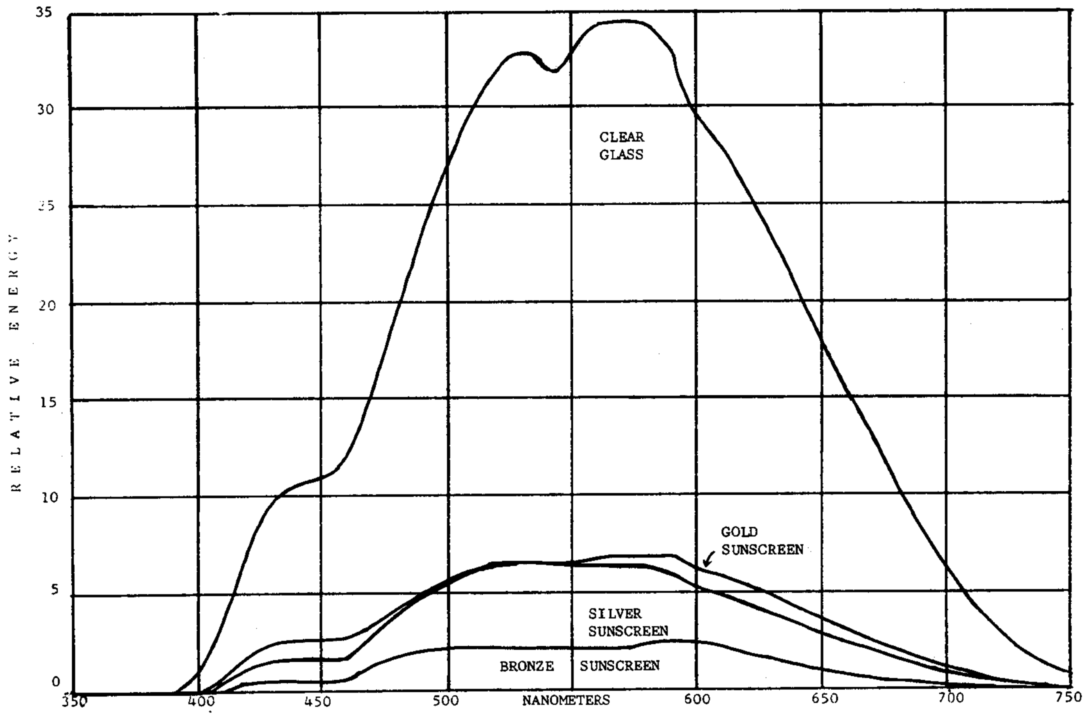


FIGURE 2. Relative spectral energy curve for white signal light through clear and sunscreen-treated glass.

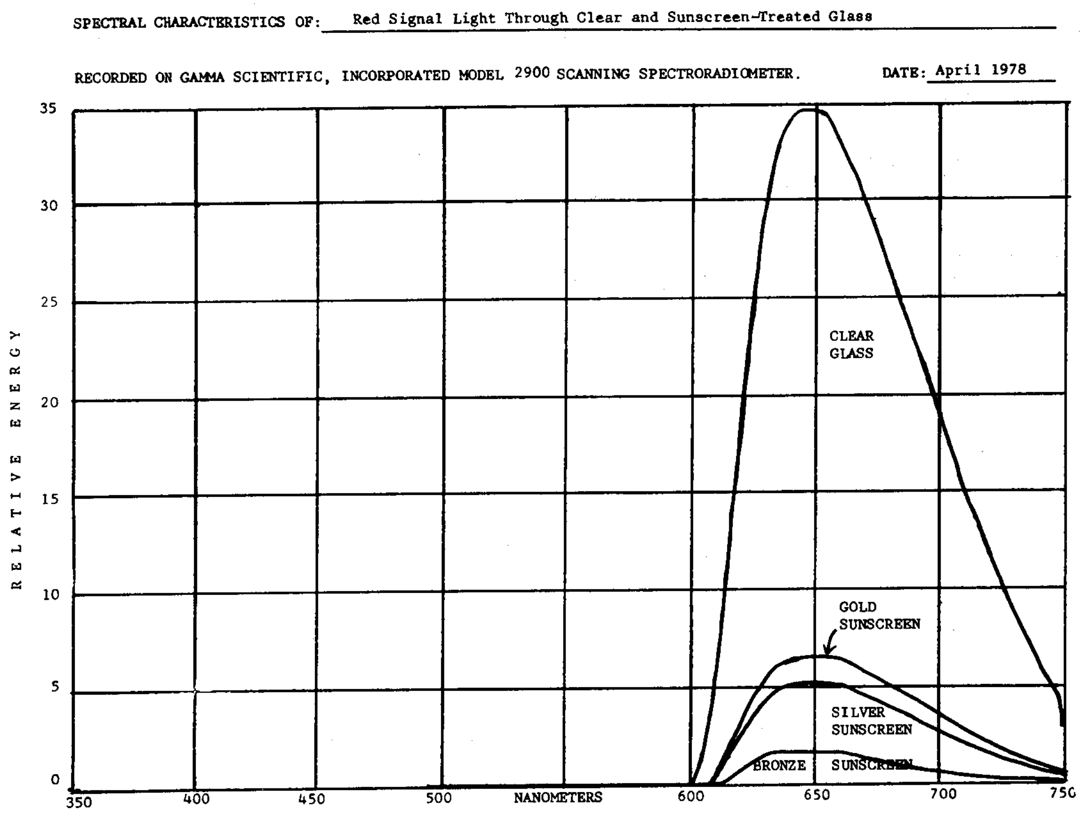


FIGURE 3. Relative spectral energy curve for red signal light through clear and sunscreen-treated glass.

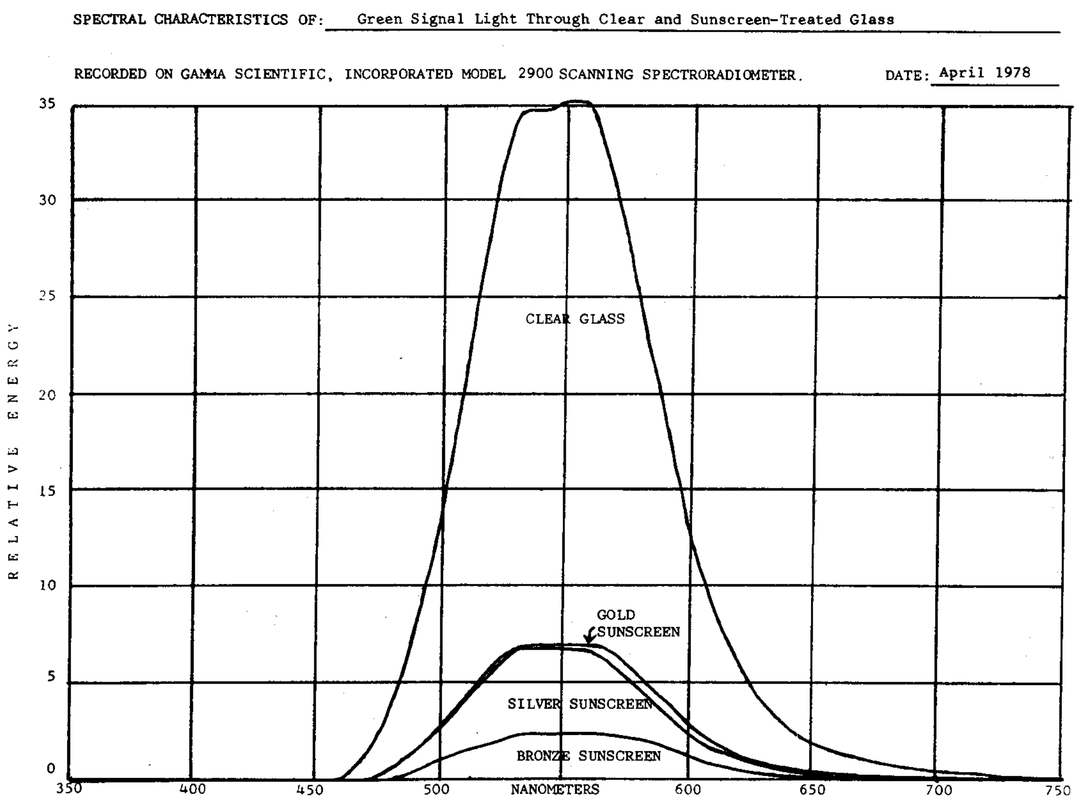


FIGURE 4. Relative spectral energy curve for green signal light through clear and sunscreen-treated glass.

relative spectral energy for each signal light source and panel combination. Relative spectral energy curves were obtained without a photopic correction filter positioned before the photomultiplier tube.

Light transmission values through each sunscreen and clear panel were also obtained with a Pritchard Spectra photometer and a standard white luminance source (Spectra 100 fL). Transmission values through the clear, gold, silver, and bronze panels were 92, 20, 18, and 8 percent, respectively. Light transmission was reduced by 2 percent when measurements were made with panels positioned 45^{0} to the measurement axis.

III. Results.

Figure 5 shows the visual acuity levels attained when viewing through the three panels under the five combinations of interior and target luminance levels. There is little or no impairment of visual acuity at any of the luminance ratios when viewing through the clear (control) panel. Both sunscreen panels are shown to be detrimental to visual acuity except at the 50-fL target luminance level.

Figure 6 shows the percentage of correct responses on the contrast discrimination task for three of the five luminance ratios. Performance was uniformly high (at or near 100 percent) with all three panels when the target luminance was 50 fL. At the lower target luminance values, contrast discrimination was uniformly high when viewing through the clear panel but was generally poorer when viewing through the sunscreen panels, especially for those targets having a relatively low figure-to-ground contrast ratio. If the negative contrast ratios (light or dark background) are converted to equivalent positive values, the two sets of contrast values are approximately equal. However, data indicate that targets with a positive figure-to-ground contrast ratio are discriminated better than those with a negative contrast ratio when viewed through the sunscreen panels.

Figure 7 gives the results for the signal light recognition task for each of the three signal light colors. Although there was a general improvement in performance as

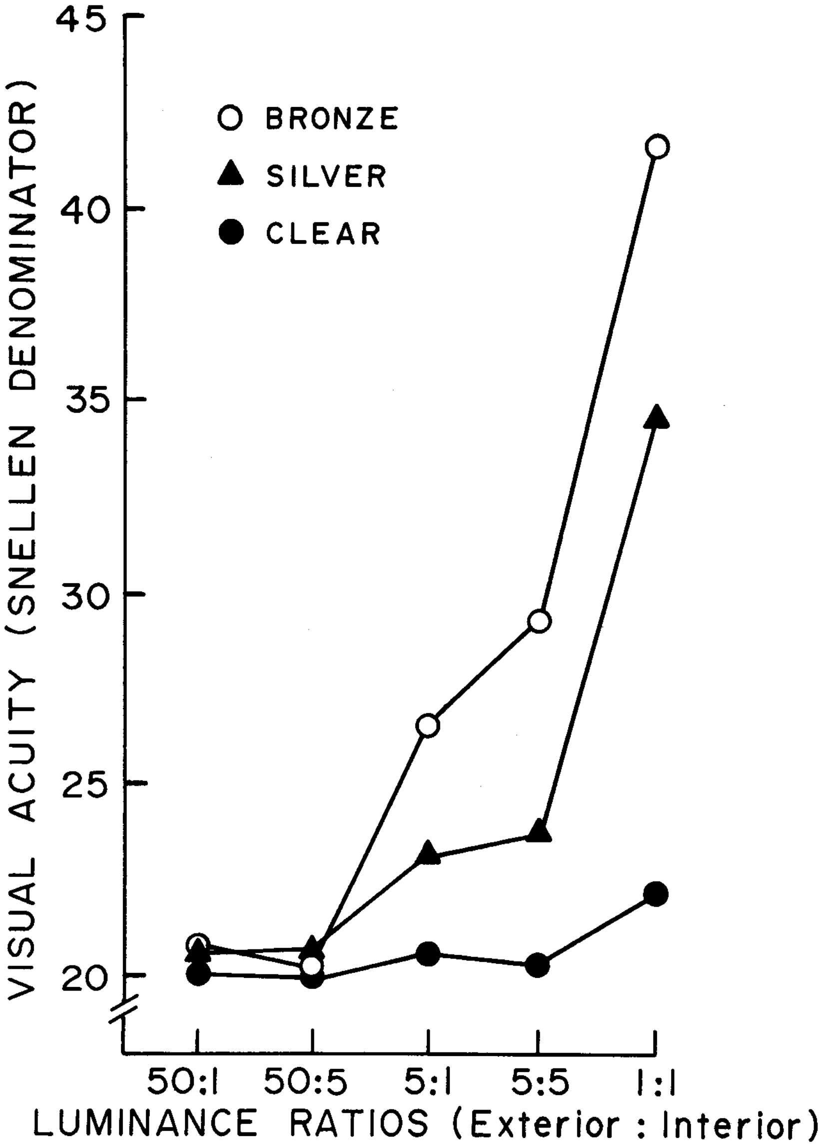


FIGURE 5. Visual acuity of Landolt C figures with clear, silver, and bronze panels under selected luminance levels.

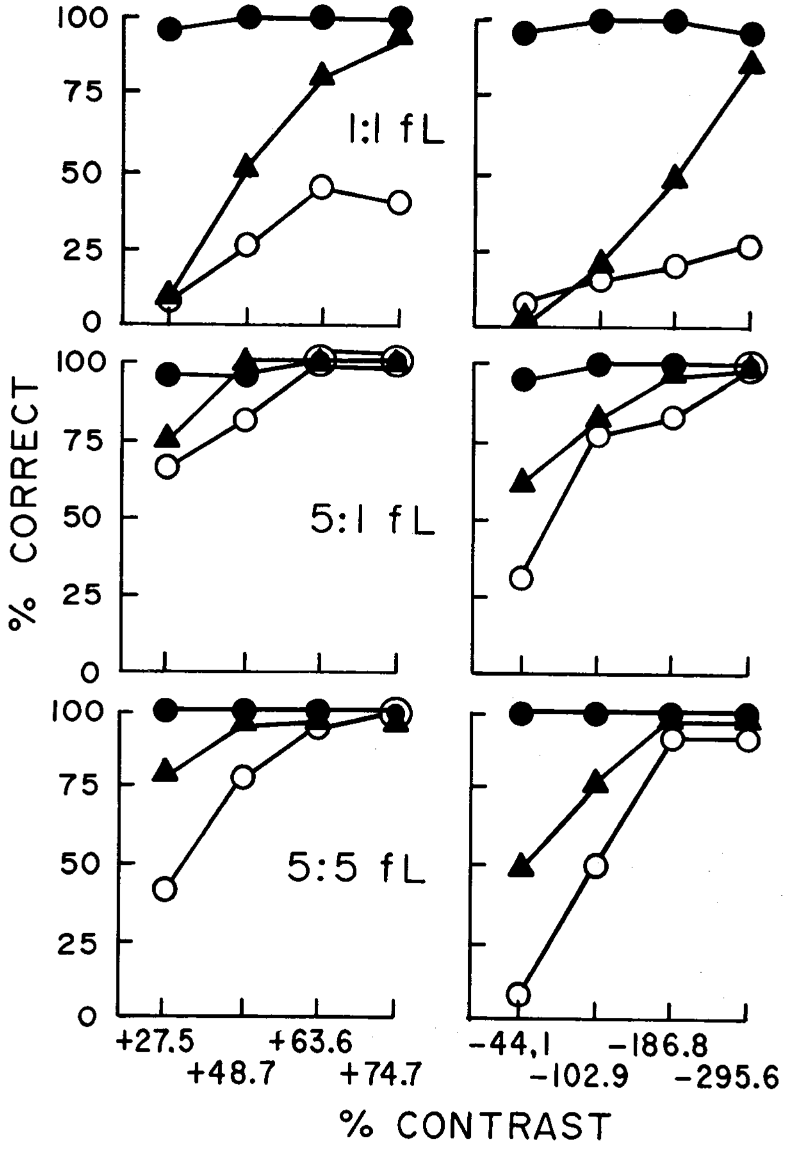


FIGURE 6. Percentage of correct scores for contour identification task with clear (closed circle), silver (triangle), and bronze (open circle) panels under three external/internal luminance levels.

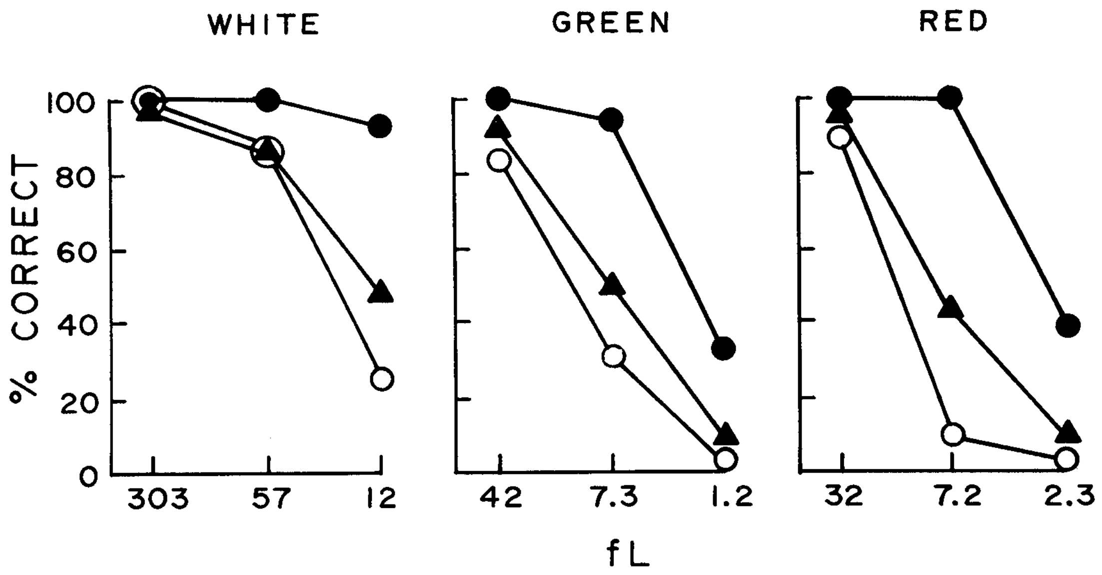


FIGURE 7. Percentage of correct scores for three signal light colors with clear (closed circle), silver (triangle), and bronze (open circle) panels under one (5:1) luminance level.

a function of increasing aperture size, the data for the three aperture sizes have been combined to yield an overall recognition value for each light at three intensity values as viewed through the three panels. Both sunscreen panels yielded overall lower recognition values than did the clear panel with the greatest differences between the panels tending to occur at the lower and intermediate brightness levels. Because of the differences in brightness levels of the three signal colors, their relative effectiveness cannot be established within the conditions of this study.

IV. Discussion.

The addition of reflective sunscreen materials to window areas is known to reduce solar heat and brightness within vehicles, buildings, etc. However, we believe these benefits must be considered with respect to demonstrated losses in visual performance that occurred under dim luminance levels. For example, under a moderate brightness level (5.0 fL), recognition visual acuity through the clear, silver, and bronze panels was 20/20, 20/24, and 20/29, respectively. Comparable acuities scored under dim lighting (1.0 fL) were 20/22, 20/35, and 20/42.

Scores on a task designed to evaluate the subjects' ability to identify the contour of test targets (square or diamond) indicated that performance decreased for both sunscreen materials with marked decreases for low contrasting targets. Performance also decreased under reduced illumination and was generally lower for gray targets on a dark-gray background than for gray targets against a light-gray background.

Detection of signal light colors in the transportation environment is considered essential for purposes of navigation, communication, and collision avoidance. Color identification scores generally decreased while viewing through either sunscreen material with decreases particularly evident for the green and red signal lights presented at the intermediate and low intensity levels.

In addition, performance scores on each task were generally highest for nontreated glass and lowest for the bronze sunscreen material. These results follow the spectral light transmission curves for the clear, silver, and bronze panels shown previously.

Although not evaluated in depth, performance appears to decrease as the internal brightness level approaches the external ambient brightness. Degradation of vision would presumably be greatest under moderately dim external illumination levels such as dusk and nighttime flying or driving. When internal brightness exceeds external levels, mirrorlike reflections from the inside viewer's side of the sunscreen-treated window could markedly reduce visual perception of the exterior environment. Under nighttime conditions, further losses would also be expected from reflections of instrument panel lights from the side windows of the airplane.

Visual performance could be reduced even further by the wearing of sunglasses while viewing through sunscreen materials. Studies cited in a text by Allen (1) and articles by Blackwell (2,3) indicate that recognition and response time to nonluminous targets may be reduced with sunglasses or tinted windshields under moderately dim ambient illumination.

REFERENCES

1. Allen, M. J.: Vision and Highway Safety, Philadelphia, Chilton Book Company, pp. 35 and 112, 1970.

2. Blackwell, H. R.: The Effect of Tinted Optical Media Upon Visual Efficiency at Low Luminance, J. OPT. SOC. AMER., 43:815, 1953.

3. Blackwell, H. R.: Visual Detection at Low Luminance Through Optical Filters, Highway Research Board Bulletin 89, p. 43, 1954.